When Your DSL Needs to Support User-Defined *Domain* Functions

Affordable Deep Embeddings via Curry-Howard-*Lambek* Correspondence

Scala Days MADRID

September 14th, 2023

Tomas Mikula

What This Talk Is About

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DSLs

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DSLs

external

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- Custom syntax
- Specialized tools
- Good error messages
- Build your own
  - Parser
  - Type checker
  - IDE integration

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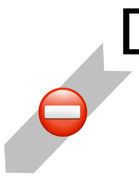

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What This Talk Is About

DSLs → embedded (internal)

external

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- Constrained syntax
- Not so good error messages
- No custom IDE
- Piggy-back on host language's
  - Parser
  - Type checker
  - IDE integration

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For example

- Parser combinators
- “Monadic” DSLs with deferred evaluation

- Easy to make
- Not introspectable
- Single interpretation
  - i.e. *run* them

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- Alternative interpretations
  - Serialize
  - Visualize
  - Statically analyze
  - Generate code from
  - …

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- Hard for humans

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- Use Scala's anonymous function syntax
- Use a macro to give it a different meaning
- Dealing with Scala AST
- Macro does not see through an `Ident`

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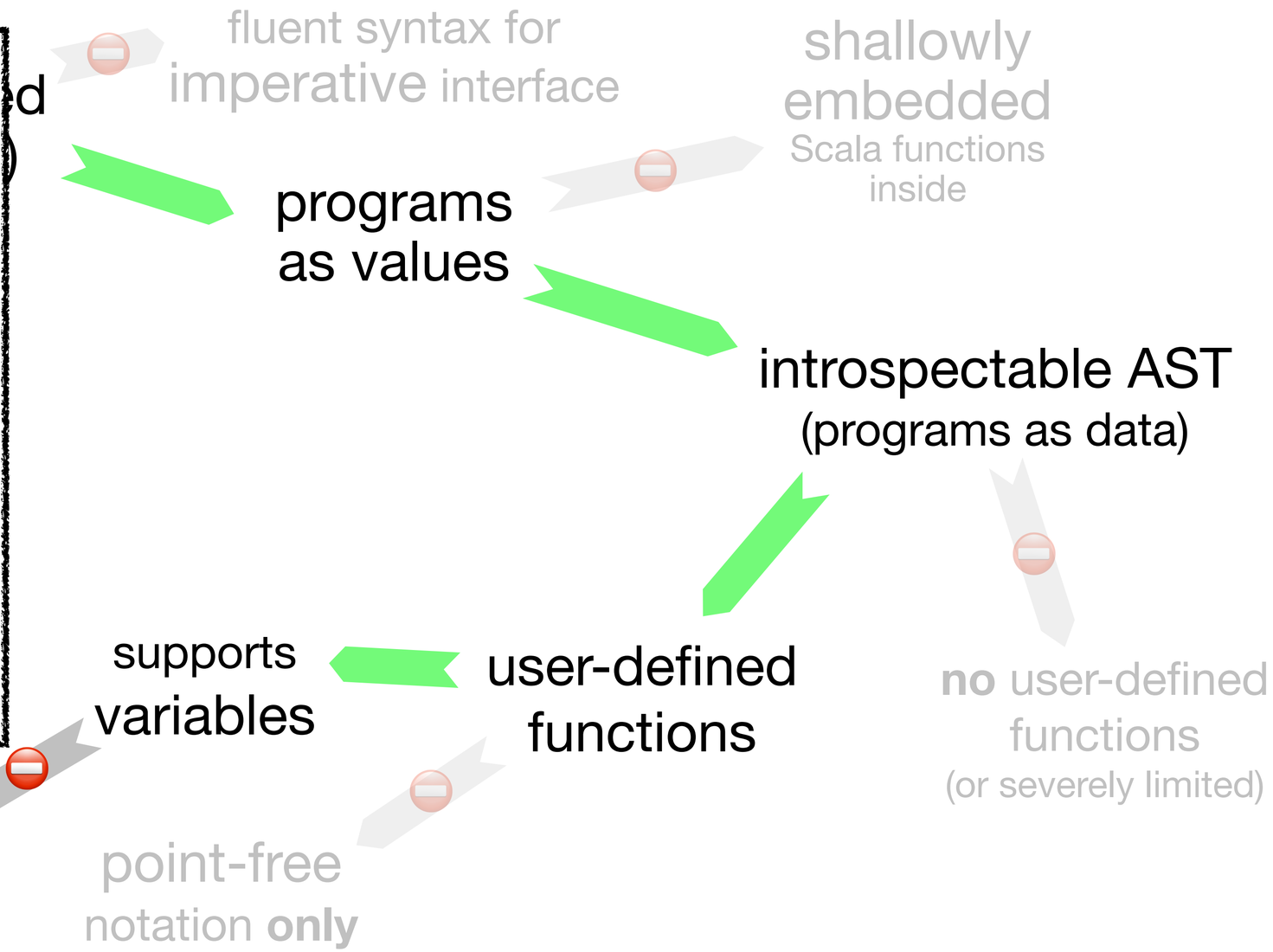

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// Declare your aliases before using them in SQL:
Author a = AUTHOR.as("a");

// Use aliased tables in your statement
create.select()
      .from(a)
      .where(a.YEAR_OF_BIRTH.gt(1920)
      .and(a.FIRST_NAME.eq("Paulo")));
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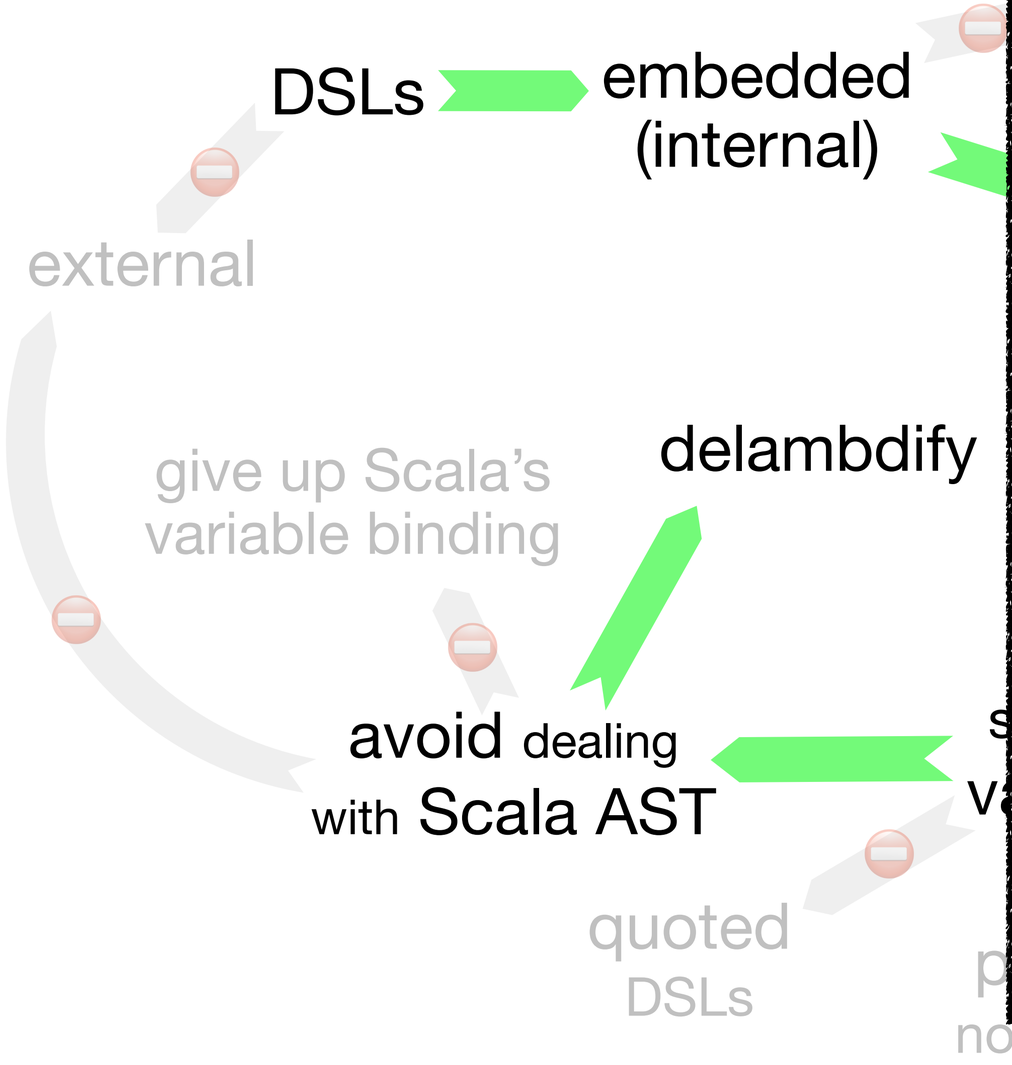

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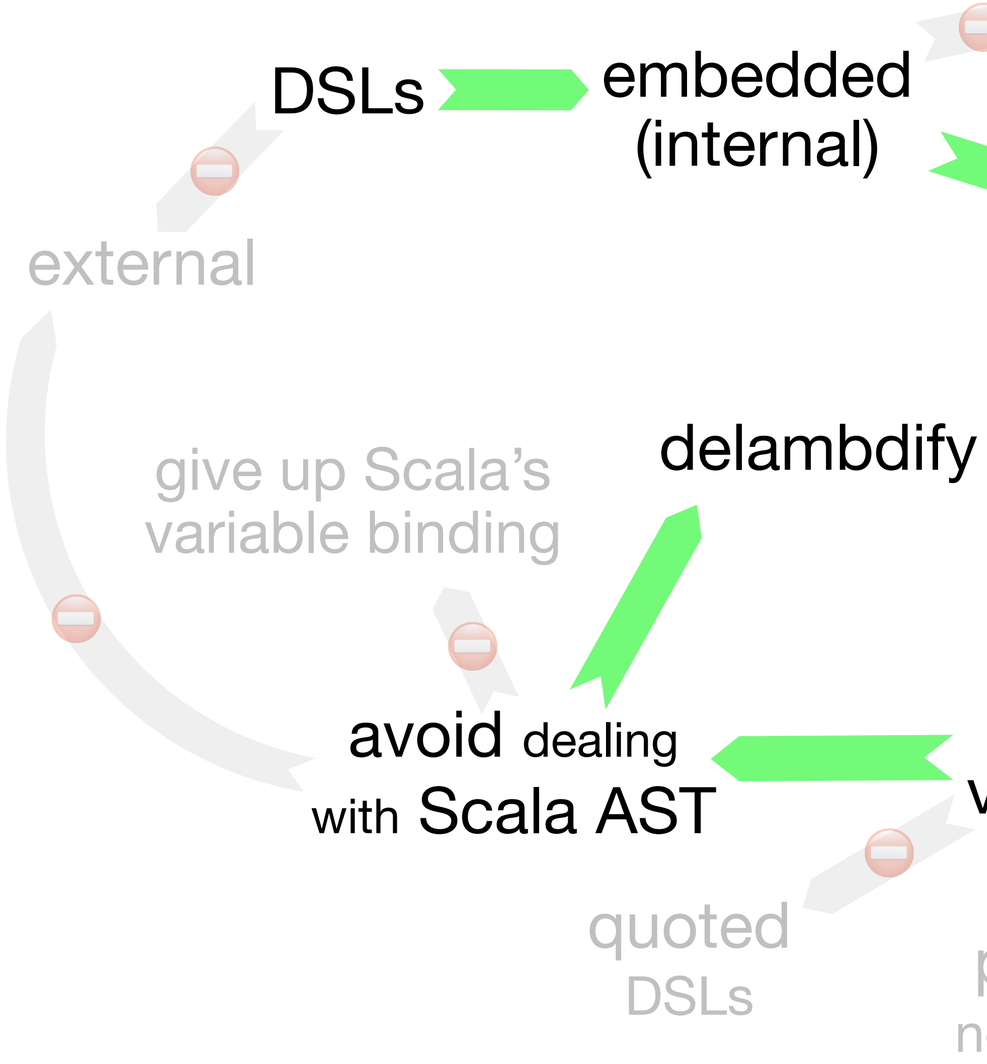

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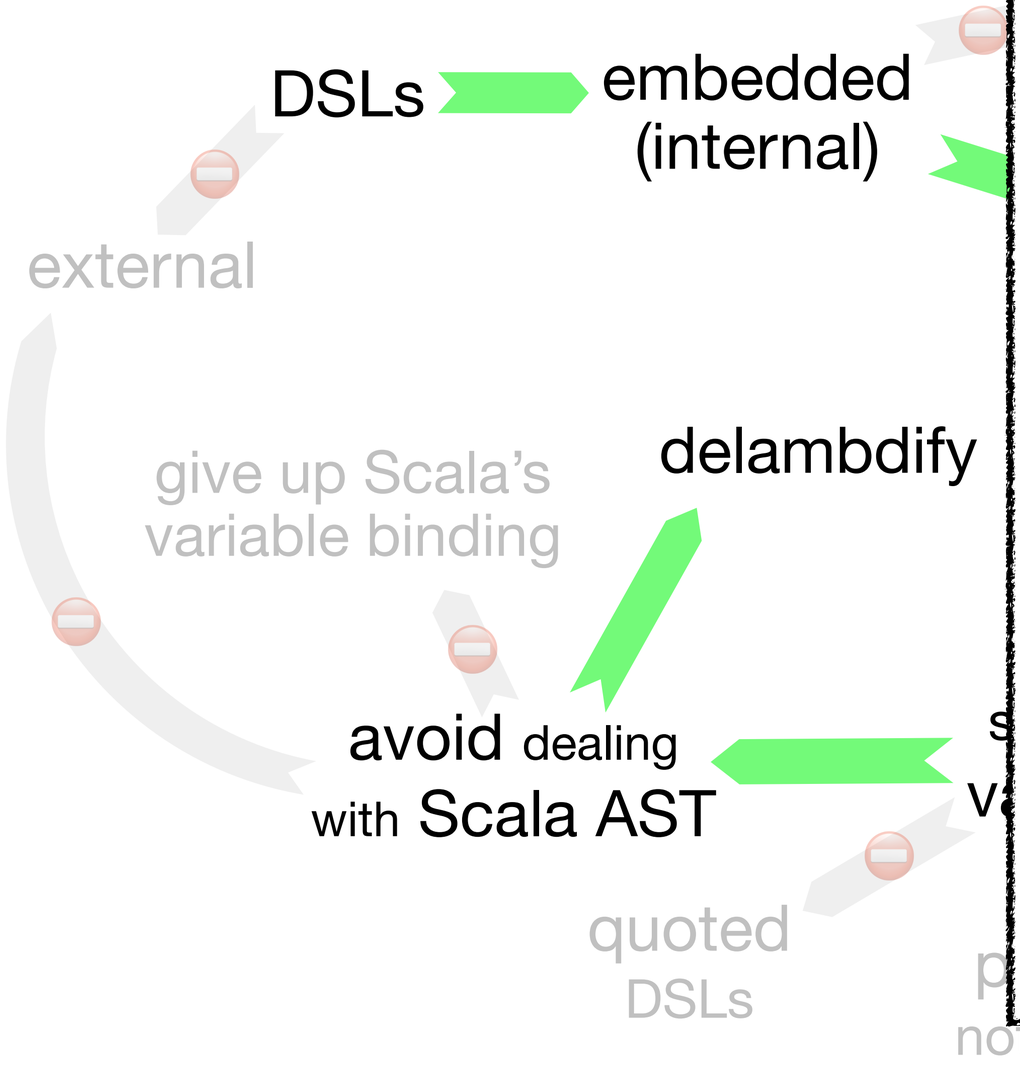

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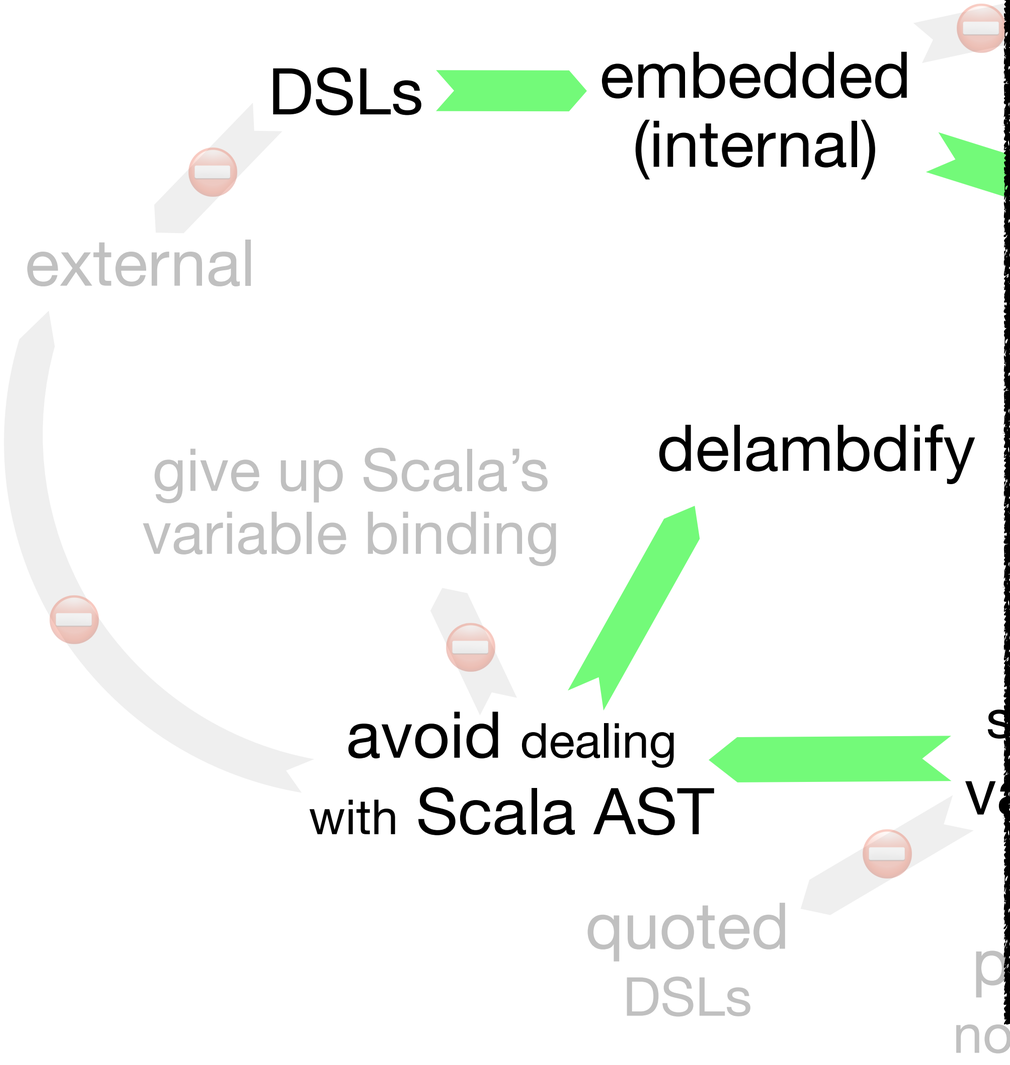

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- Dealing with variables error-prone

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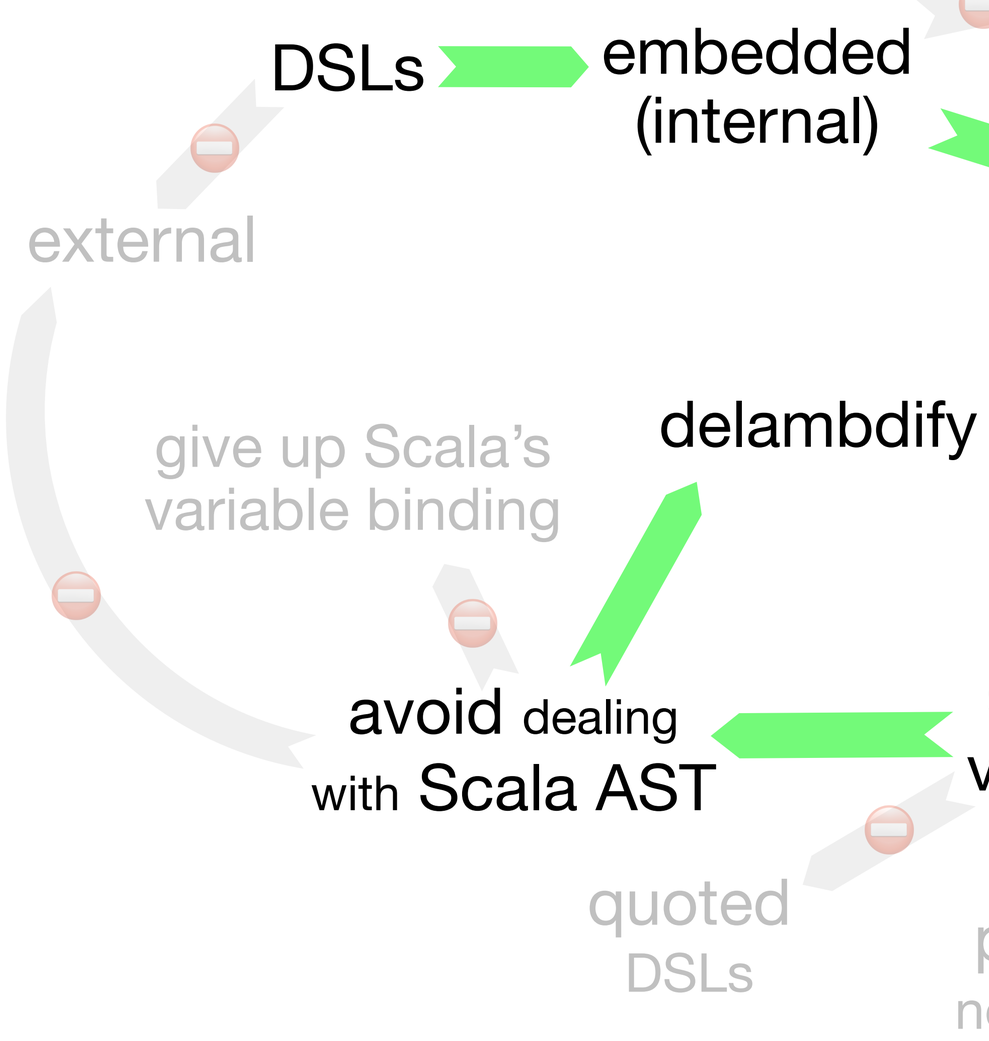

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- Non-locality of substitution

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- Programs as data
- Dealing with variables error-prone
- Non-locality of substitution
- Malformed programs representable

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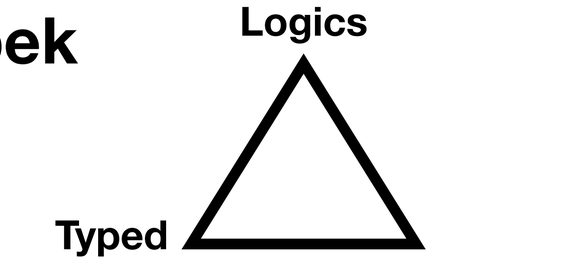

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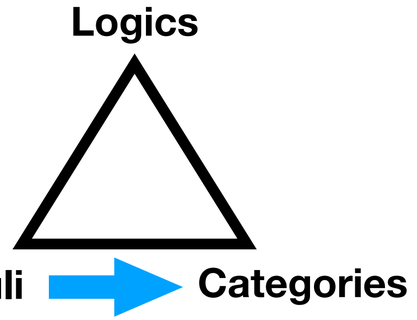

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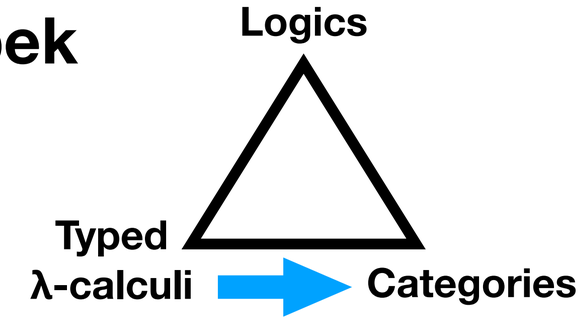

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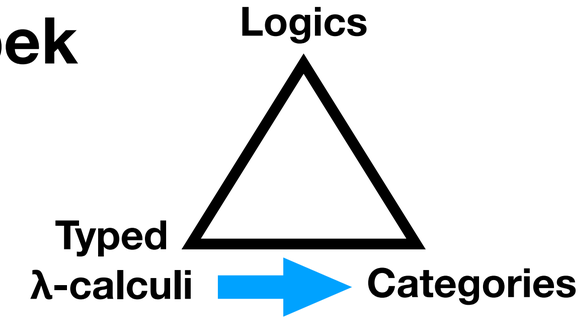

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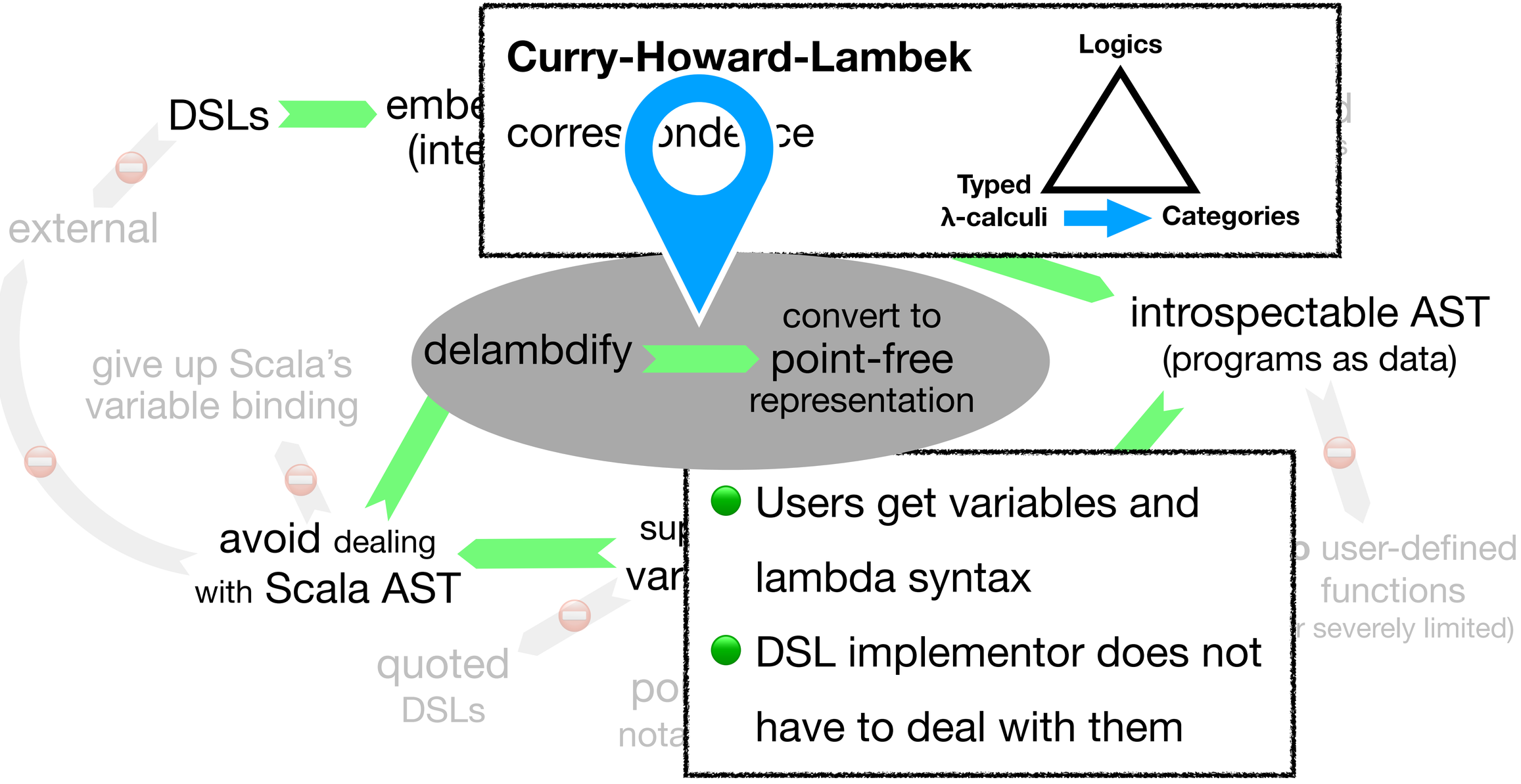

Goal

Language User

writes lambdas

```
fun { a =>
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  val c = g(a)
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AndThen(
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    Par(f, g),
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)): AST[A, B]
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```
enum AST[A, B]:
  // Pure data!
  // No Scala functions
  // inside!

  case AndThen[A, B, C](
    f: AST[A, B],
    g: AST[B, C],
  ) extends AST[A, C]

  case Par[A1, A2, B1, B2](
    f1: AST[A1, B1],
    f2: AST[A2, B2],
  ) extends AST[(A1, A2), (B1, B2)]

  case Dup[A]() extends AST[A, (A, A)]

  // ...
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- (often) long running (hours, days)

Demo Domain: **Workflows**

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  - for human input
- require **durable execution**

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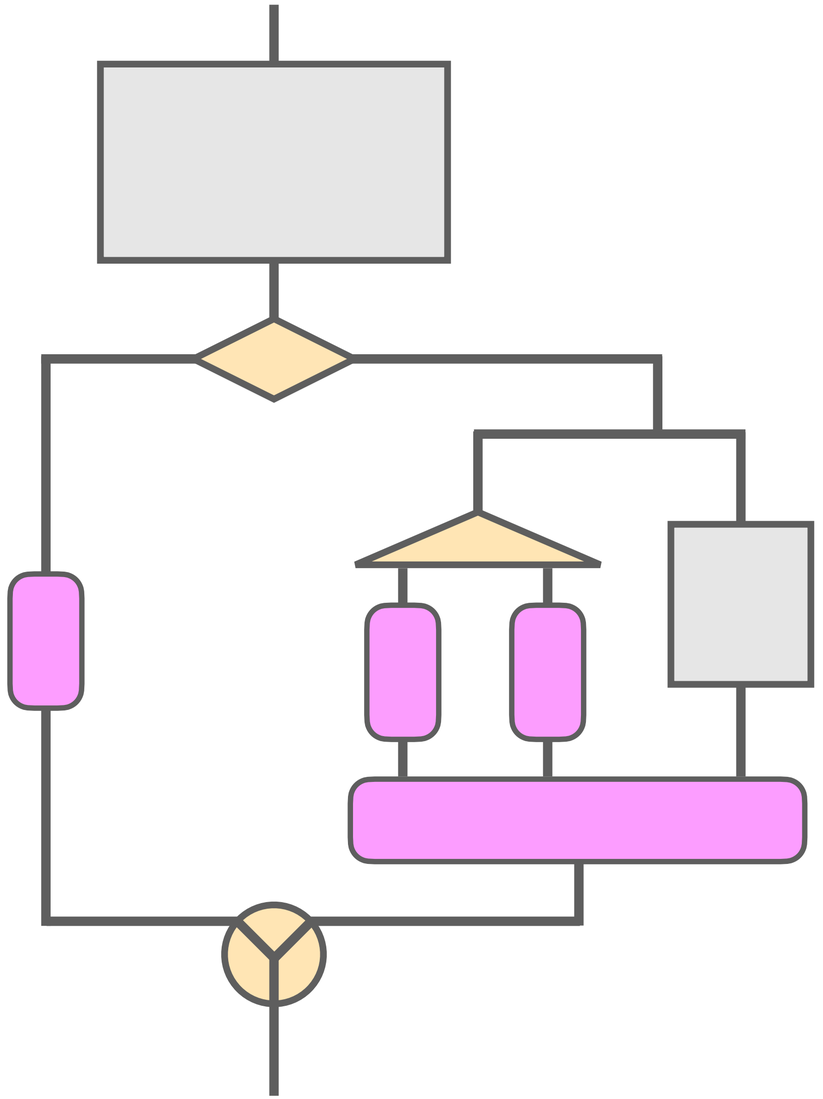
- scripted *activities*
- (often) long running (hours, days)
- (often) mostly waiting
  - for activity to complete
  - for human input
- require **durable execution**
  - can’t assume to stay in memory for the whole execution

Workflow: Example



nested workflow

built-in operator

activity

unit-typed input/output

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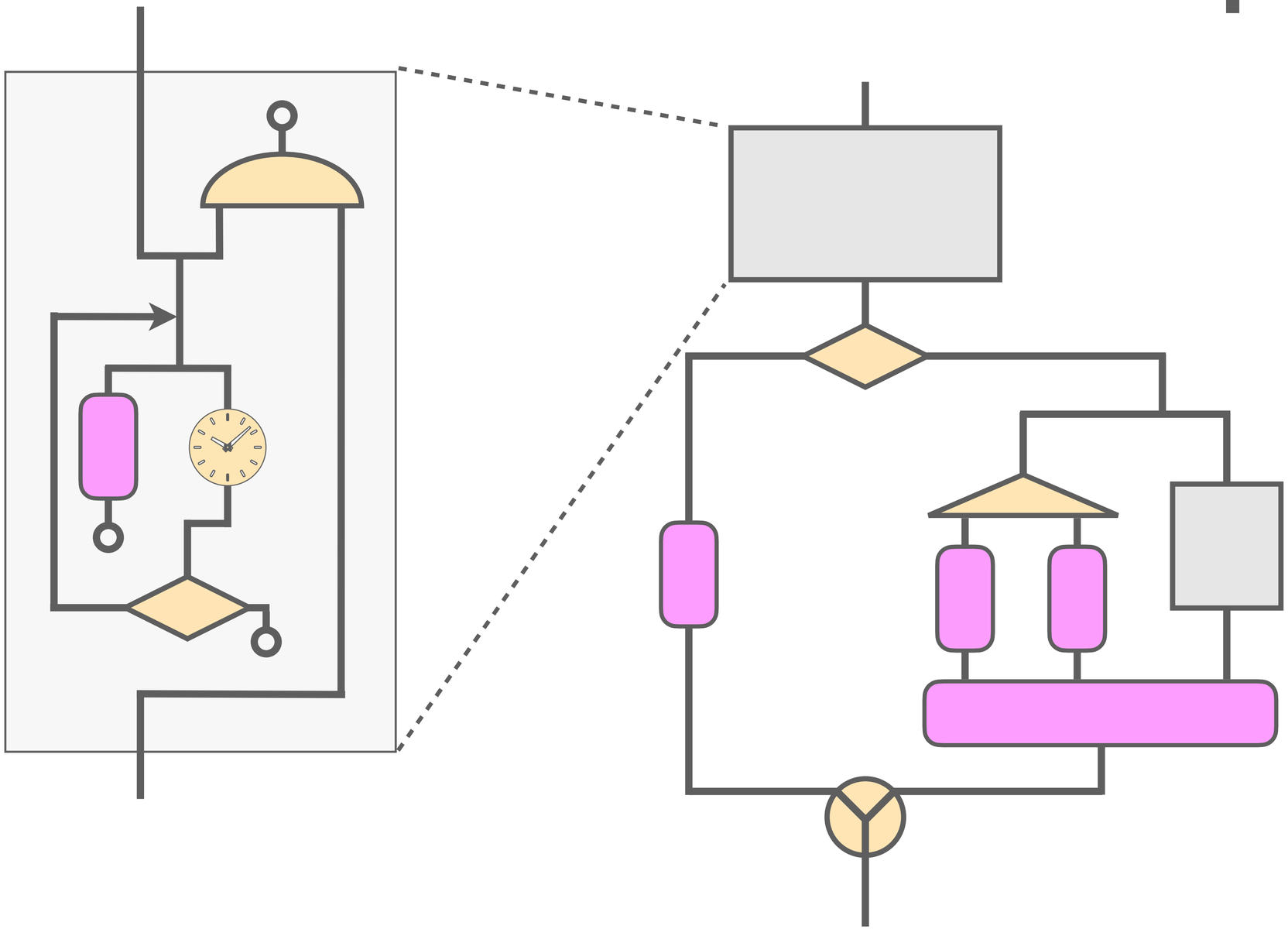

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Workflow DSL Requirements

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- expressive control flow

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- expressive control flow
  - branching

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- expressive control flow
  - branching
  - loops

Workflow DSL Requirements

- expressive control flow
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- graphical rendering

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  - statically

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- expressive control flow
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Maybe later

- graphical rendering
  - statically
  - mid-execution
- static analyses
- execution traces
- switch to an external DSL later
  - *without having to rewrite old workflows*

Demo Sub-Domain: **Background Check**

Inspired by https://learn.temporal.io/examples/go/background-checks/

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- Ask candidate (via email) to accept
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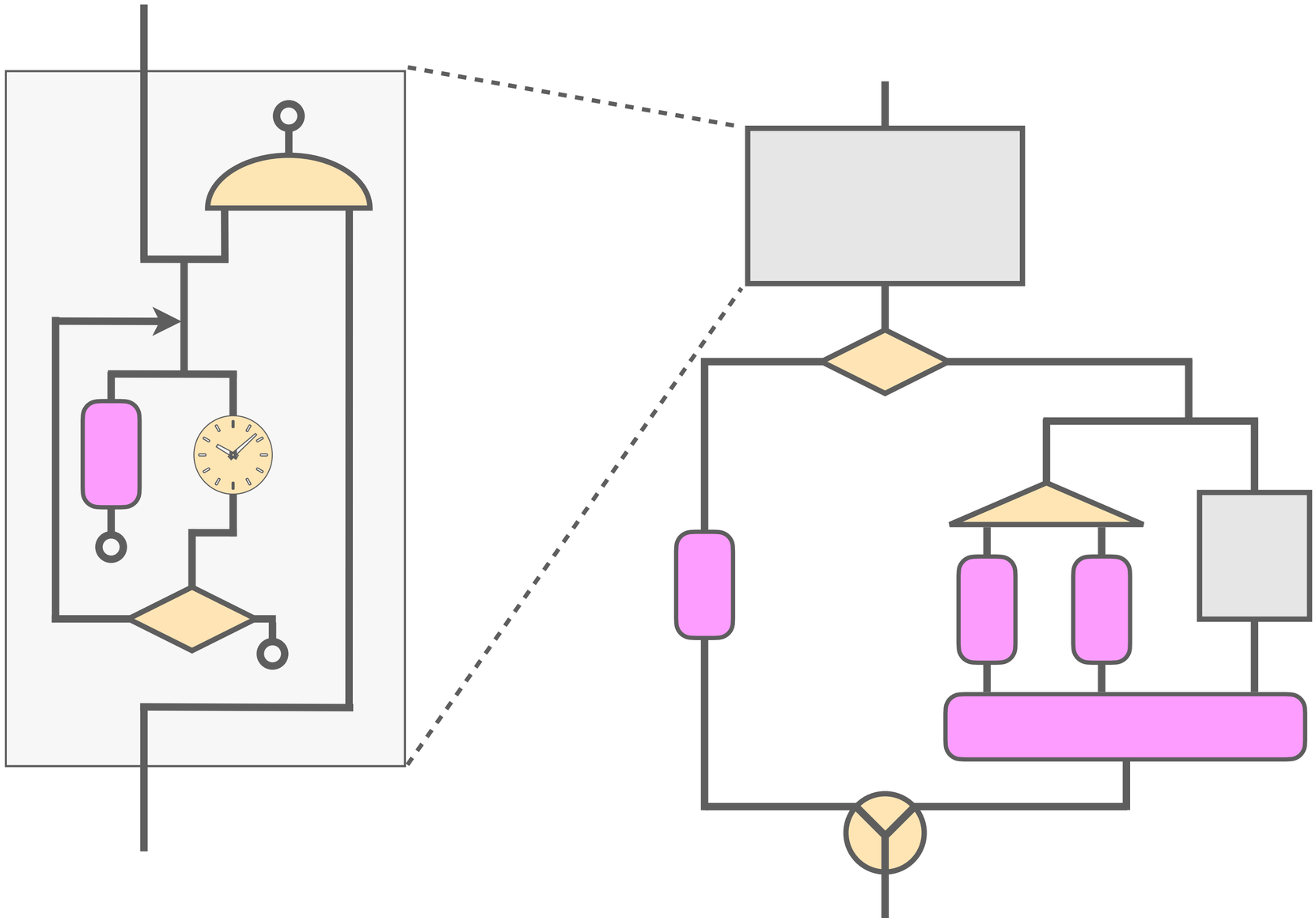
  - Check civil record
  - Verify employment history
    - Notify a human researcher
- Produce report (for the HR person)

Background Check Workflow



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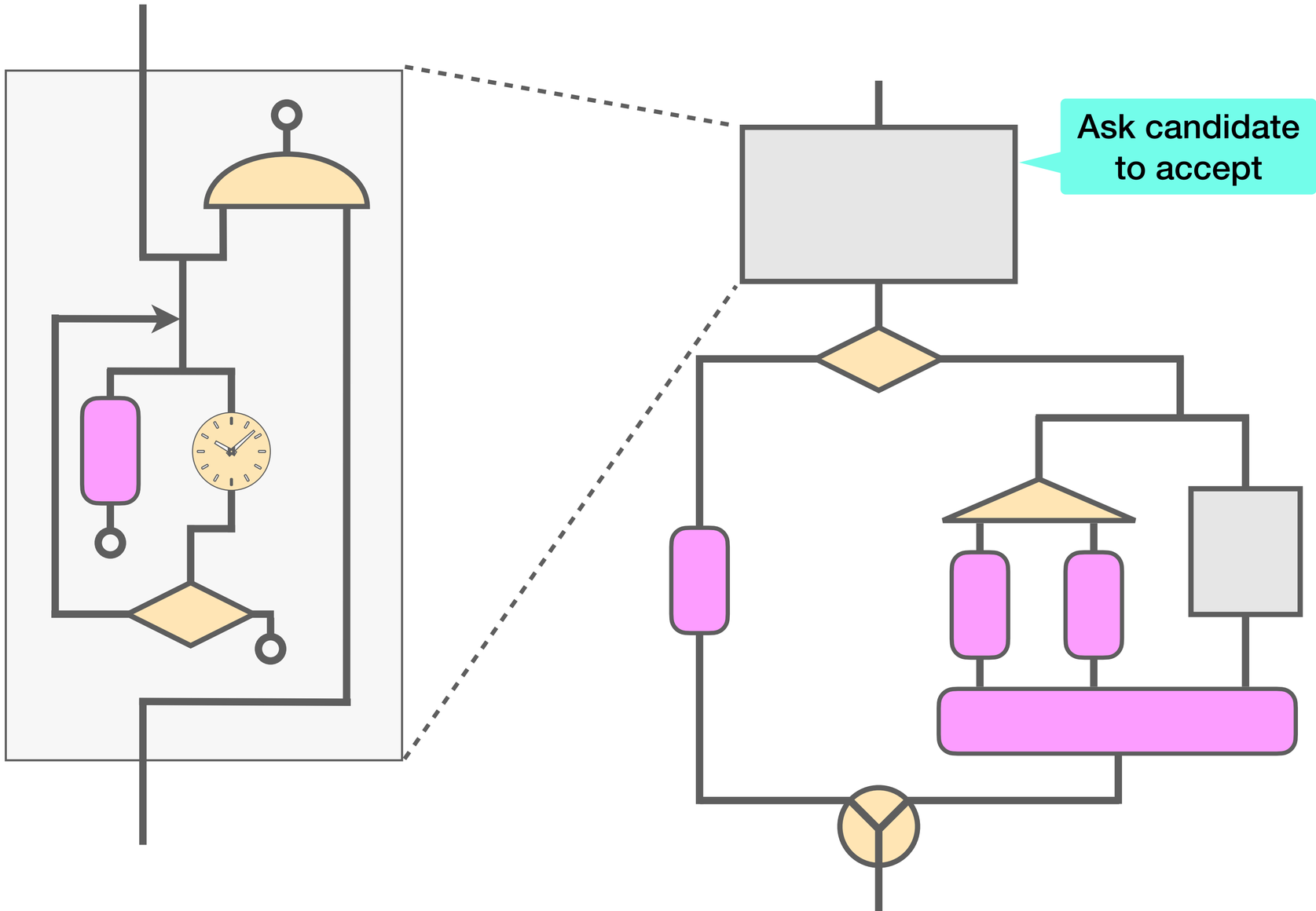
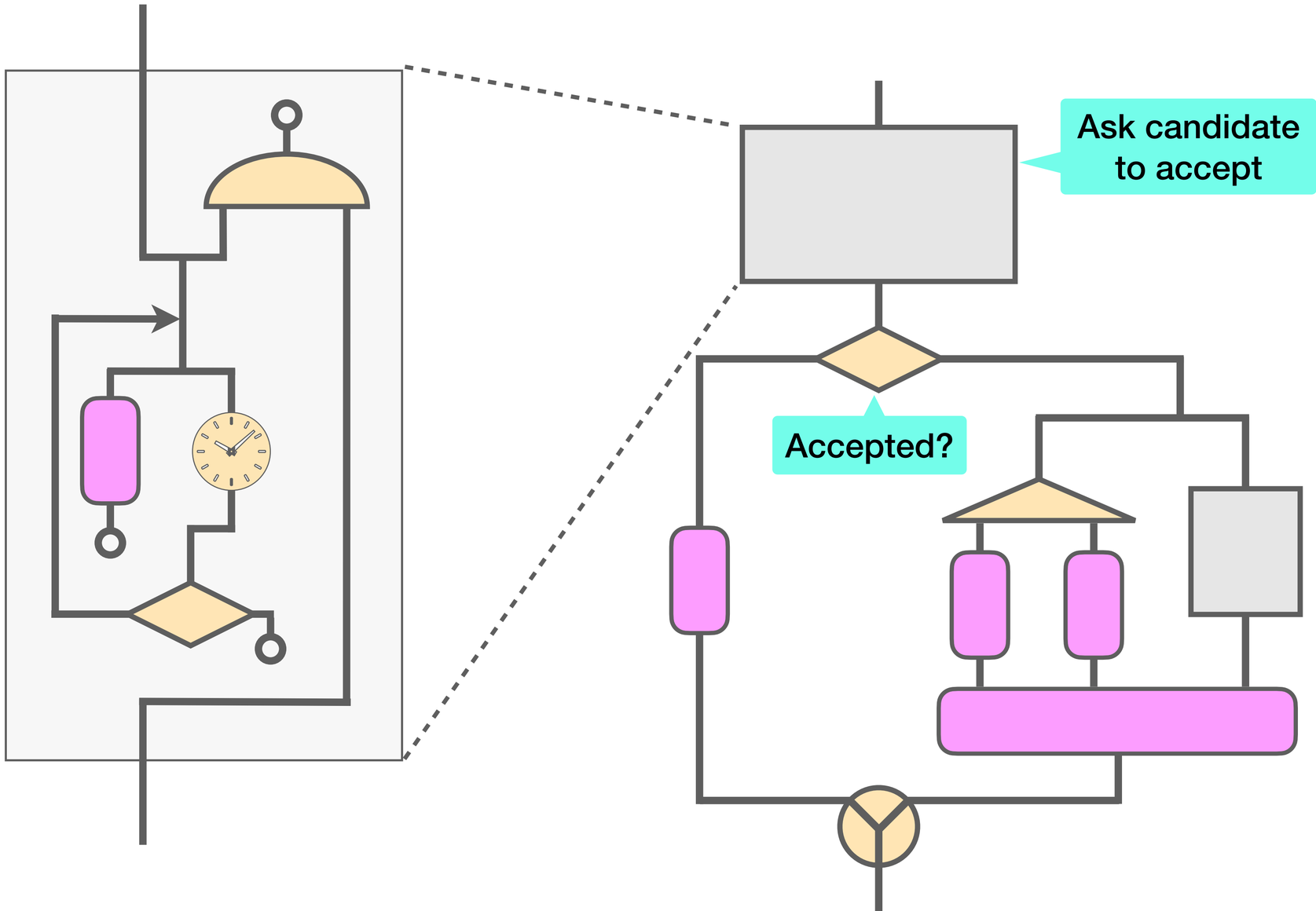
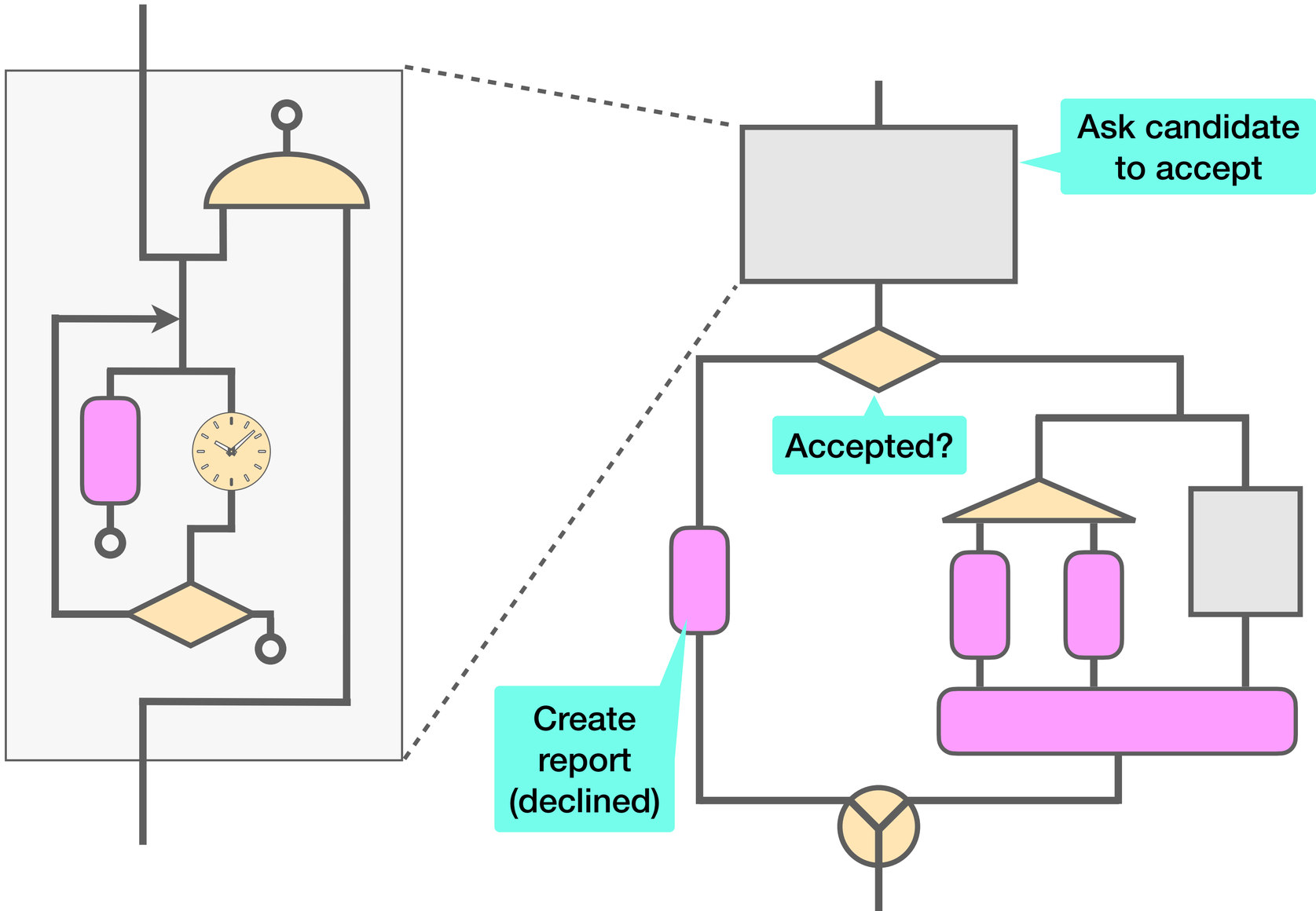


Background Check Workflow



Background Check Workflow



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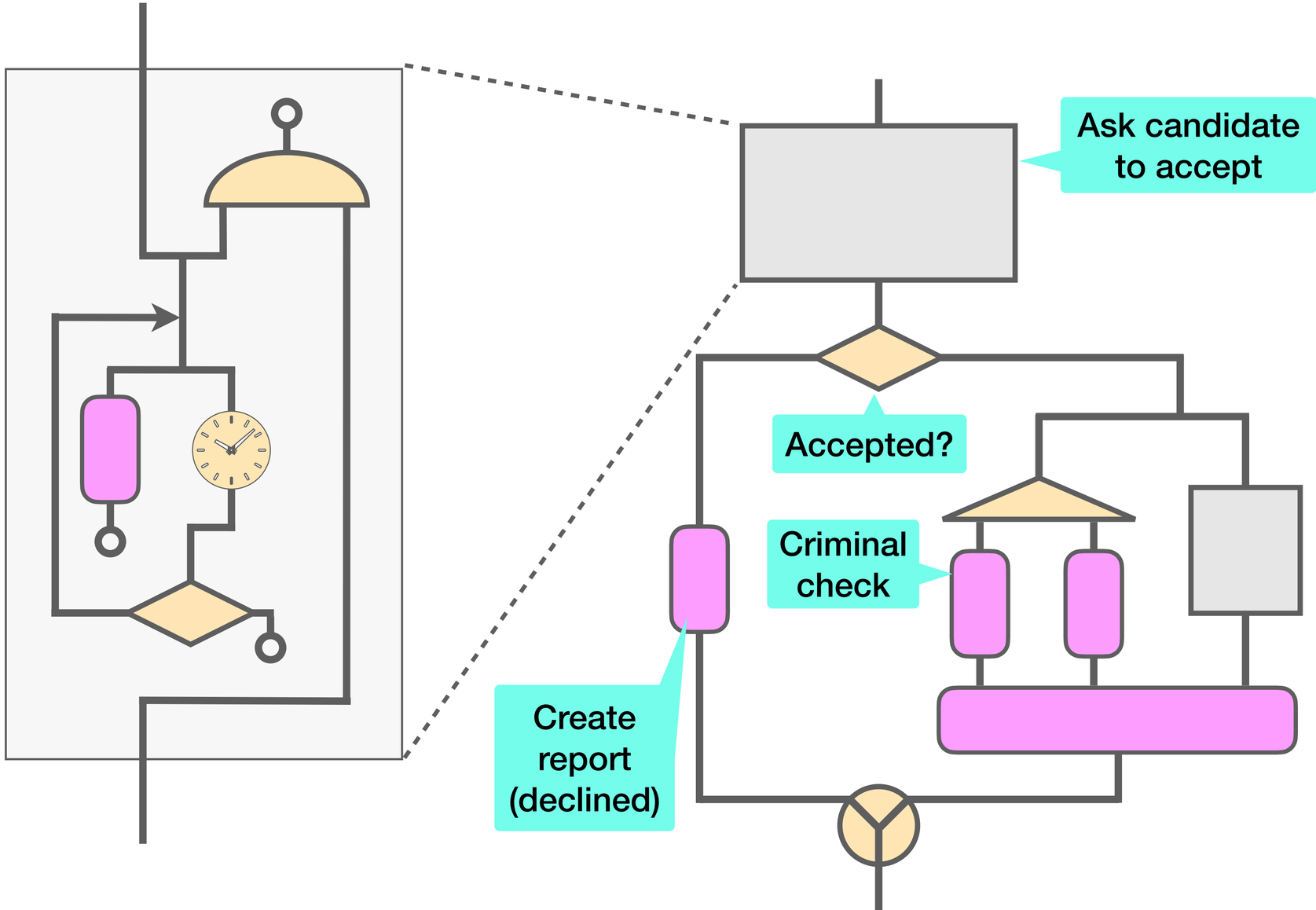

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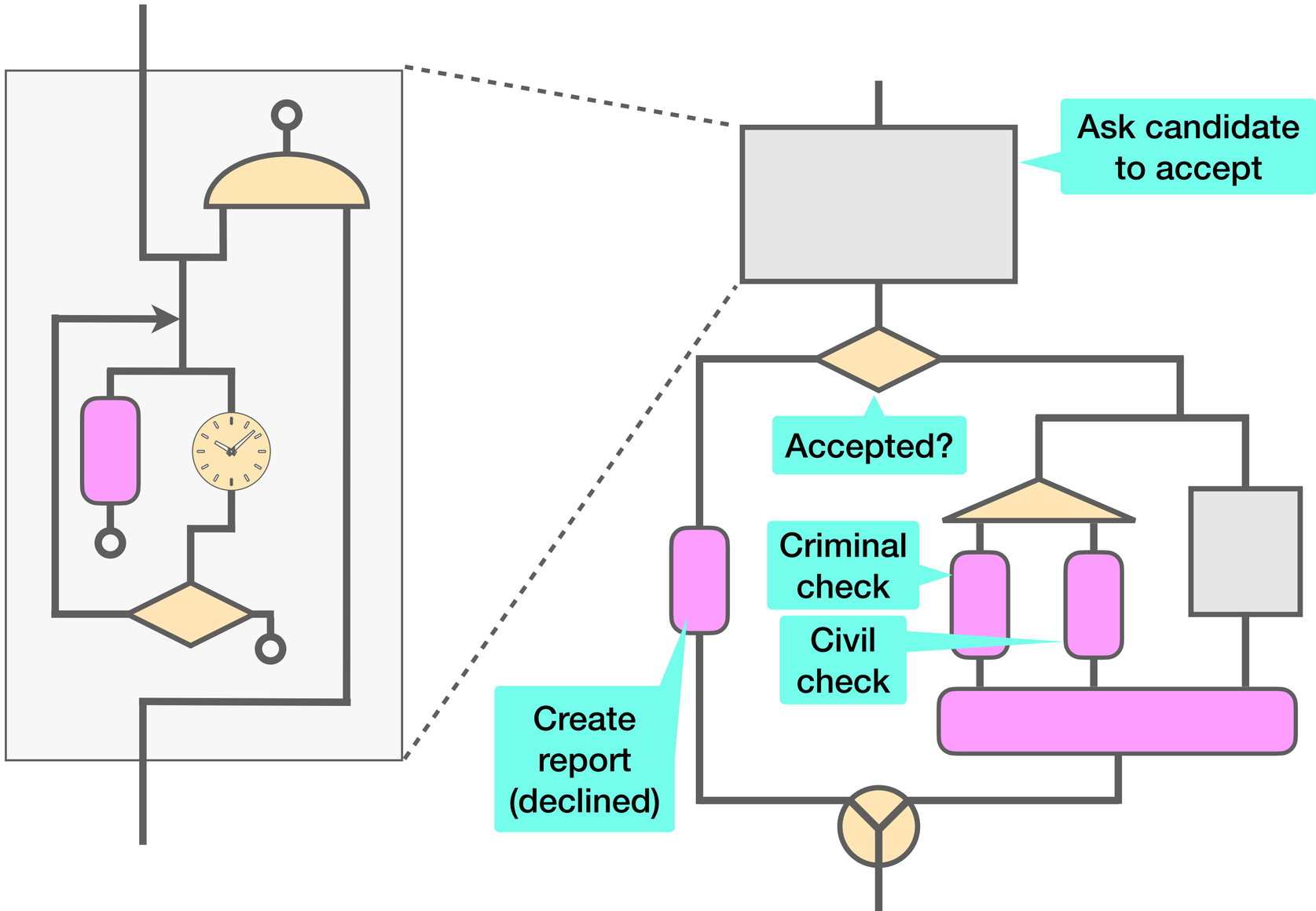

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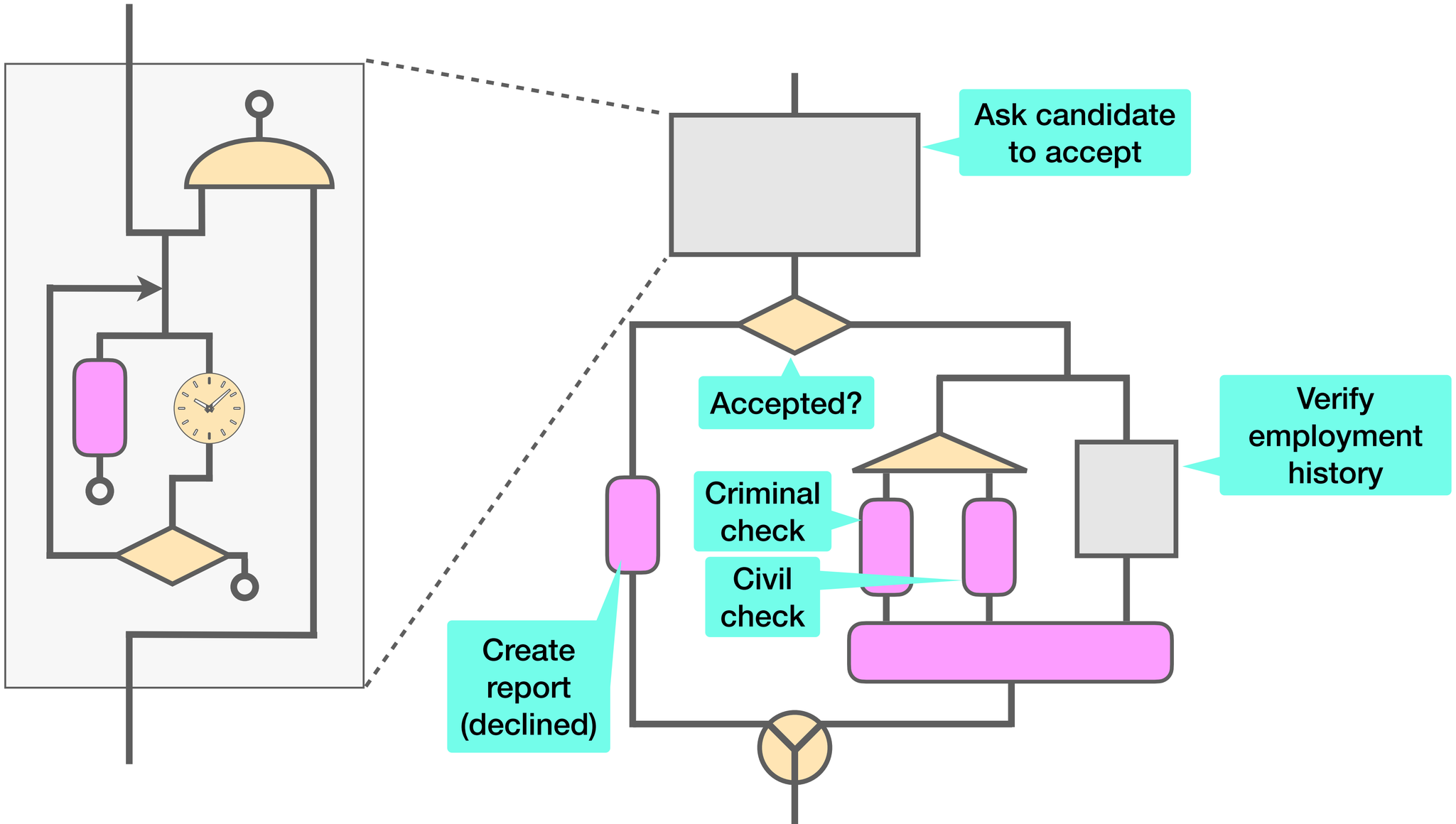

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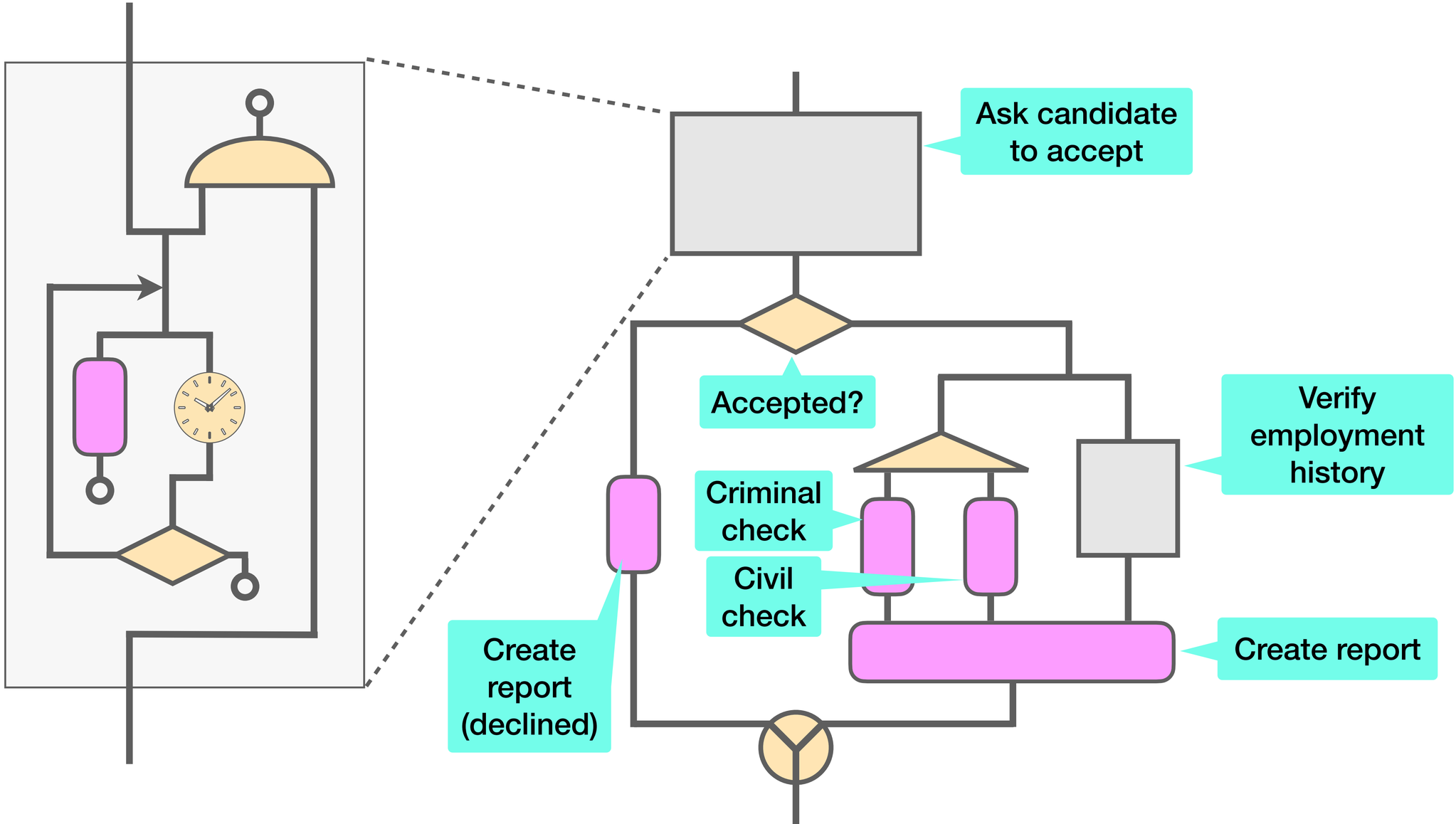
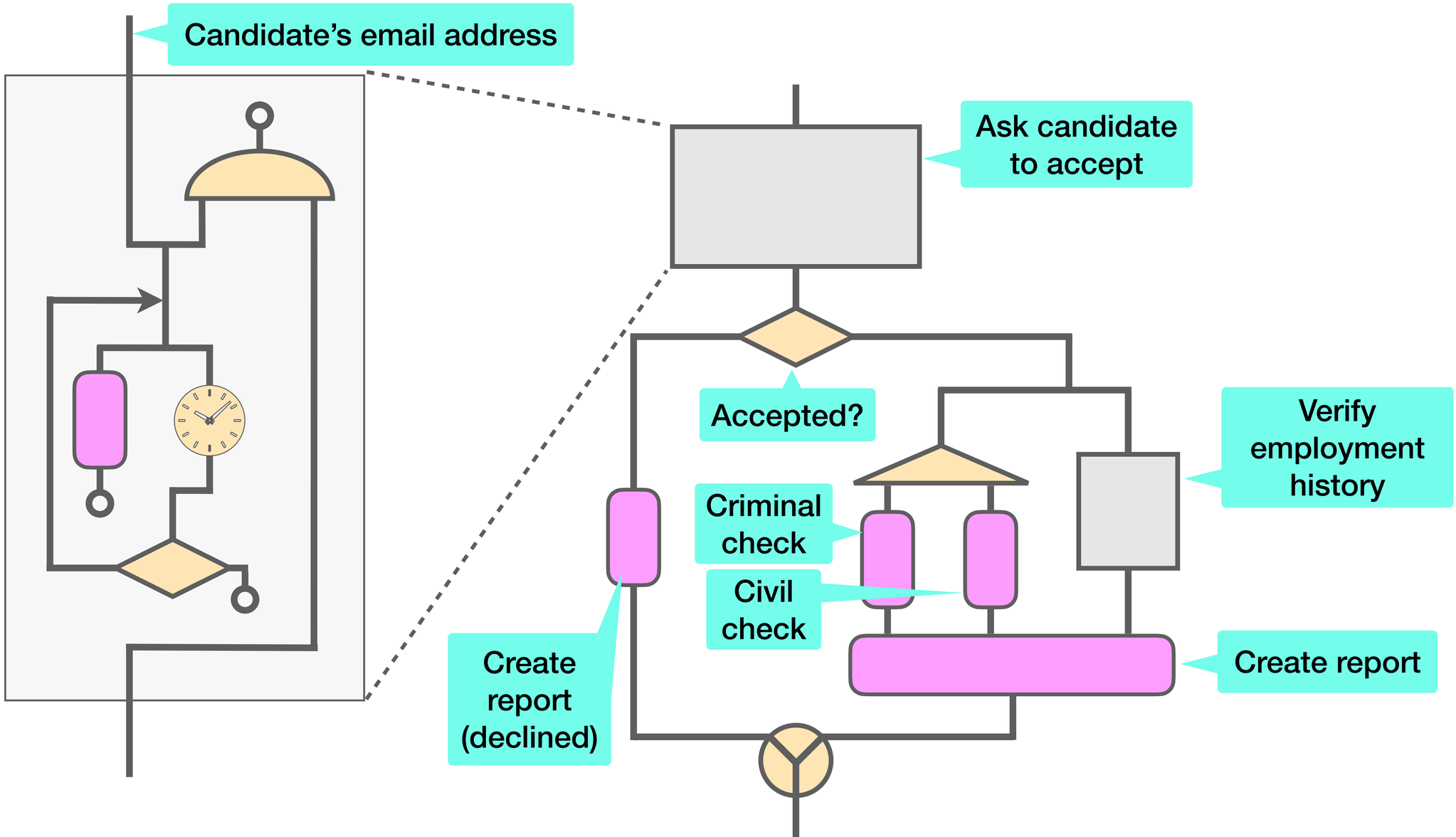


Background Check Workflow



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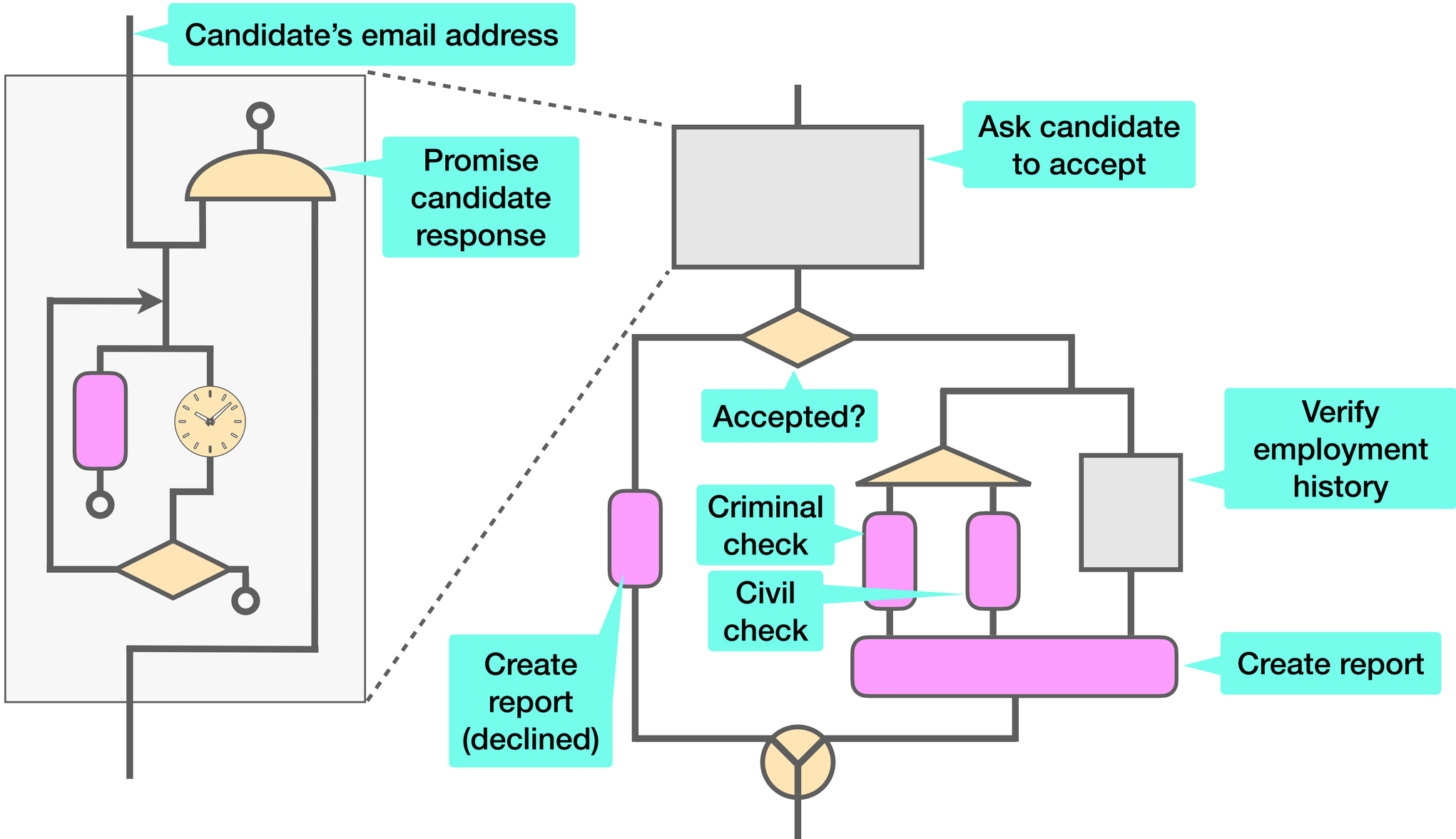

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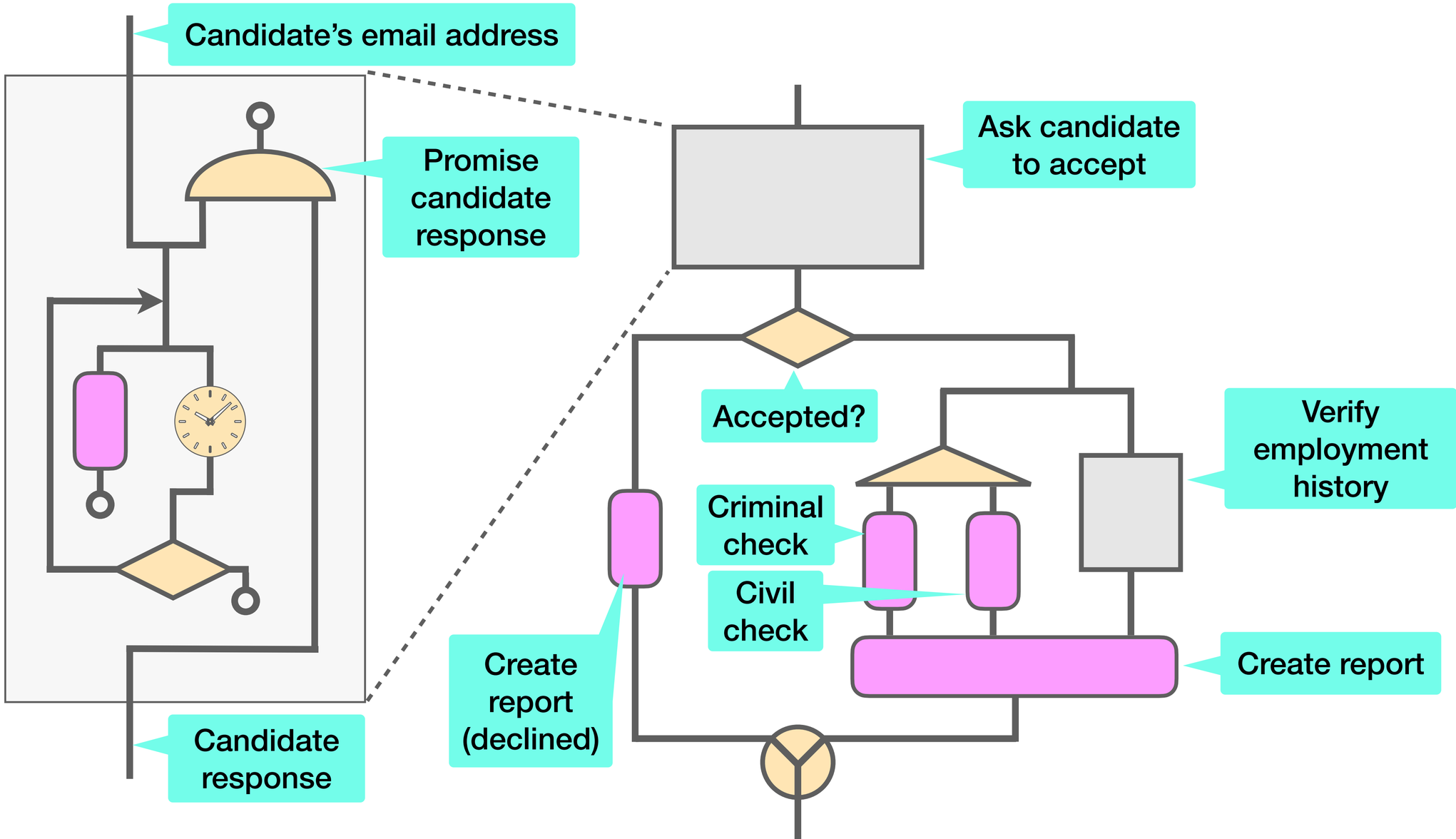

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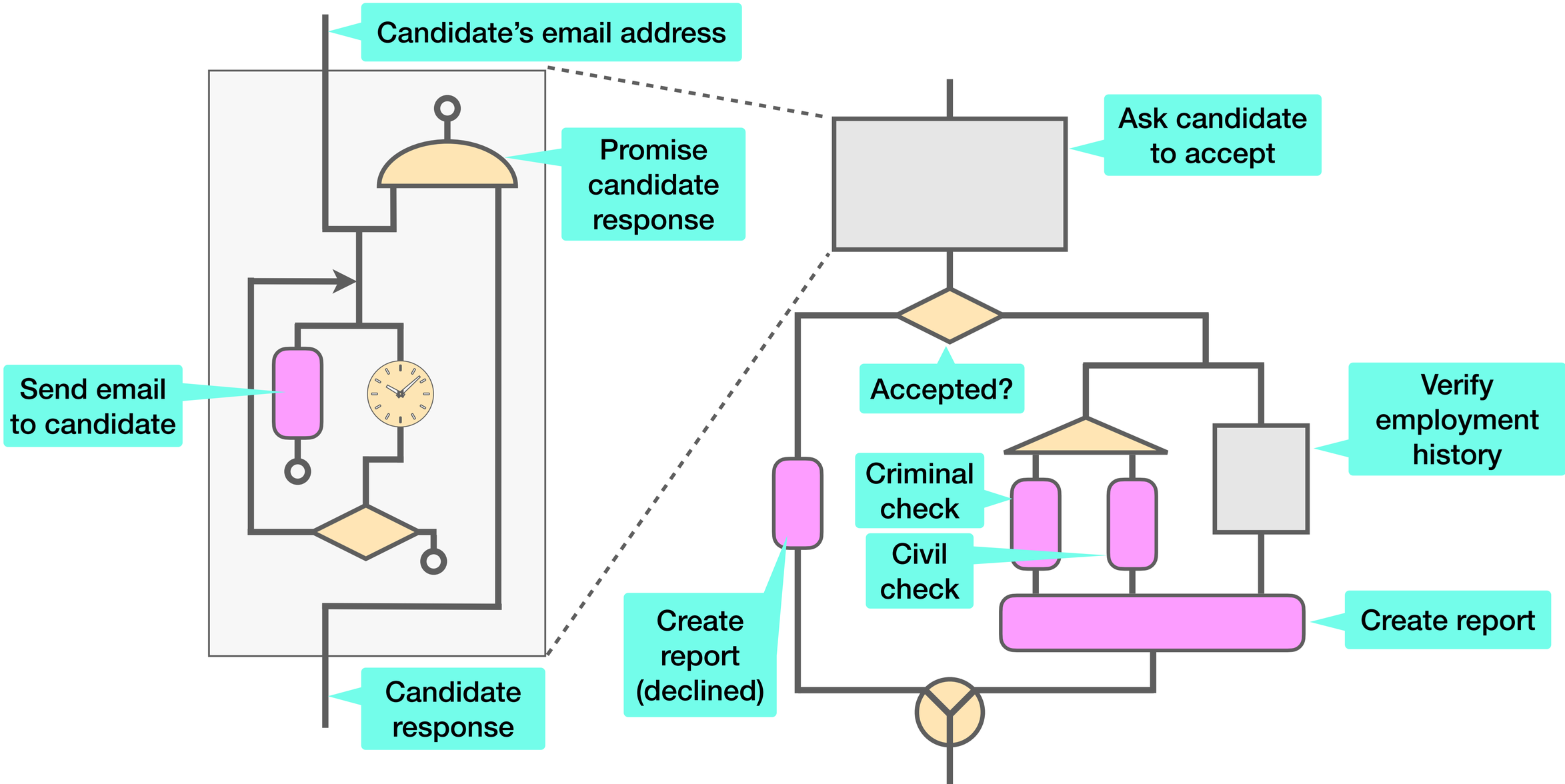

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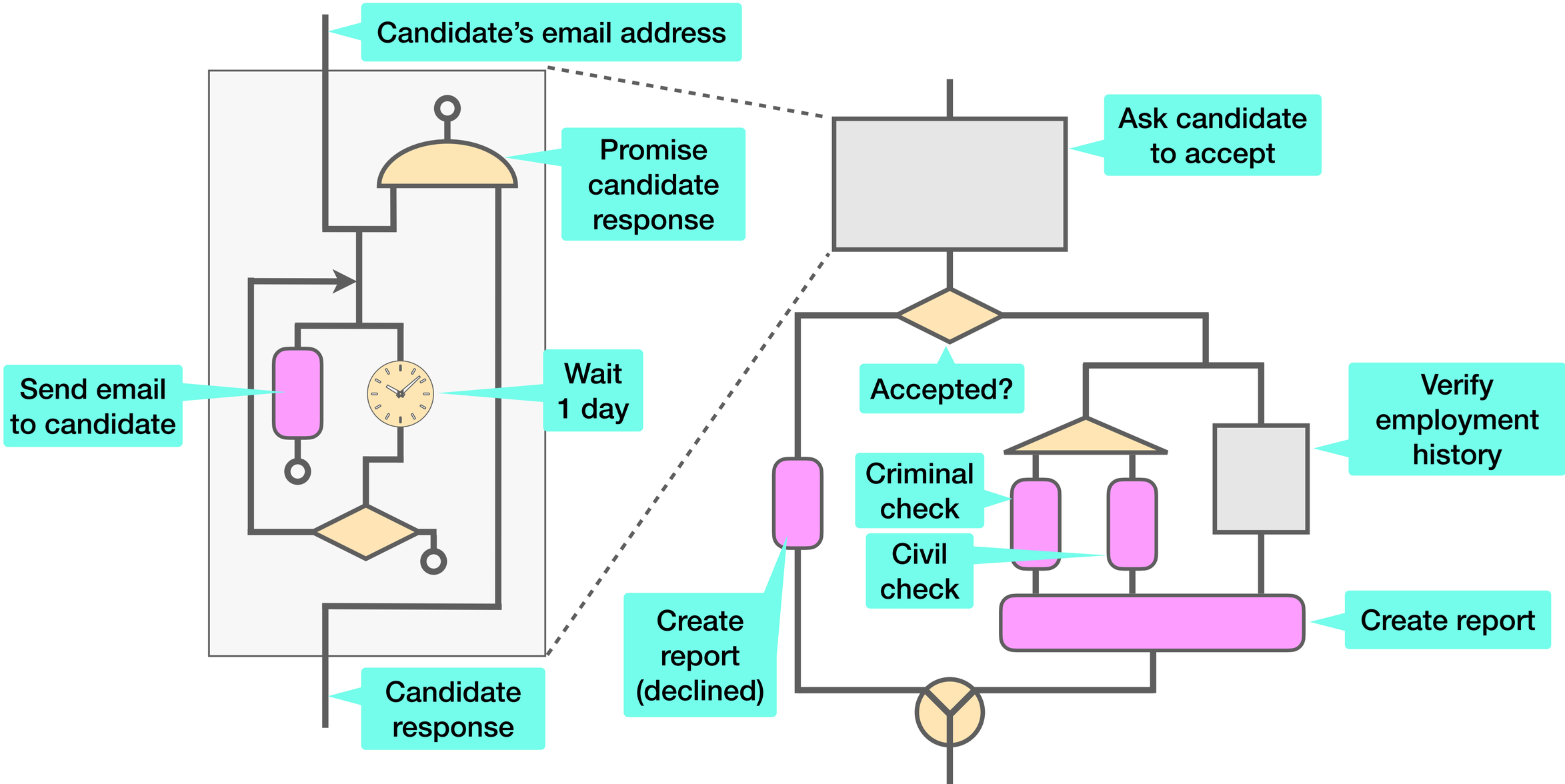

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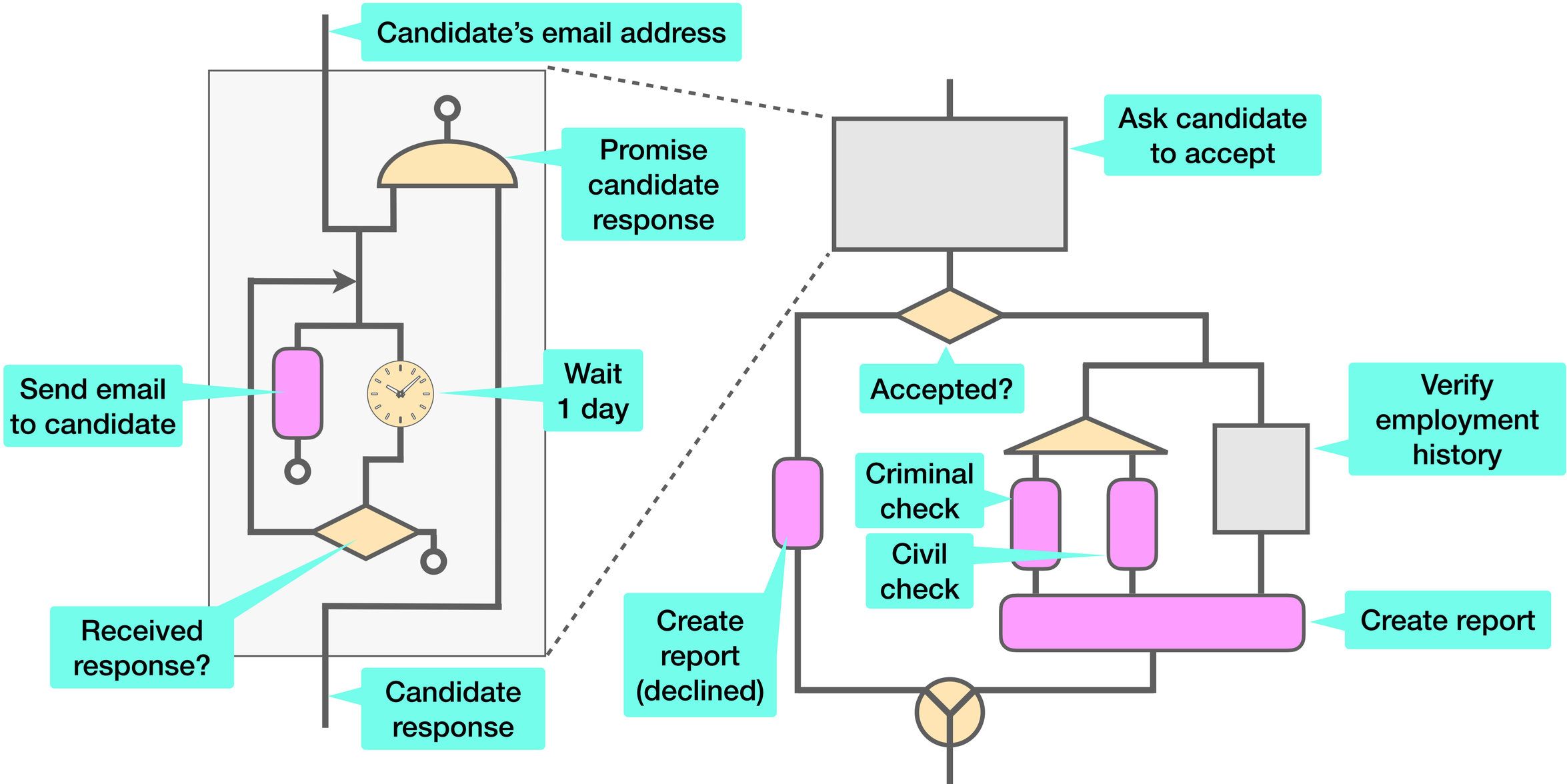

User Code

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val backgroundCheck: Flow[EmailAddress, Report] =
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      case Right(personalId ** employmentHistory) =>
        val crimi = checkCrimi(personalId)
        val civil = checkCivil(personalId)
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        Report.results(crimi ** civil ** verif)
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Internal Representation

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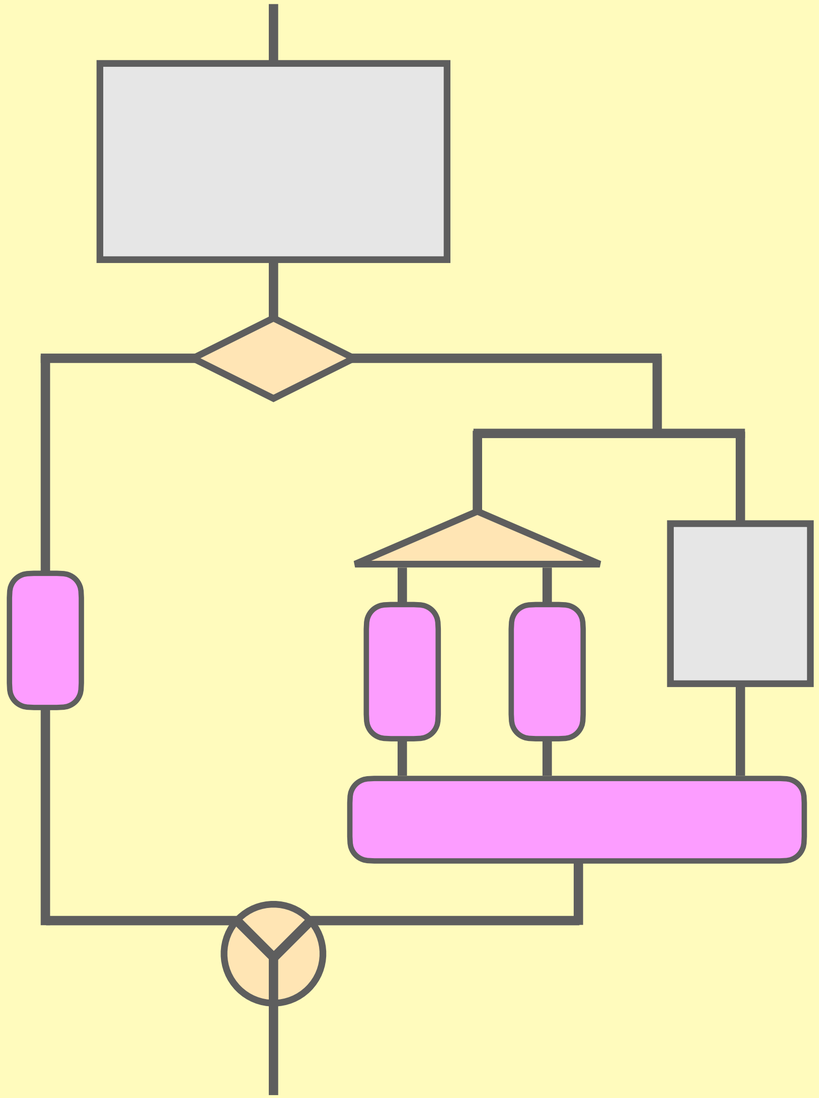

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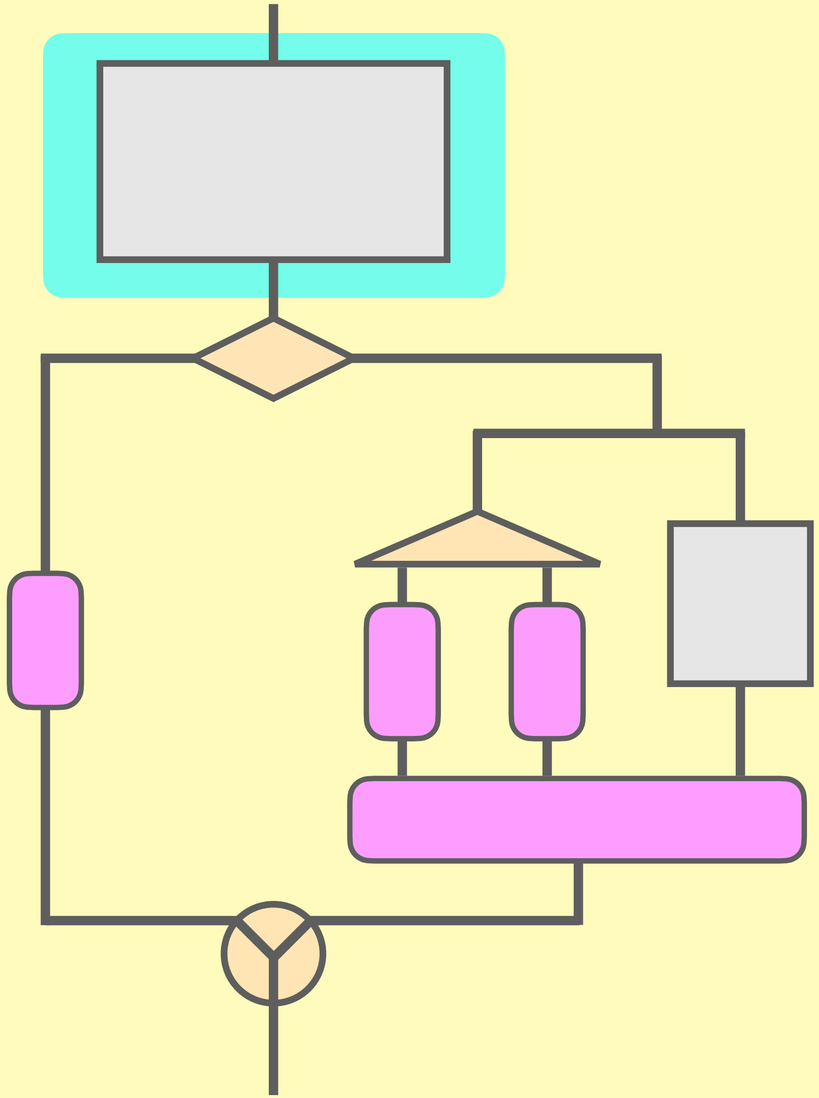

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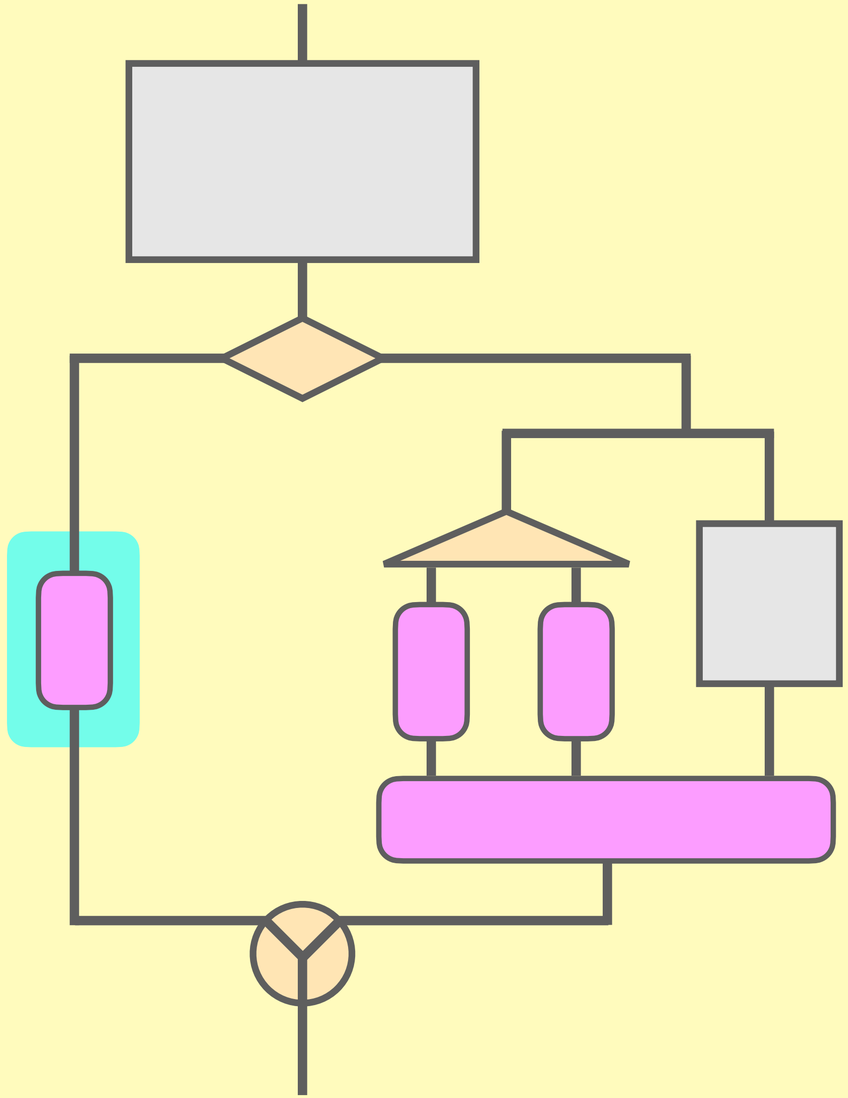

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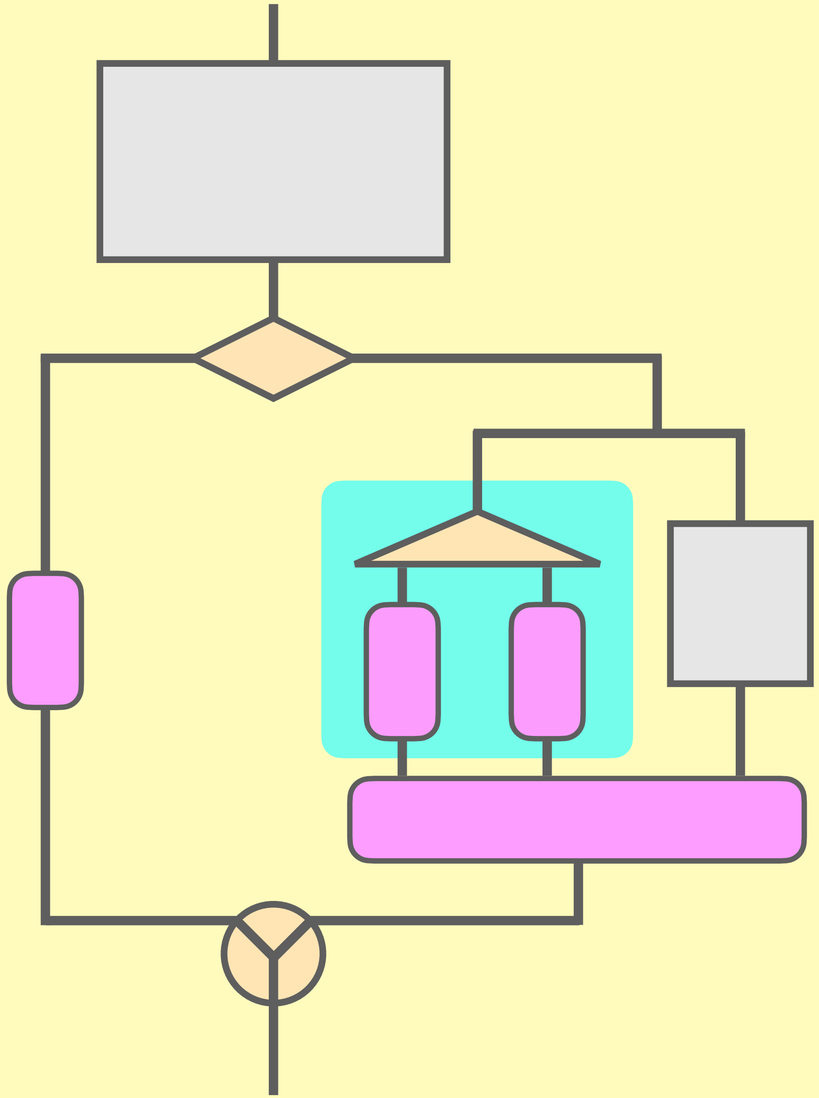

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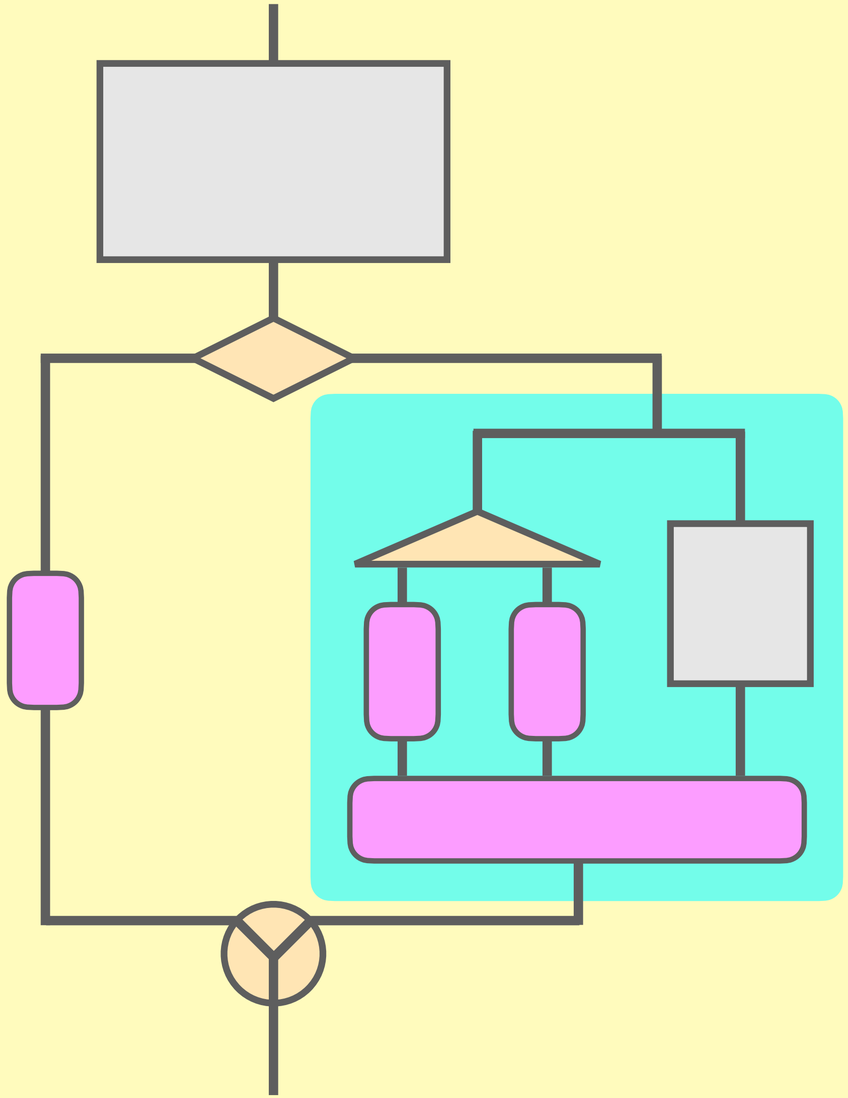

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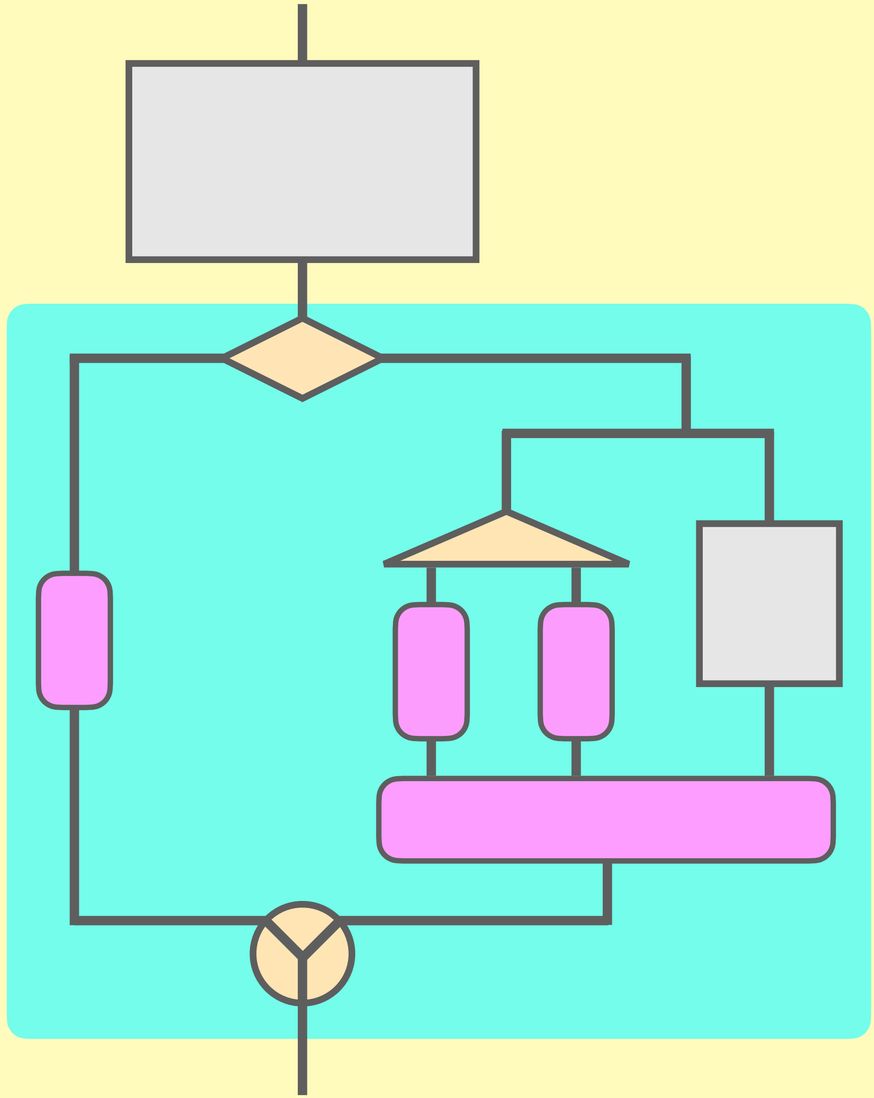

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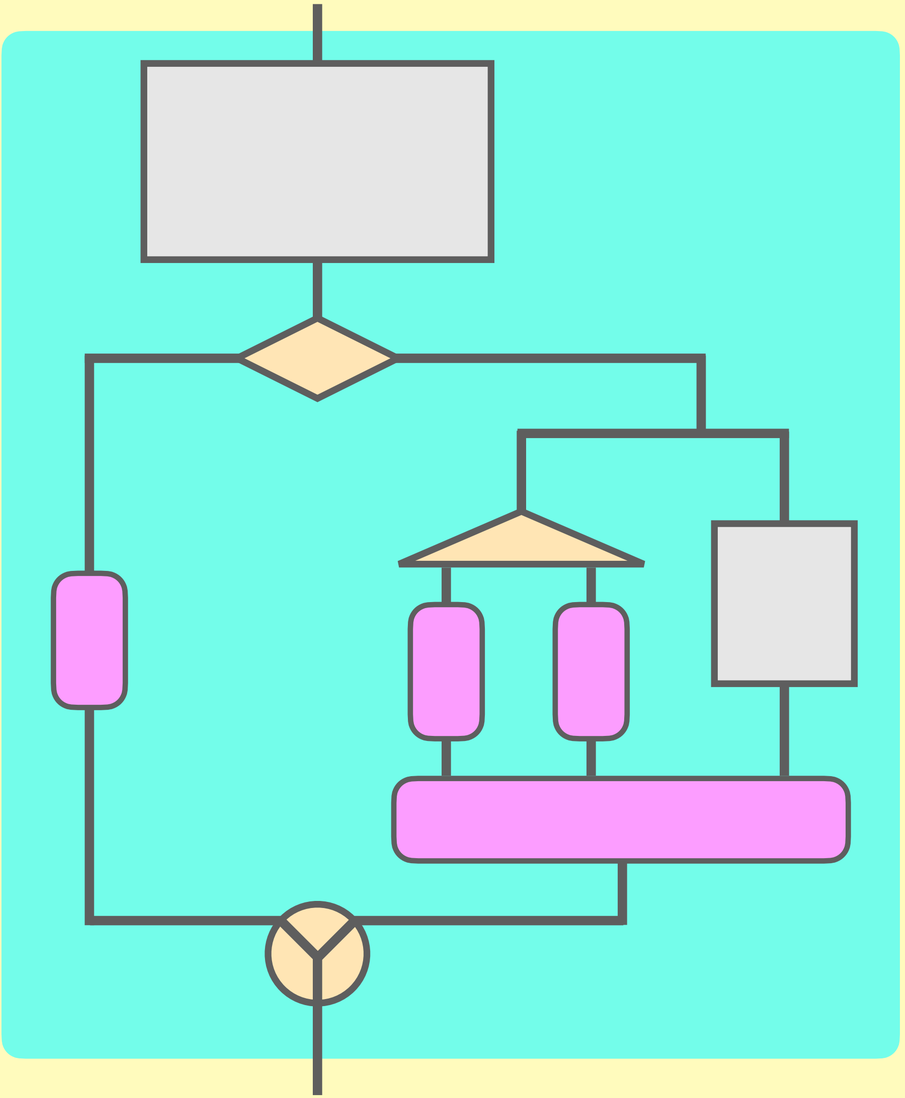

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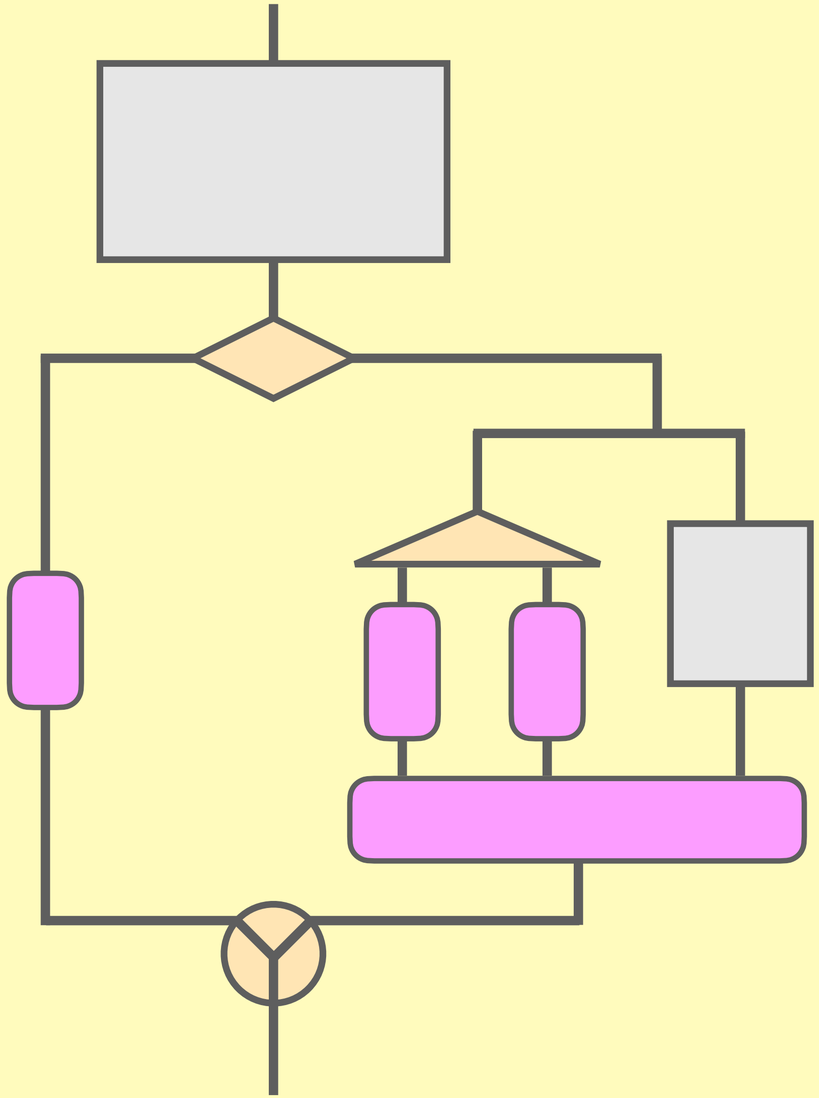

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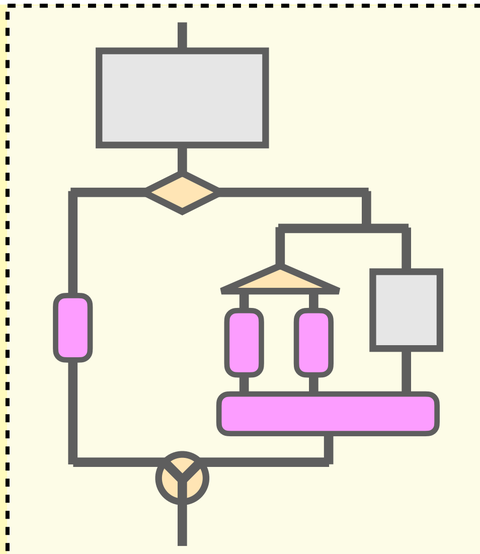

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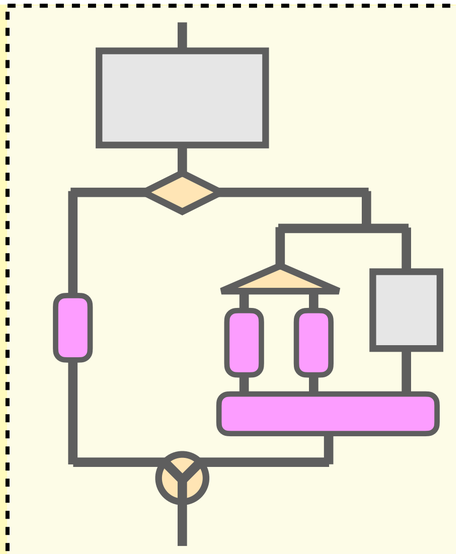
   results(crimi ** civil ** verif)
 }
}
```


```
AndThen(
 askForAccept,
 Switch(
  declined,
  AndThen(
   Par(
    AndThen(
     Dup(),
     Par(checkCrimi, checkCivil)
    ),
    verify
   ),
   results
)))
```



Goal

```
Flow { candidate =>
 askForAccept(candidate) switch {
  case Left(x) =>
   declined(x)
  case Right(id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
 }
}
```


```
AndThen(
 askForAccept,
 Switch(
  declined,
  AndThen(
   Par(
    AndThen(
     Dup(),
     Par(checkCrimi, checkCivil)
    ),
    verify
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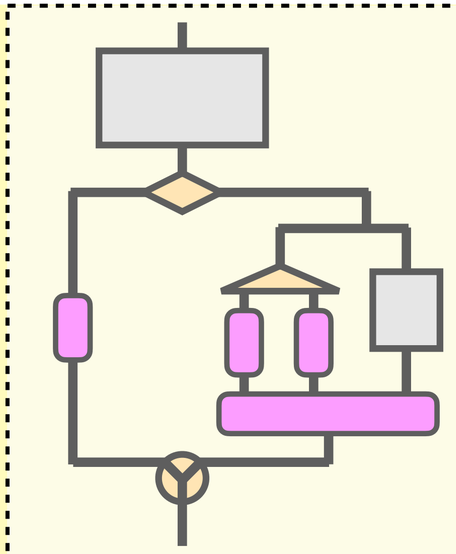
   results
)))
```



```
case Right(id ** history) =>
 val crimi = checkCrimi(id)
 val civil = checkCivil(id)
 val verif = verify(history)
 results(crimi ** civil ** verif)
```

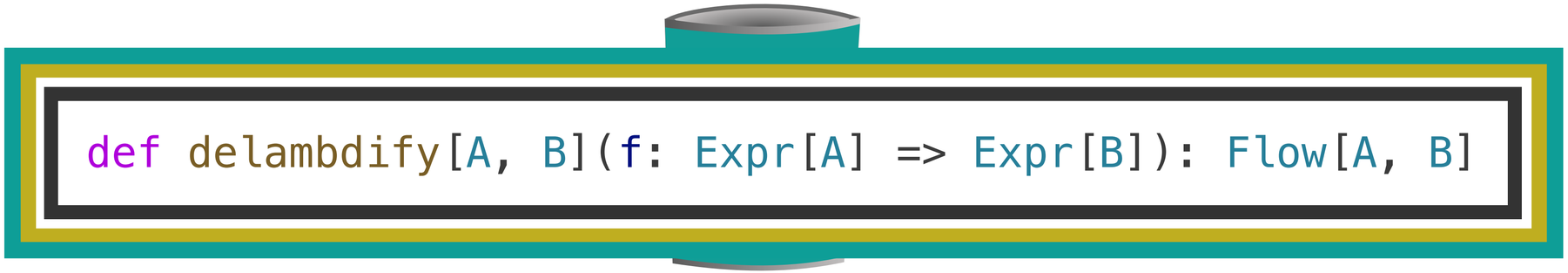
```
case       (id ** history) =>
 val crimi = checkCrimi(id)
 val civil = checkCivil(id)
 val verif = verify(history)
 results(crimi ** civil ** verif)
```

```
val onAccept:  Expr[PersonalId ** EmploymentHistory]  =>  Expr[Report]  =

  case      (id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
```


```
val onAccept:  Expr[PersonalId ** EmploymentHistory]  =>  Expr[Report]  =

  case      (id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
```

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val onAccept:  Expr[PersonalId ** EmploymentHistory]  =>  Expr[Report]  =

  case      (id ** history) =>
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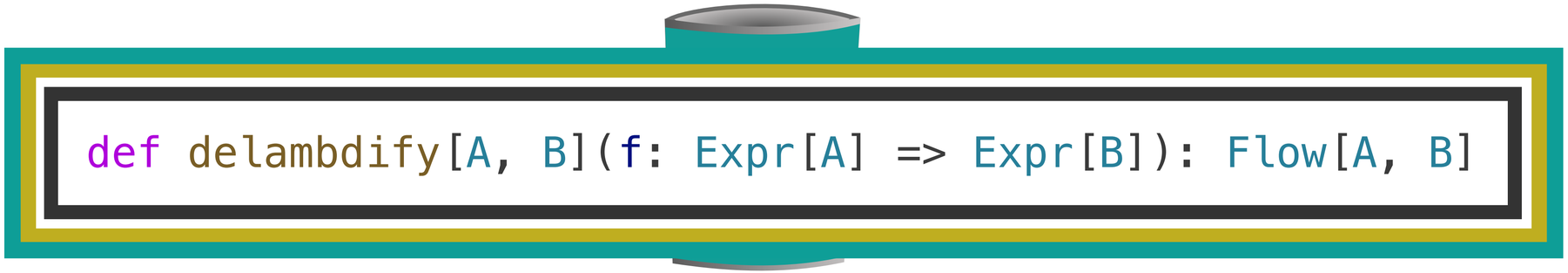


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val onAccept:  Expr[PersonalId ** EmploymentHistory]  =>  Expr[Report]  =

  case      (id ** history) =>
   val crimi = checkCrimi(id)
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   val verif = verify(history)
   results(crimi ** civil ** verif)
```

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

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

```
val onAccept:  Expr[PersonalId ** EmploymentHistory]  =>  Expr[Report]  =

  case      (id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
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   results(crimi ** civil ** verif)
```

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅 : Expr[A] = freshVariable()
```

```
val onAccept:  Expr[PersonalId ** EmploymentHistory]  =>  Expr[Report]  =

  case      (id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
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delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
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def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅  : Expr[A] = freshVariable()
  val expr : Expr[B] = f(🍅)
```

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```

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

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def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅 : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```

```
val onAccept:  Expr[PersonalId ** Employmenti

  case      (id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
```

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅  : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]

expr : Expr[Report] =
```

```
val onAccept:  Expr[PersonalId ** Employmenti

  case      (id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
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   results(crimi ** civil ** verif)
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delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
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   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
```
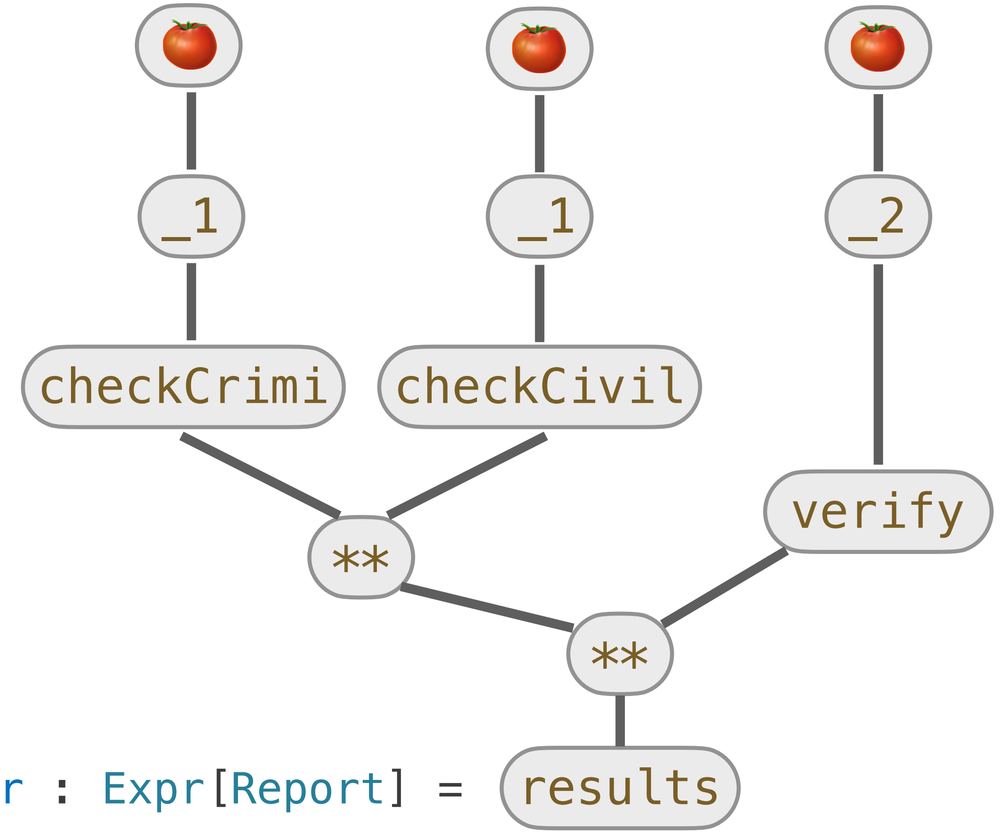

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```




```
expr : Expr[Report] =
```

```
def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅  : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
  Lam(🍅, expr)
```

```
val onAccept:  Expr[PersonalId ** Employmenti

  case       (id ** history) =>
   val crimi = checkCrimi(id)
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f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```

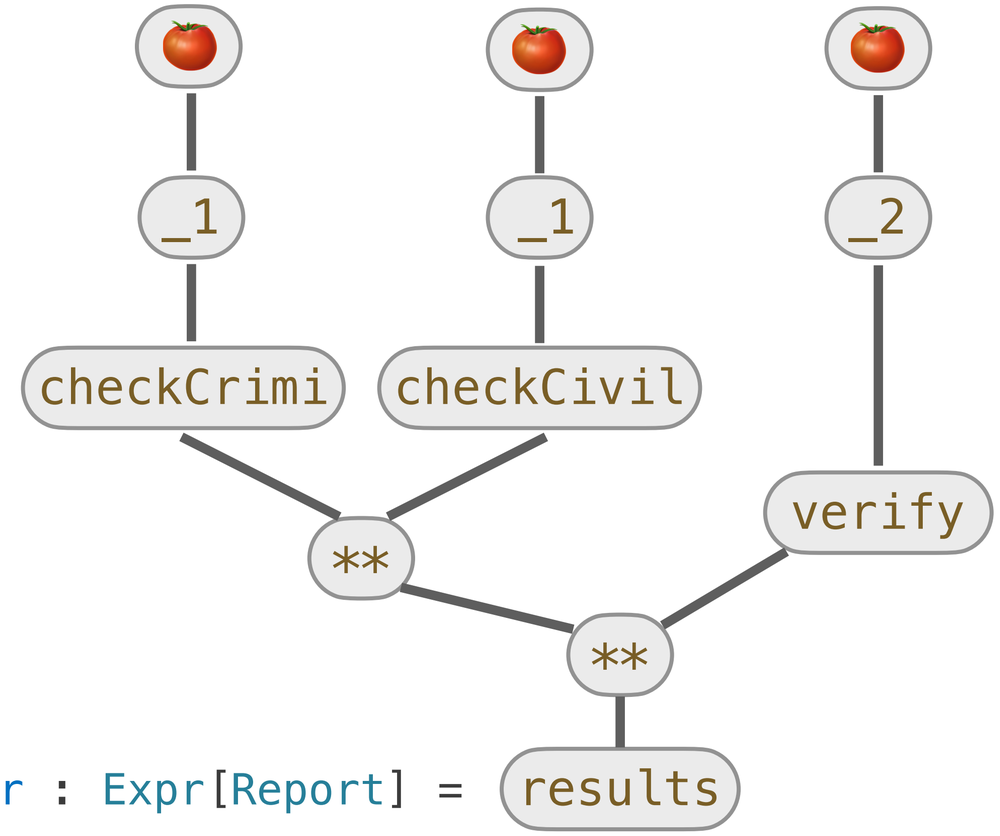

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def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
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  val expr : Expr[B] = f(🍅)
  Lam(🍅, expr)
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   val verif = verify(history)
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delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
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```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
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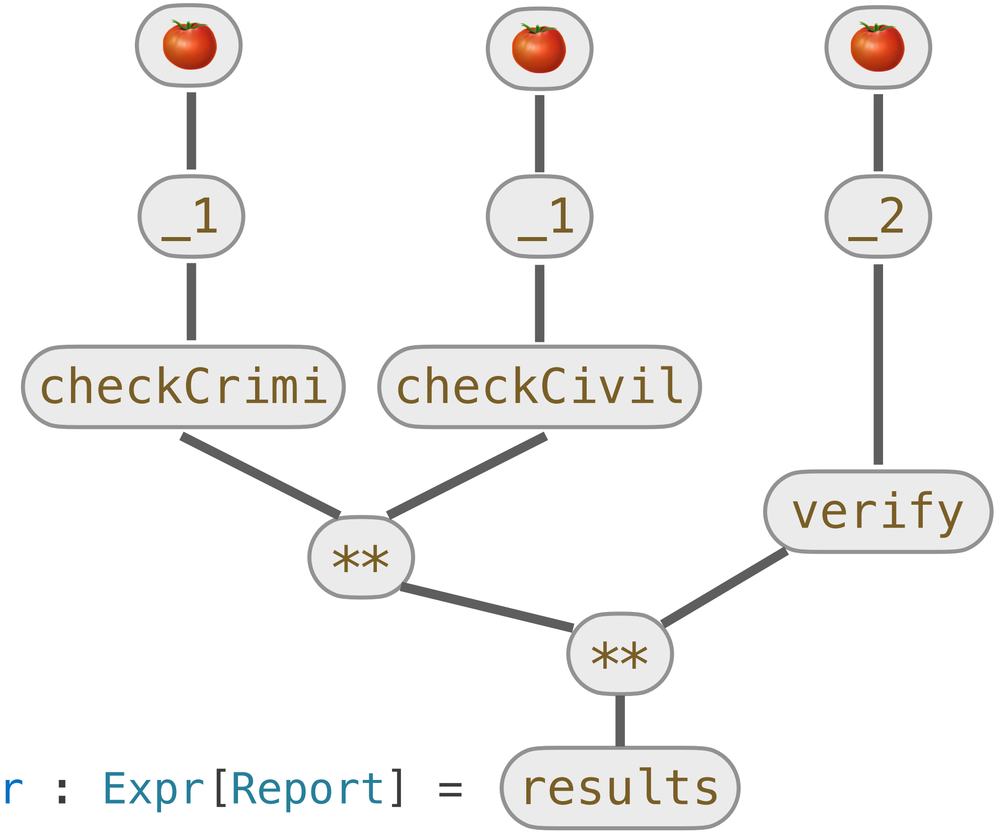


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```
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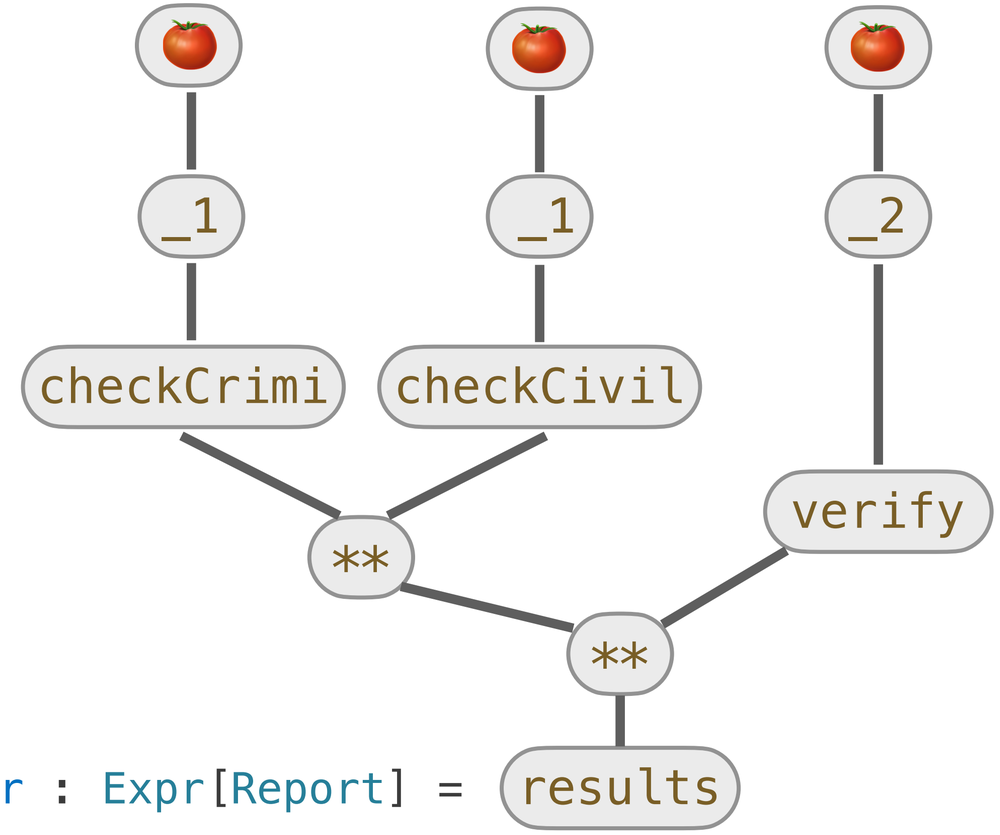
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```

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```

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  val 🍅  : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
  eliminate(🍅, from = expr)
```

```
val onAccept:  Expr[PersonalId ** Employmenti

  case       (id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
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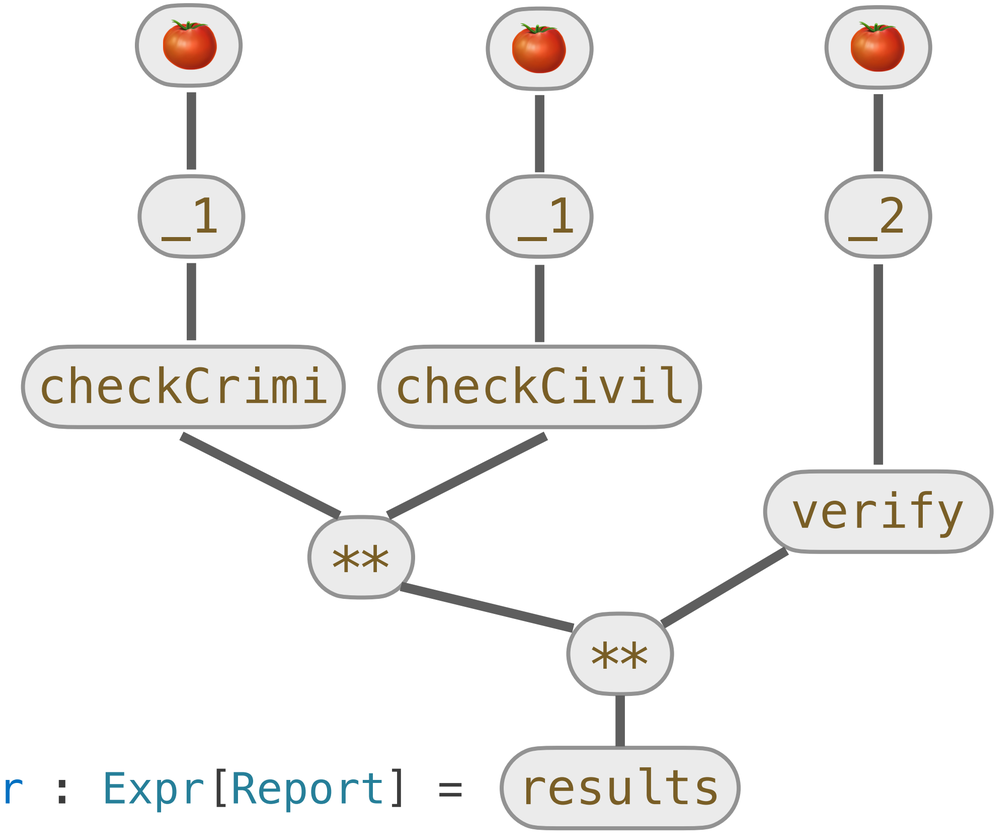
```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```



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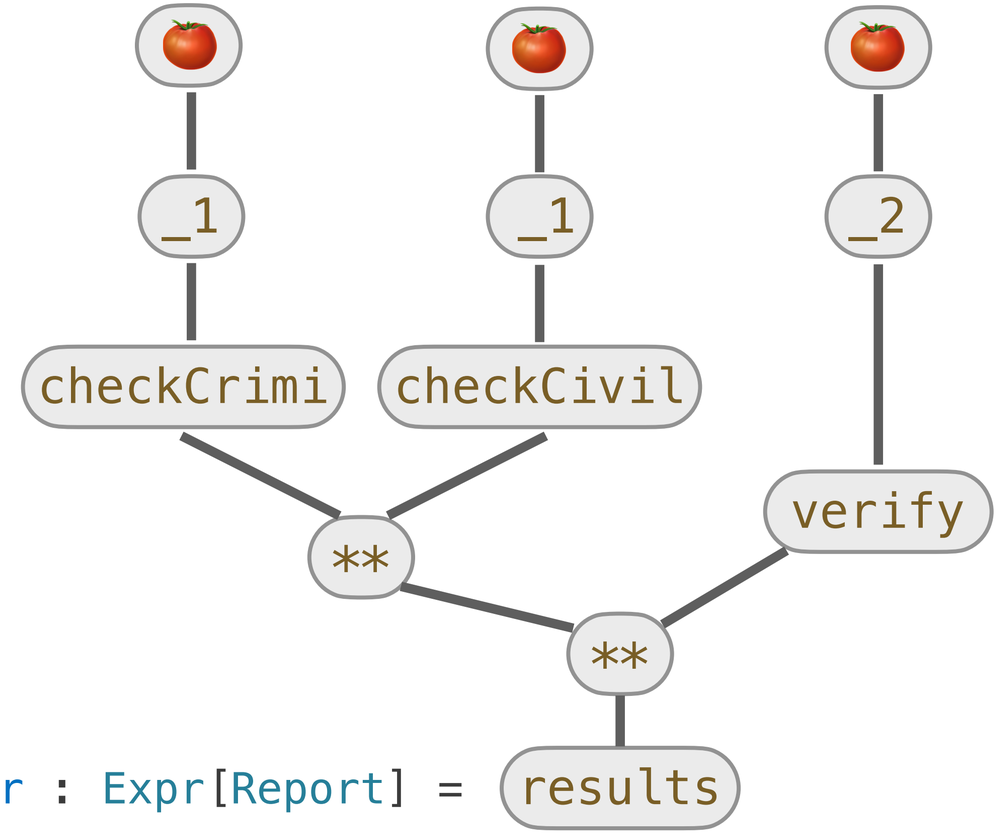
  val 🍅  : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
  eliminate(🍅, from = expr)
```

```
val onA                                   Employmenti
  case
   val
   val
   val
   resu                                        f)
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```



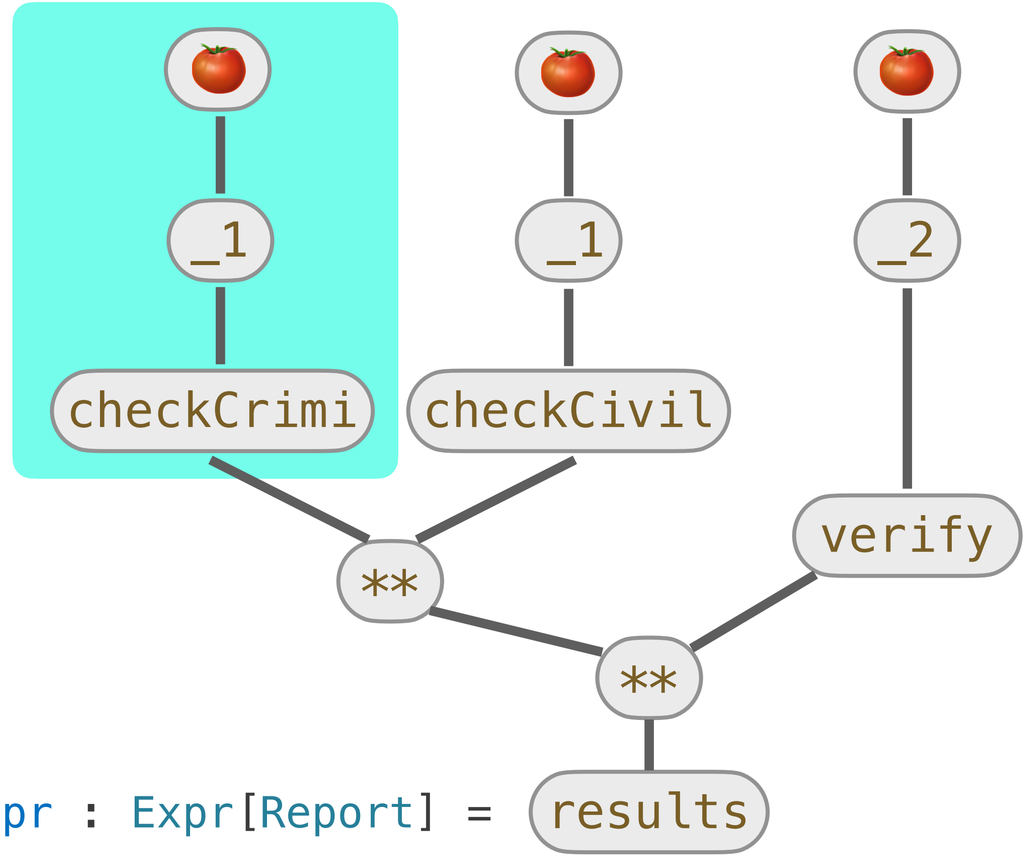

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅 : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
  eliminate(🍅, from = expr)
```

```
val onA                                   Employmenti
  case
   val
   val
   val
   resu                                        f)
```

```
_1 >>> checkCrimi
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```



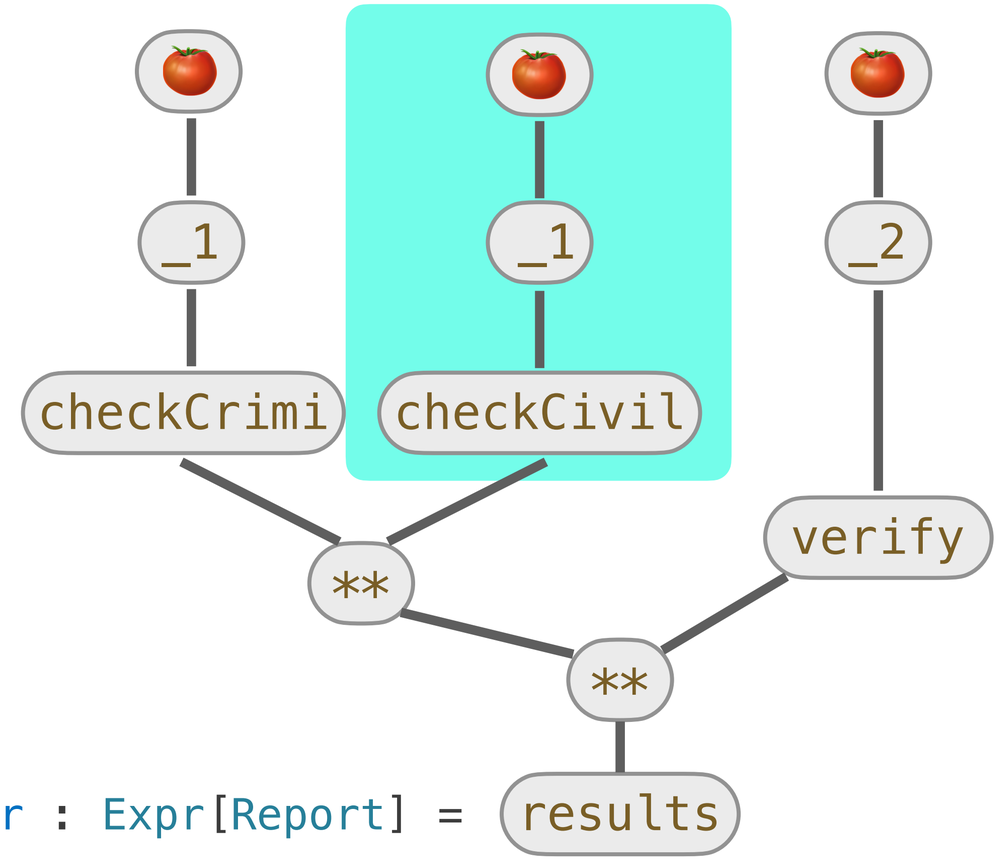

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅 : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
  eliminate(🍅, from = expr)
```

```
val onA                                   Employmenti
  case
   val
   val
   val
   resu                                        f)
```

```
_1 >>> checkCrimi
_1 >>> checkCivil
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```



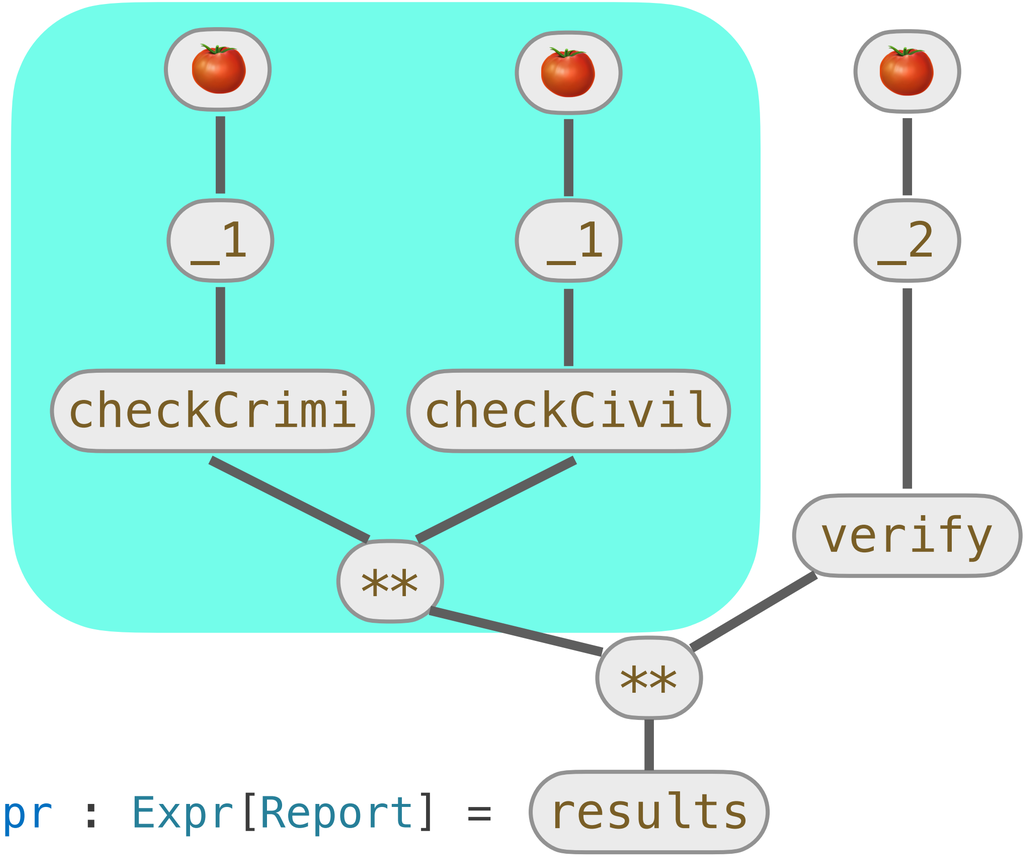

```
expr : Expr[Report] =
```

```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅 : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
  eliminate(🍅, from = expr)
```

```
Dup() >>> Par(
  _1 >>> checkCrimi,
  _1 >>> checkCivil
)
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
expr : Expr[Report] = results
```




```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

```
def delambdify[A, B](f: Expr[A] => Expr[B]): Flow[A, B] =
  val 🍅  : Expr[A] = freshVariable
  val expr : Expr[B] = f(🍅)
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```

```
Dup() >>> Par(
  _1 >>> checkCrimi,
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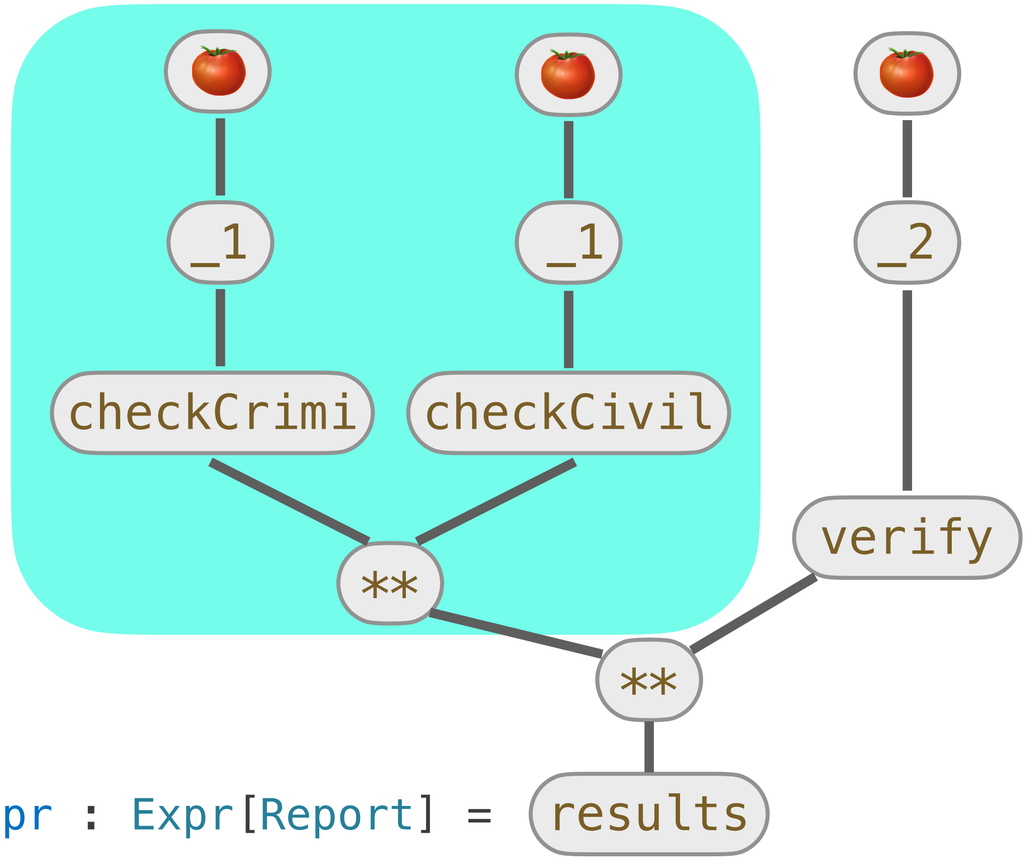
)
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```

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```
_1 >>> Dup() >>> Par(
  checkCrimi,
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```
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
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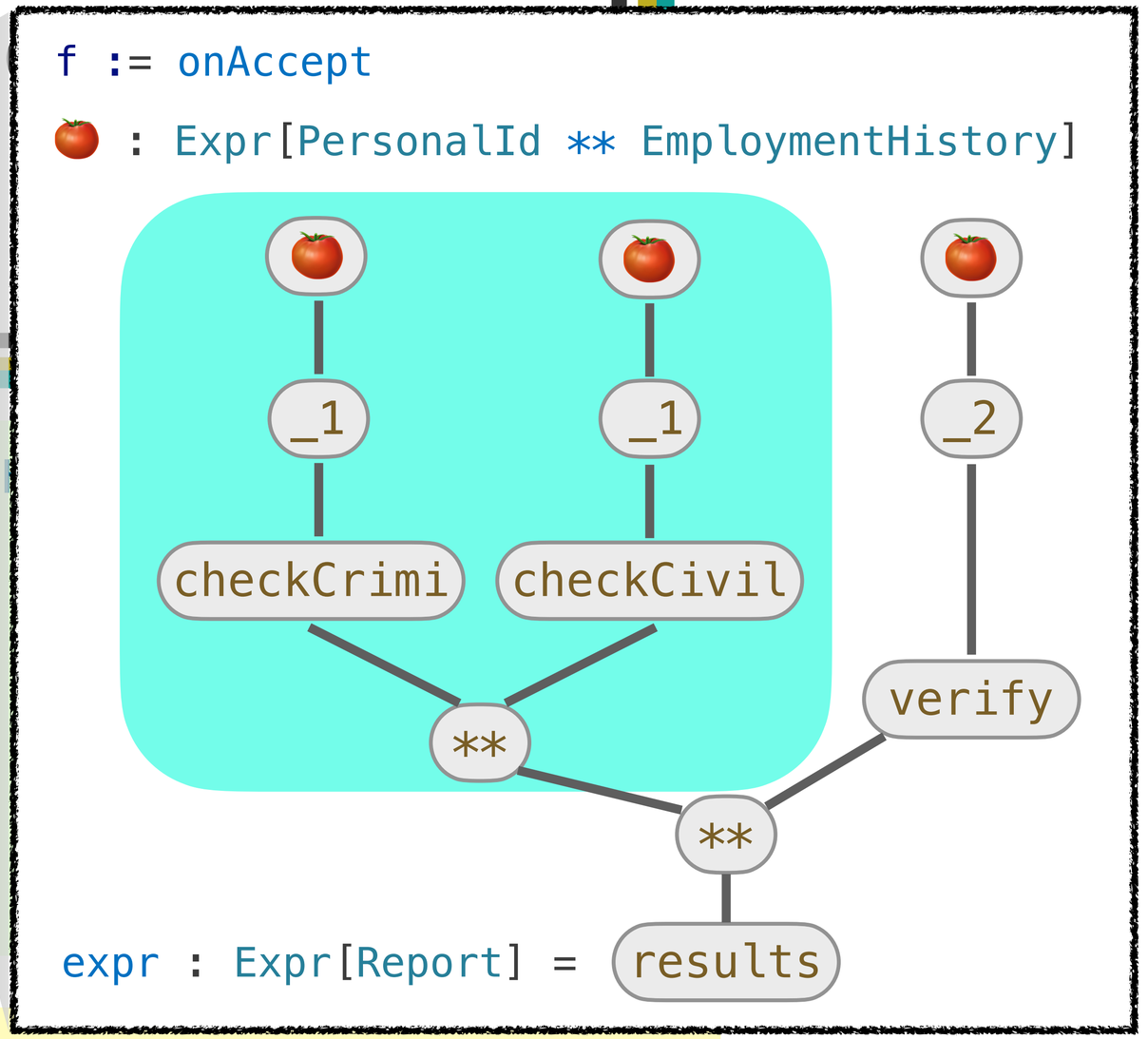

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  val expr : Expr[B] = f(🍅)
  eliminate(🍅, from = expr)
```
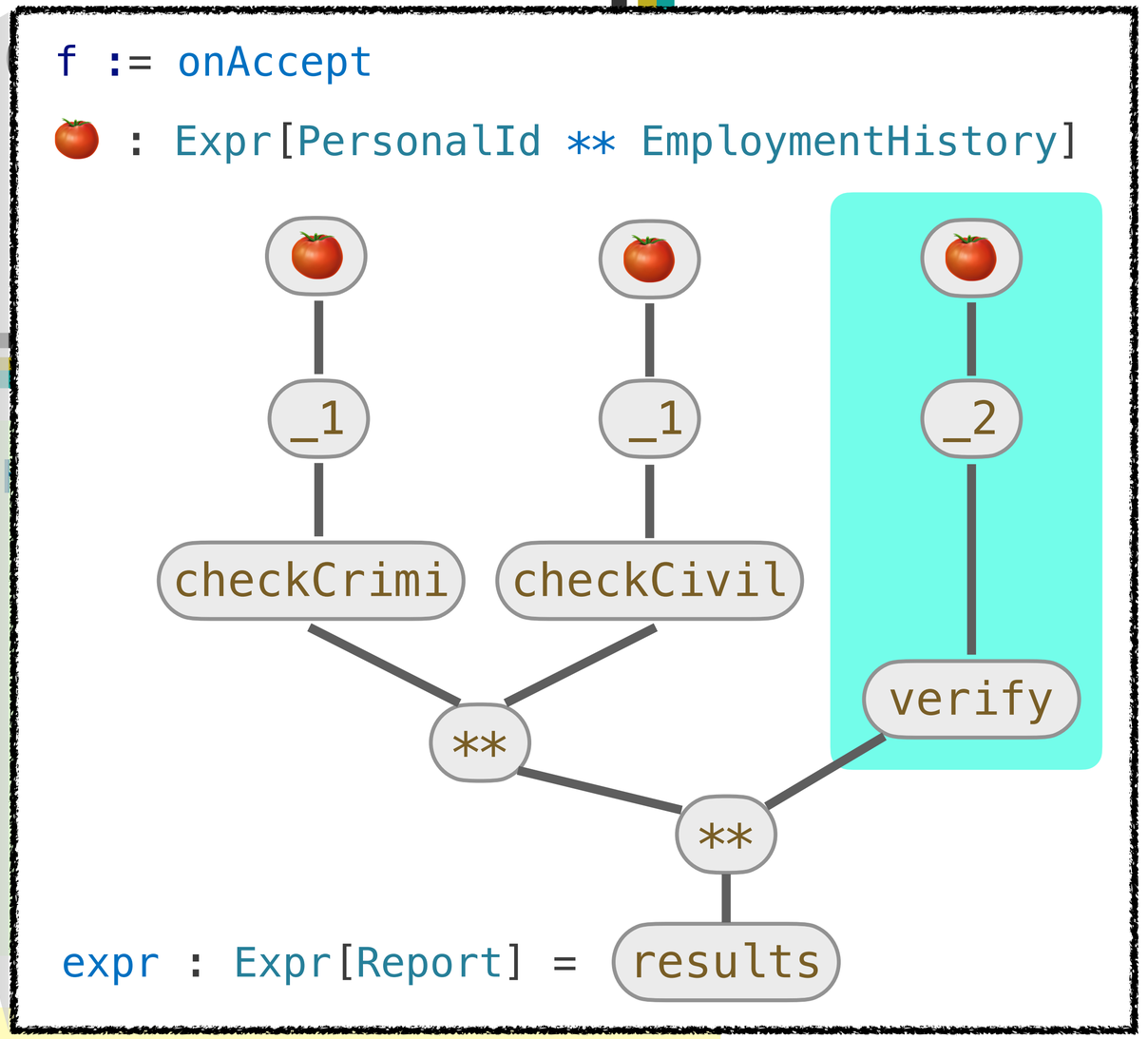

```
val onA                                   Employmenti
  case
   val
   val
   val
   resu                                        .f)
```

```
_1 >>> Dup() >>> Par(
  checkCrimi,
  checkCivil
)
_2 >>> verify
```

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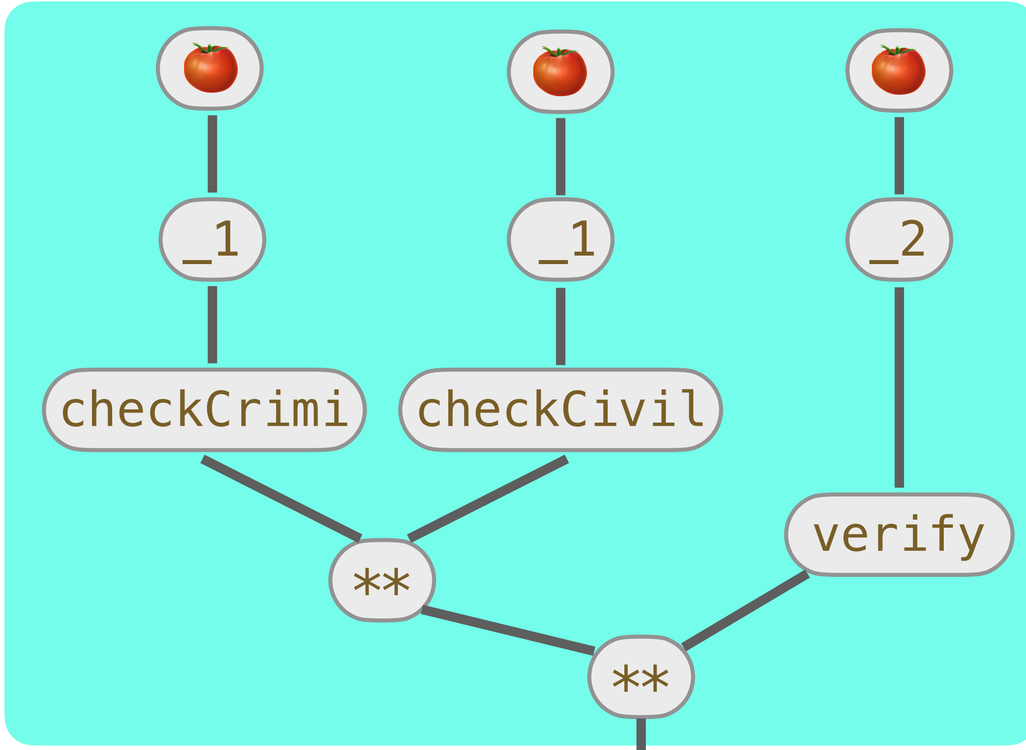
```
Dup() >>> Par(
  _1 >>> Dup() >>> Par(
    checkCrimi,
    checkCivil
  ),
  _2 >>> verify
)
```

```
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
expr : Expr[Report] = results
```

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f := onAccept
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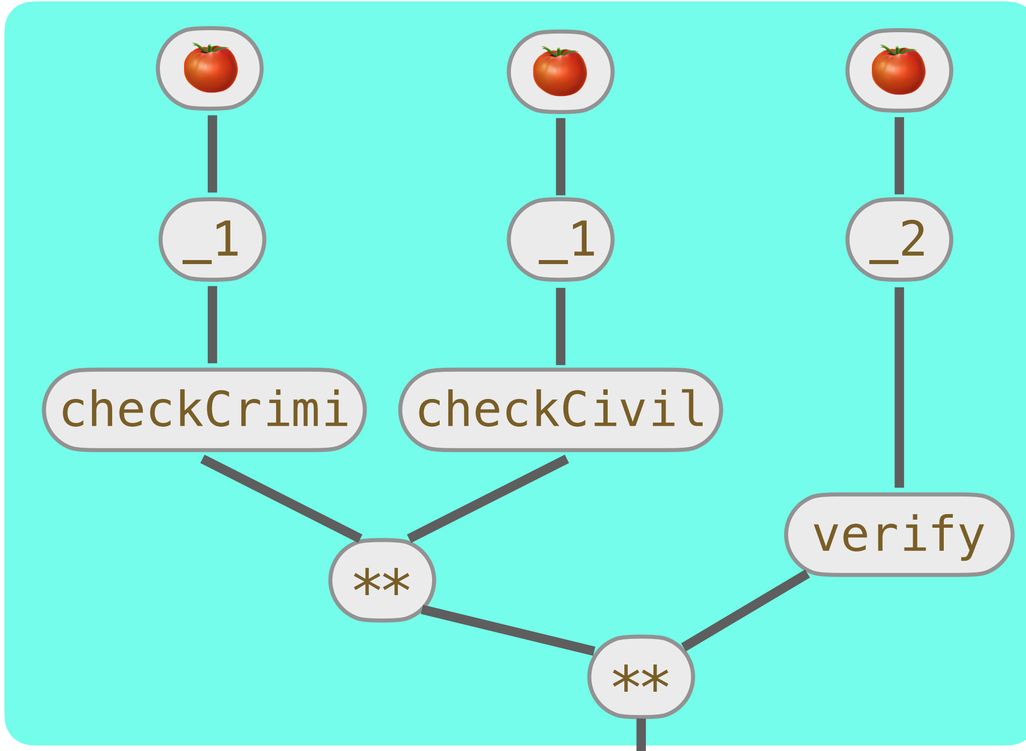


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delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

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Par(
  Dup() >>> Par(
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  ),
  verify
)
```

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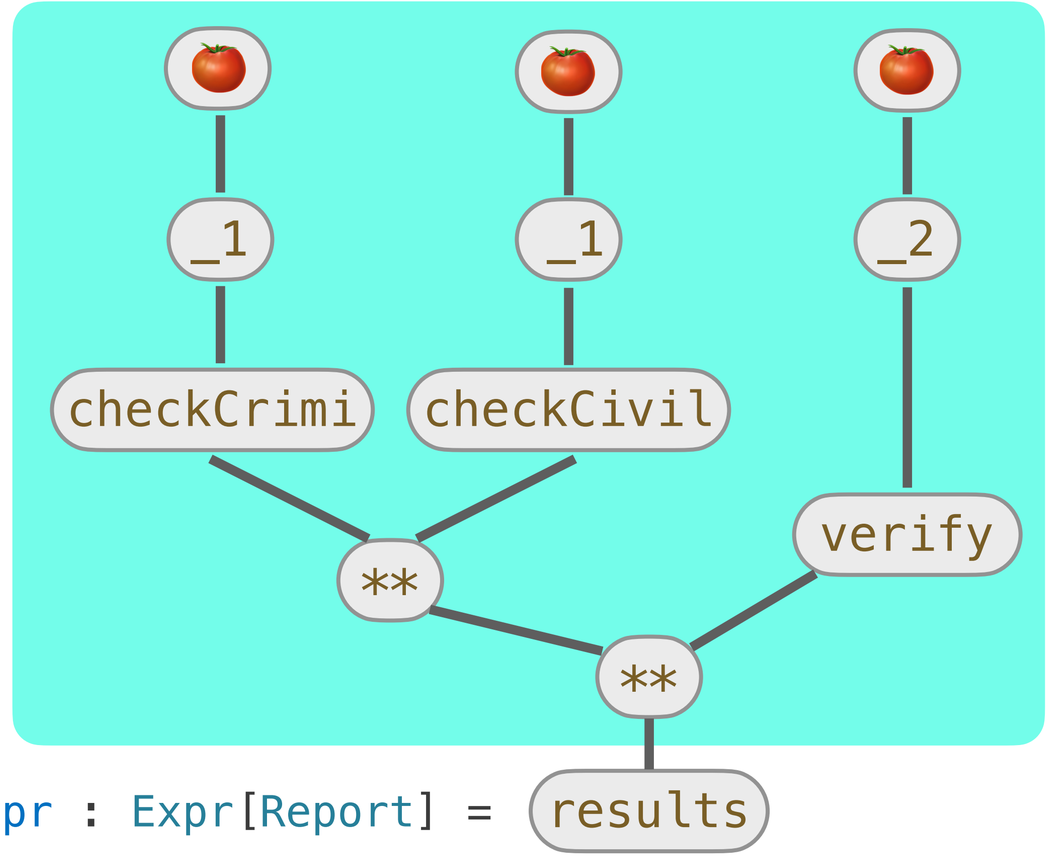
f := onAccept
🍅 : Expr[PersonalId ** EmploymentHistory]
```

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delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
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  Dup() >>> Par(
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) >>> results
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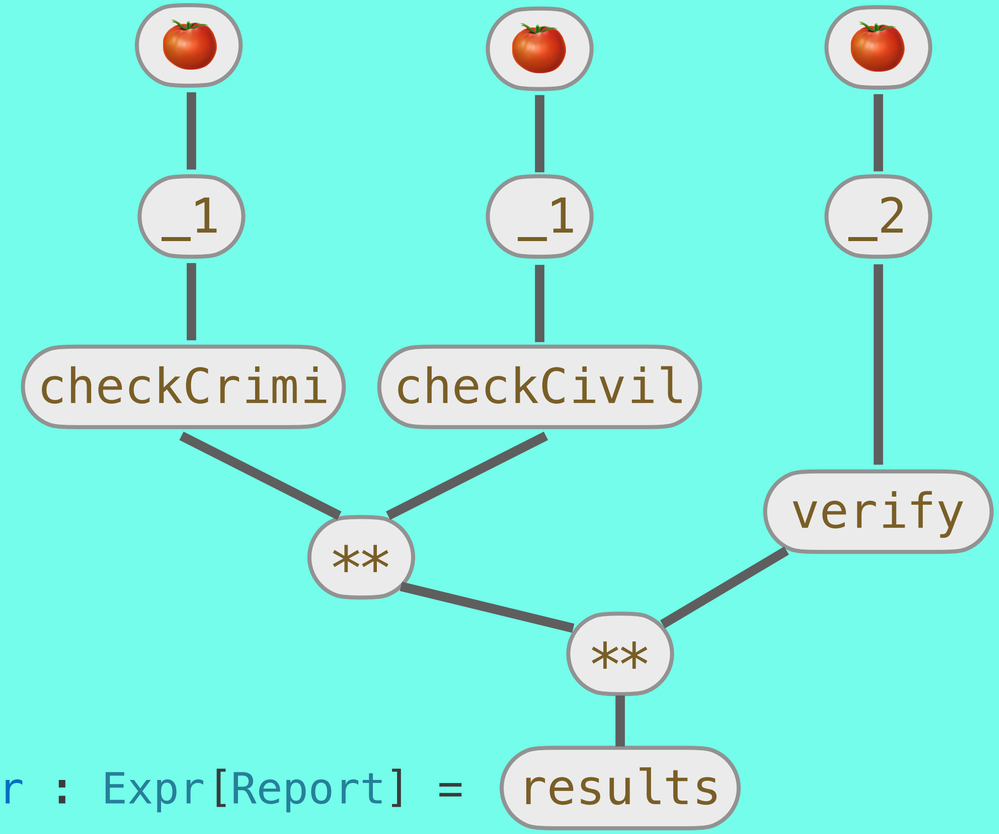


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expr : Expr[Report] =
```

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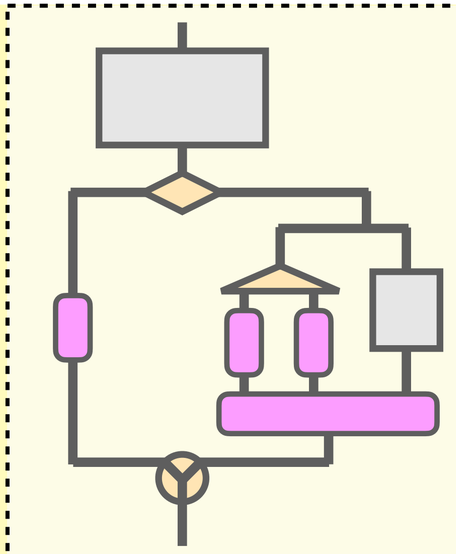
delambdify(onAccept): Flow[PersonalId ** EmploymentHistory, Report]
```

… delambdified so far …

```
Flow { candidate =>
 askForAccept(candidate) switch {
  case Left(x) =>
   declined(x)
  case Right(id ** history) =>
   val crimi = checkCrimi(id)
   val civil = checkCivil(id)
   val verif = verify(history)
   results(crimi ** civil ** verif)
 }
}
```


```
AndThen(
 askForAccept,
 Switch(
  declined,
  AndThen(
   Par(
    AndThen(
     Dup(),
     Par(checkCrimi, checkCivil)
    ),
    verify
   ),
   results
)))
```



… delambdified so far …

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    AndThen(
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   ),
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)))
```

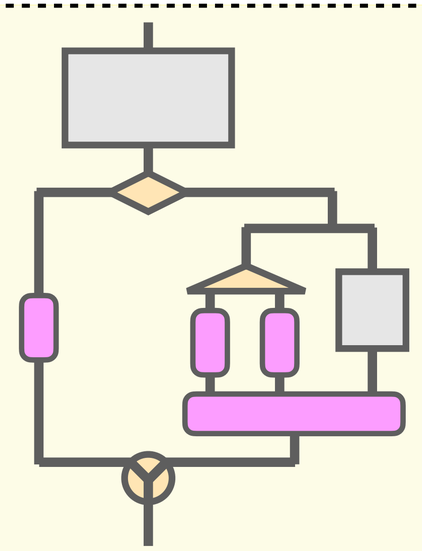

… delambdified so far …

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Flow { candidate =>
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  case Left(x) =>
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   val civil = checkCivil(id)
   val verif = verify(history)
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 }
}
```


```
AndThen(
 askForAccept,
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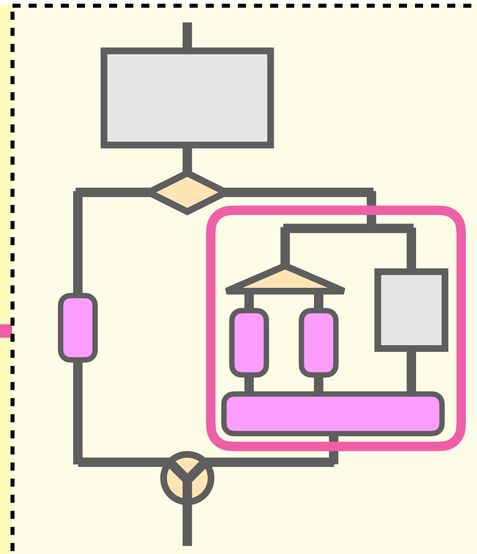
   Par(
    AndThen(
     Dup(),
     Par(checkCrimi, checkCivil)
    ),
    verify
   ),
   results
)))
```



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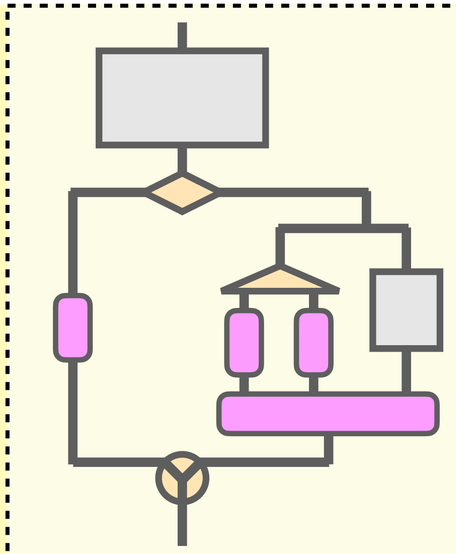

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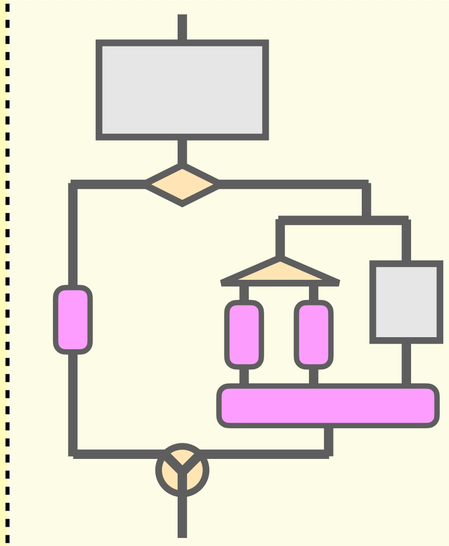

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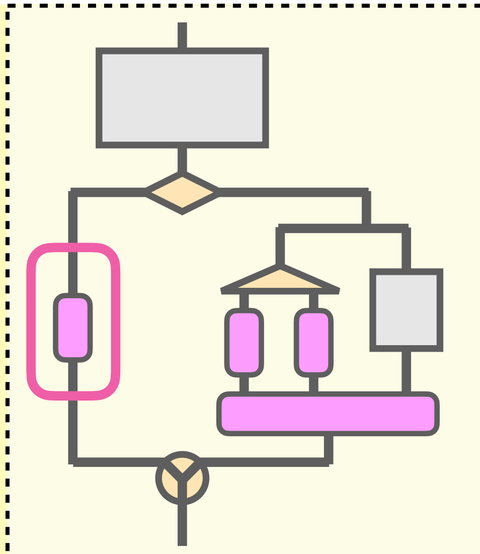

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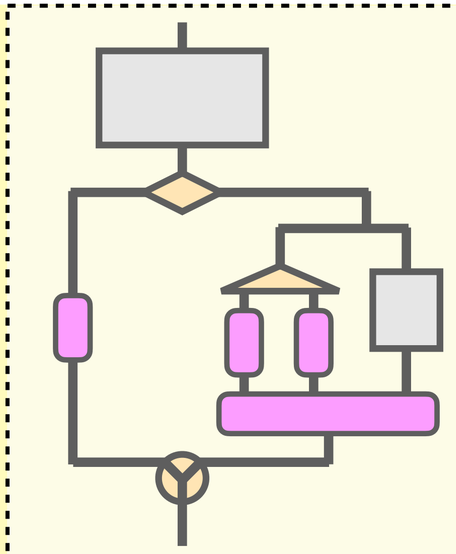

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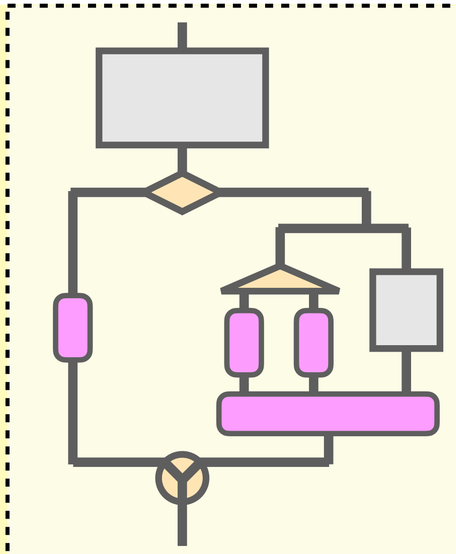

`switch` : the easy case

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non-capturing

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   val verif = verify(history)
   results(crimi ** civil ** verif)
 }
}
```

```
extension [A, B](expr: Expr[A ++ B])
  def switch[R](
    f: Either[Expr[A], Expr[B]] => Expr[R],
  ): Expr[R] =
    val f1: Flow[A, R] = delambdify(a => f(Left(a)))
    val f2: Flow[B, R] = delambdify(b => f(Right(b)))
    val ff: Flow[A ++ B, R] = Switch(f1, f2)
    ff(expr)
```

… delambdified so far …

```
Flow { candidate =>
 askForAccept(candidate) switch {
  case Left(x) =>
   declined(x)
  case Right(id ** history) =>
   val crimi = checkCrimi(id)
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)))
```

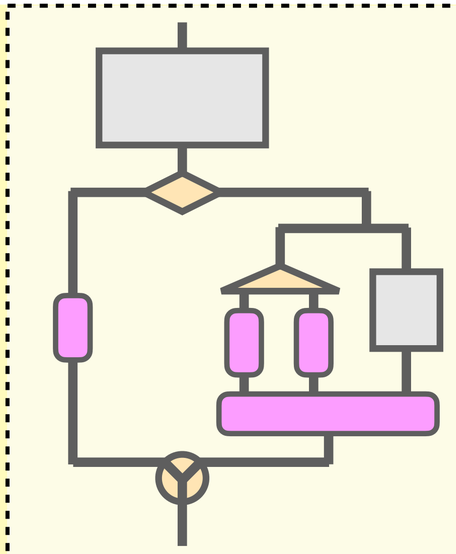

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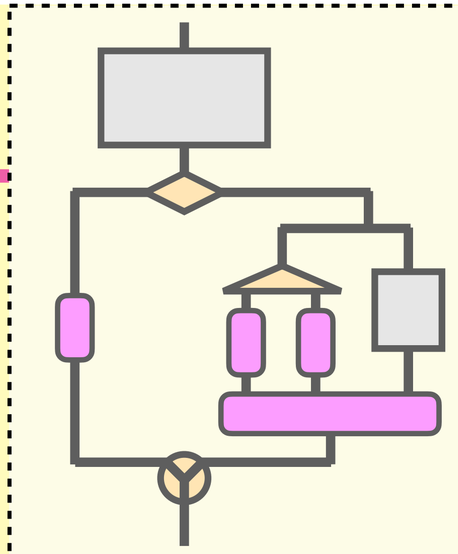

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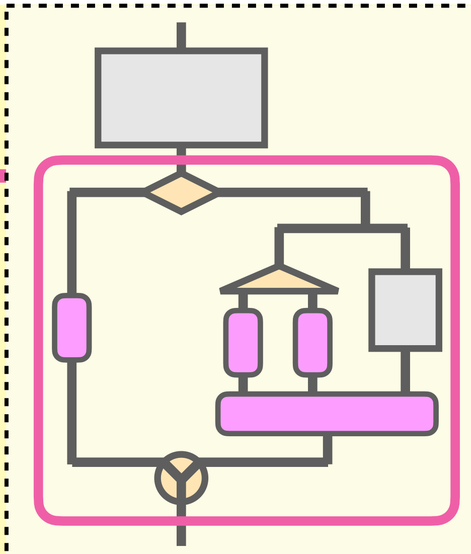

`switch`: the capturing case

```
def switch[A, B, …, R](
```

`switch`: the capturing case

```
def switch[A, B, …, R](
  fa: Expr[A] => Expr[R],
  fb: Expr[B] => Expr[R],
  …
```

`switch` : the capturing case

```
def switch[A, B, …, R](
  fa: Expr[A] => Expr[R],
  fb: Expr[B] => Expr[R],
  …
  sum:      [X,Y] => (Flow[X, R], Flow[Y, R]) => Flow[X ++ Y, R],
```

`switch` : the capturing case

```
def switch[A, B, …, R](
  fa: Expr[A] => Expr[R],
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  …
  sum:      [X,Y] => (Flow[X, R], Flow[Y, R]) => Flow[X ++ Y, R],
```

```
case Switch[X, Y, R](
  l: Flow[X, R],
  r: Flow[Y, R],
) extends Flow[X ++ Y, R]
```

`switch` : the capturing case

```
def switch[A, B, …, R](
  fa: Expr[A] => Expr[R],
  fb: Expr[B] => Expr[R],
  …
  sum:      [X,Y] => (Flow[X, R], Flow[Y, R]) => Flow[X ++ Y, R],
  distrib: [X,Y,Z] => Flow[X ** (Y ++ Z), (X ** Y) ++ (X ** Z)]
```

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case Switch[X, Y, R](
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```

```
case Switch[X, Y, R](
  l: Flow[X, R],
  r: Flow[Y, R],
) extends Flow[X ++ Y, R]
```

```
case Distribute[X, Y, Z]()
extends Flow[
  X ** (Y ++ Z),
  (X ** Y) ++ (X ** Z)
]
```

`switch` : the capturing case

```
def switch[A, B, …, R](
  fa: Expr[A] => Expr[R],
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): (
```

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case Switch[X, Y, R](
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): (
  Expr[Q],
```

```
case Switch[X, Y, R](
  l: Flow[X, R],
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) extends Flow[X ++ Y, R]
```

```
case Distribute[X, Y, Z]()
extends Flow[
  X ** (Y ++ Z),
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]
```

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def switch[A, B, …, R](
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```

Captured

```
case Switch[X, Y, R](
  l: Flow[X, R],
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) extends Flow[X ++ Y, R]
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```
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extends Flow[
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  (X ** Y) ++ (X ** Z)
]
```

`switch` : the capturing case

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Captured

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  r: Flow[Y, R],
) extends Flow[X ++ Y, R]
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```
case Distribute[X, Y, Z]()
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  distrib: [X,Y,Z] => Flow[X ** (Y ++ Z), (X ** Y) ++ (X ** Z)]
): (
  Expr[Q],
  Flow[Q ** (A ++ B ++ …), R]
) // for some type Q
```

```
case Switch[X, Y, R](
  l: Flow[X, R],
  r: Flow[Y, R],
) extends Flow[X ++ Y, R]
```

```
case Distribute[X, Y, Z]()
extends Flow[
  X ** (Y ++ Z),
  (X ** Y) ++ (X ** Z)
]
```

Captured

Also Applicable To

- Loops

```
case DoWhile[A, B]( iteration: Flow[A, A ++ B] ) extends Flow[A, B]
```

- Recursion
  - incl. recursive types
- Higher-order functions
  - Including closures
- Linearly typed DSLs

… status so far …

… status so far …

```
Flow { x =>
 ... switch {
  case ... =>
   ...
  case ... =>
   val y = ...
   ...
 }
}
```

… status so far …

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Flow { x =>
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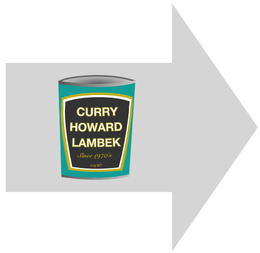
code



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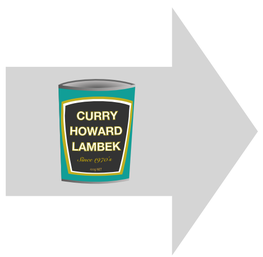
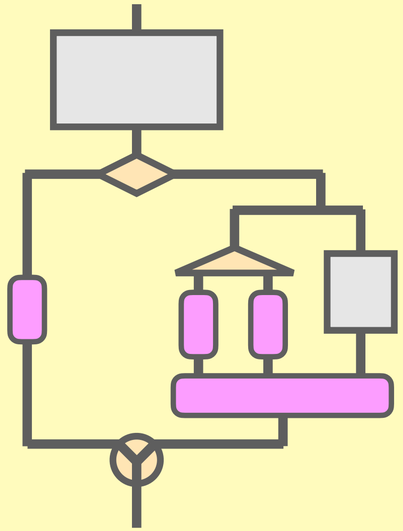



```
AndThen(
 ...
 Switch(
  ...
  Par(
   Dup()...
   ...
  ),
))
```



… as data

… status so far …

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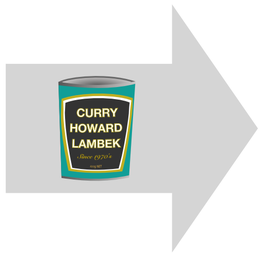
   ...
  case ... =>
   val y = ...
   ...
 }
}
```

code

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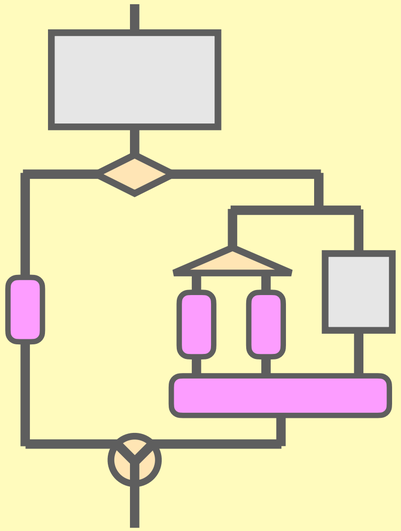

… as data

… status so far …

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    ...
   case ... =>
    val y = ...
    ...
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}
```
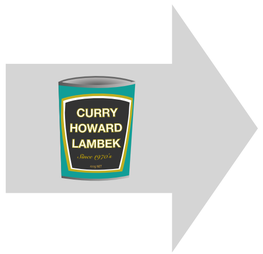

code

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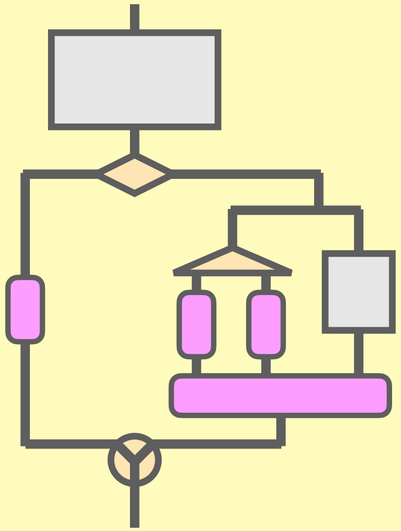

… as data

?

… status so far …

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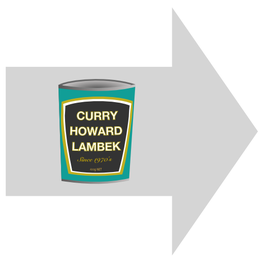
code

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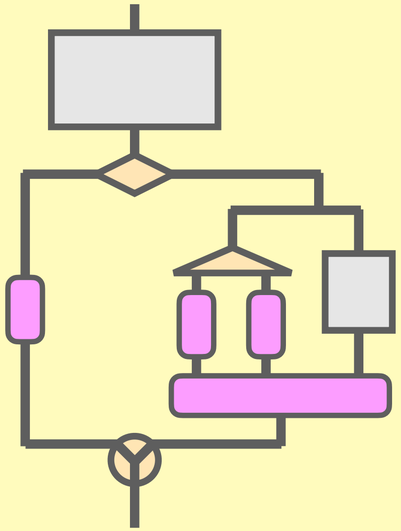


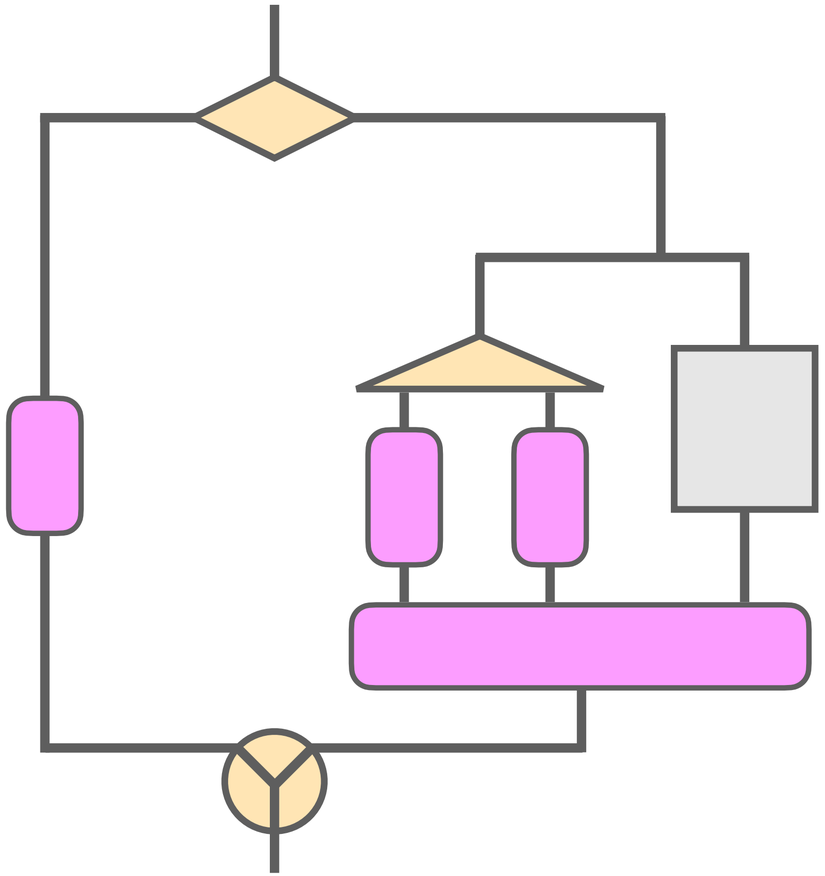
… as data

?

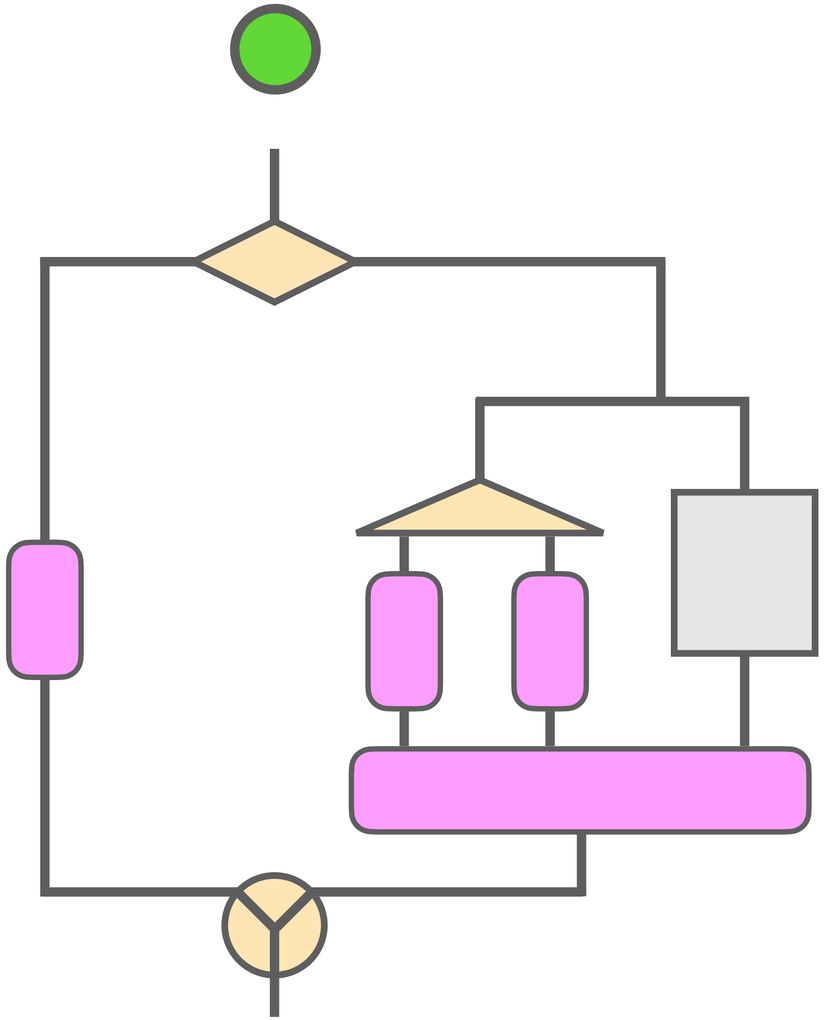
Where’s the *(durable) execution?*

Durable Execution

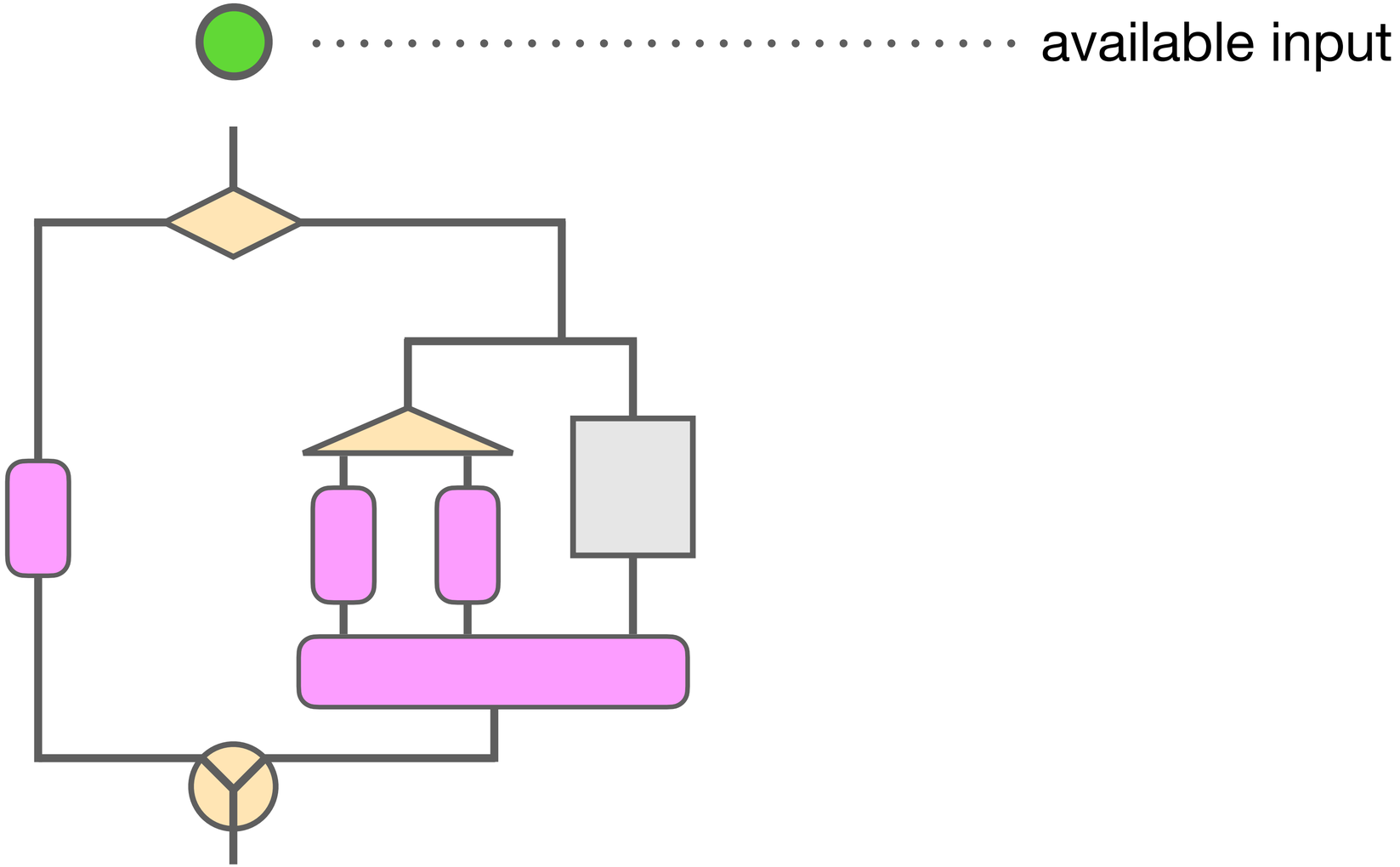
Durable Execution



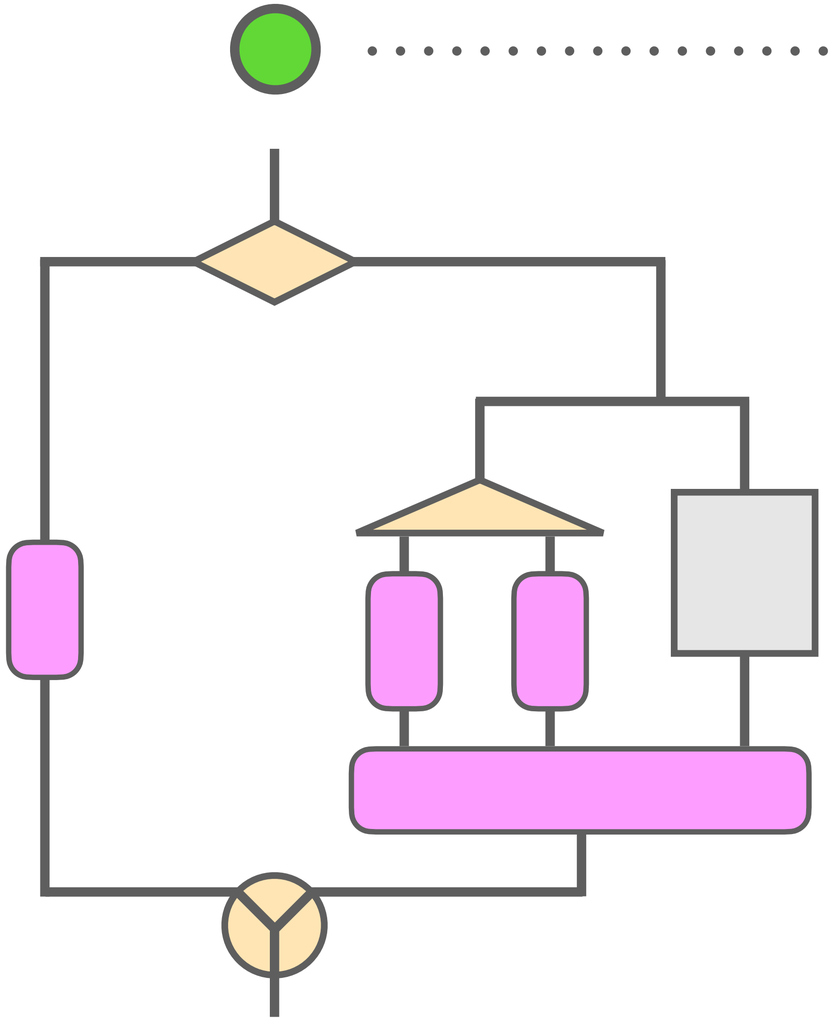
Durable Execution



Durable Execution



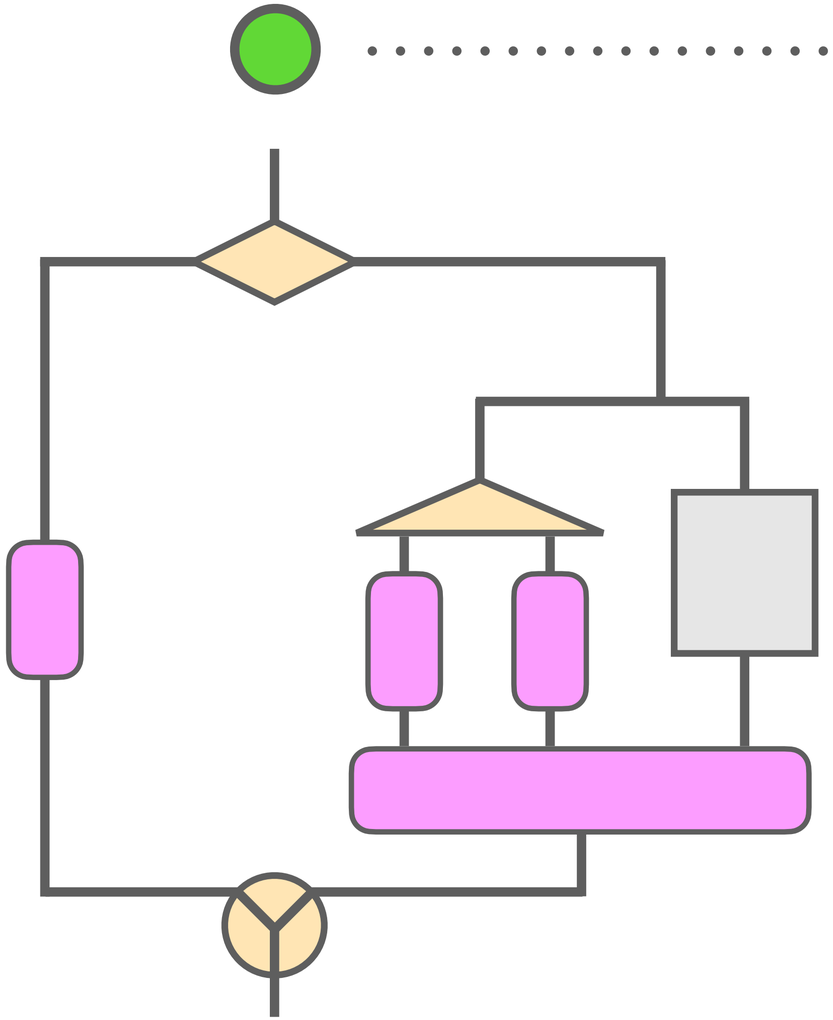
Durable Execution



available input

- data

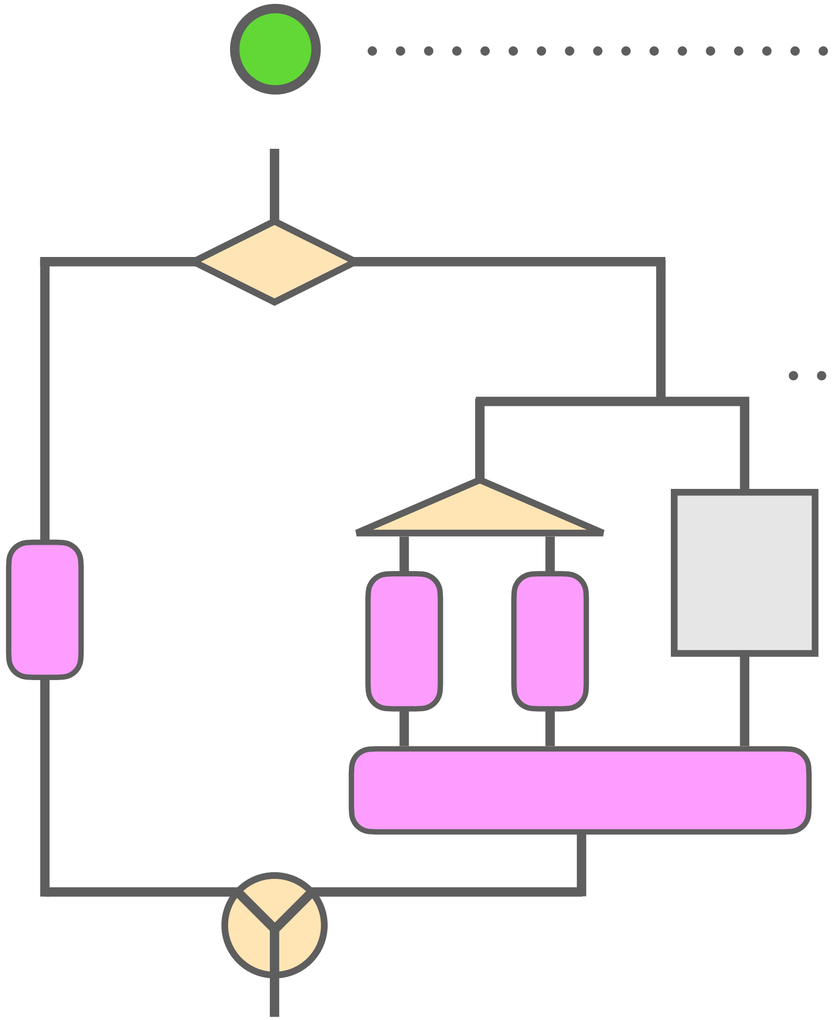
Durable Execution



available input

- data
- persistable

Durable Execution

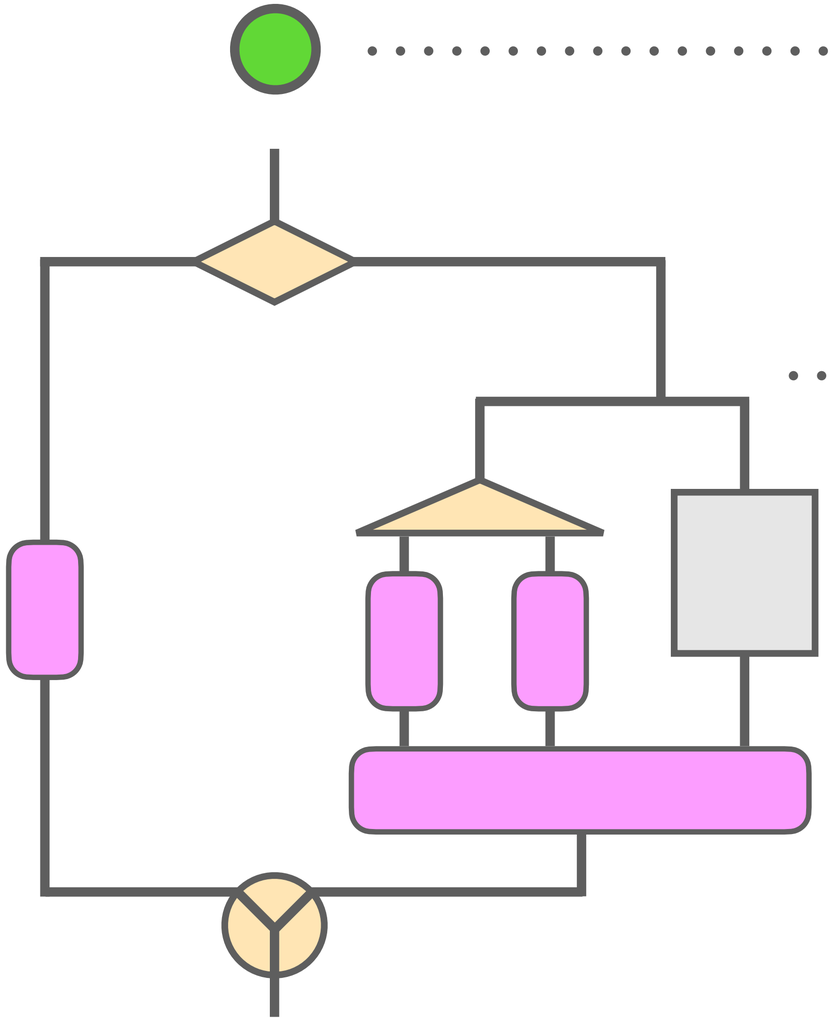


available input

- data
- persistable

continuation

Durable Execution



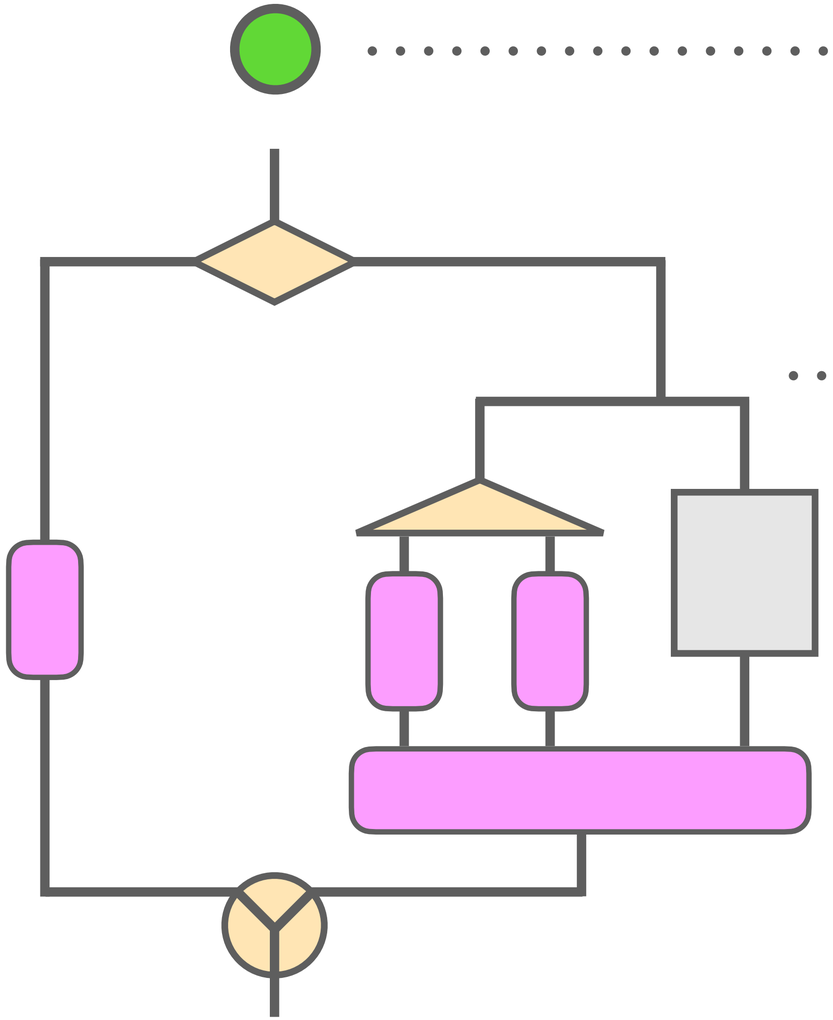
available input

- data
- persistable

continuation

- data

Durable Execution



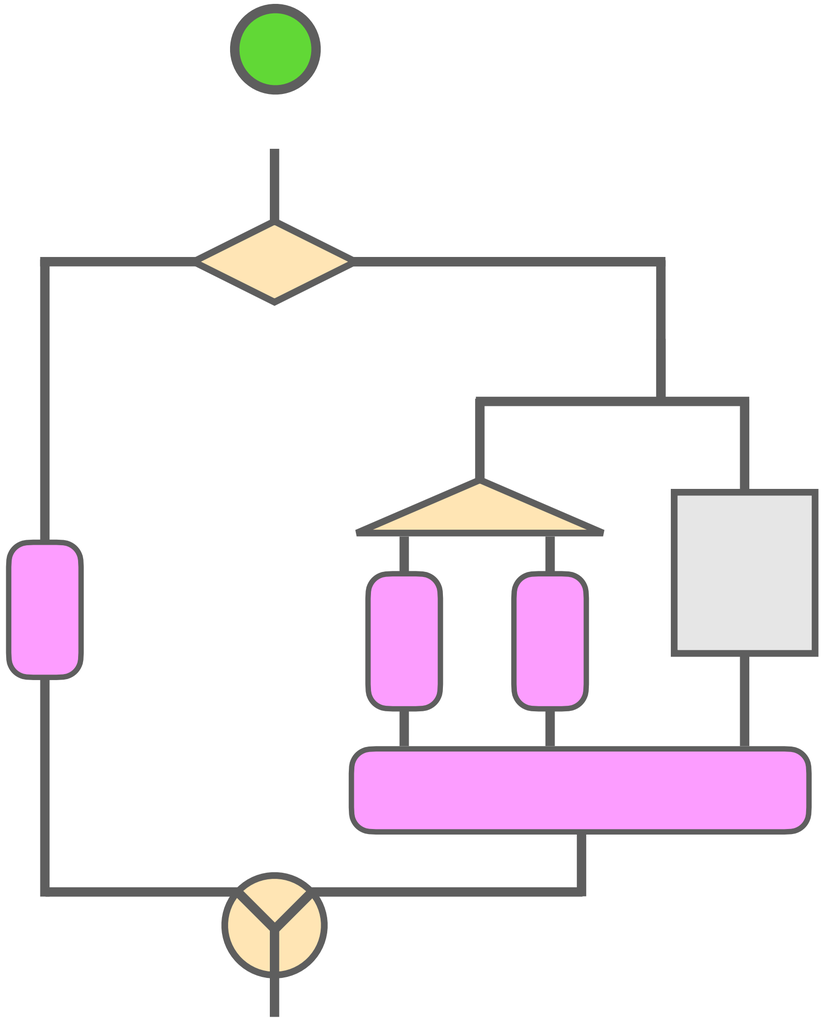
available input

- data
- persistable

continuation

- data
- persistable

Durable Execution



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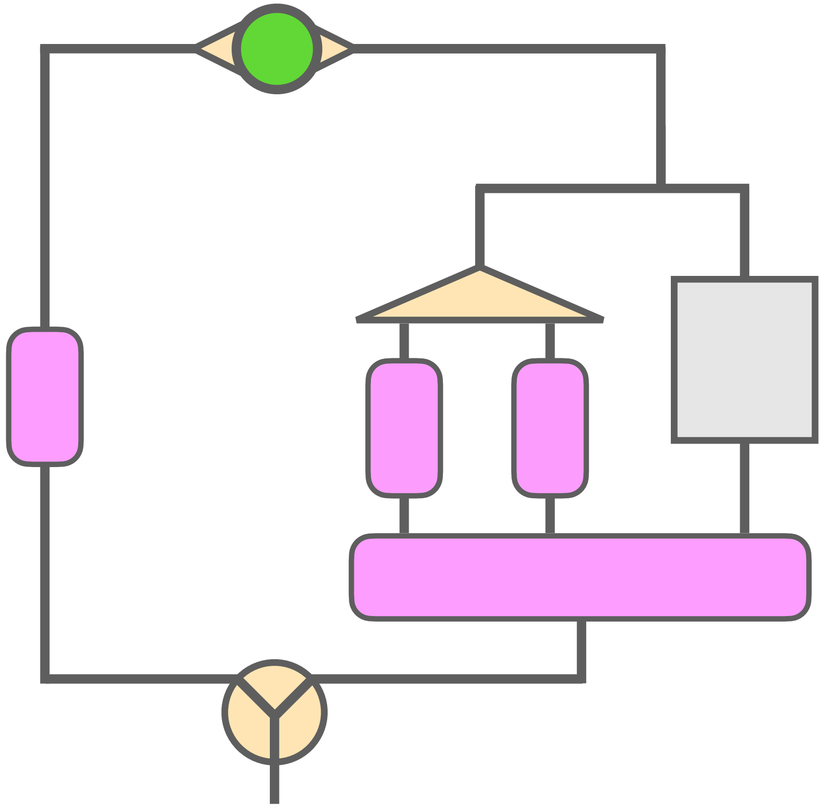

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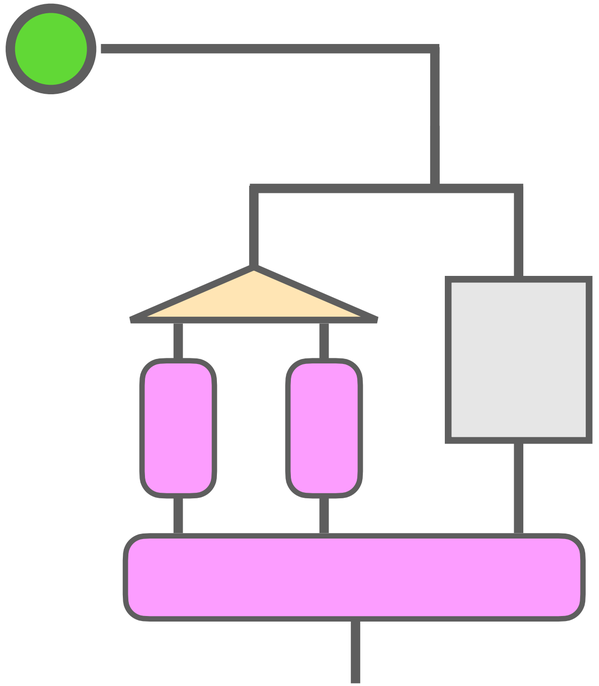

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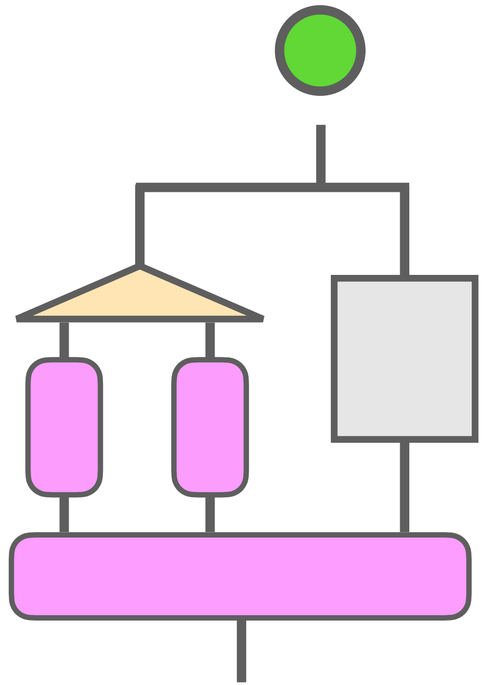

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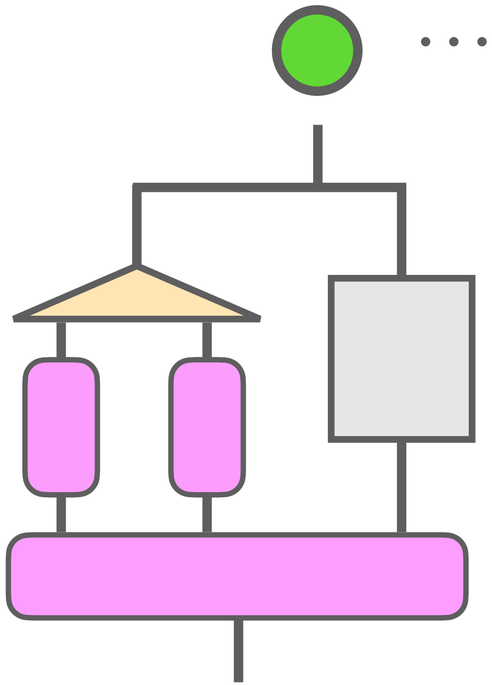


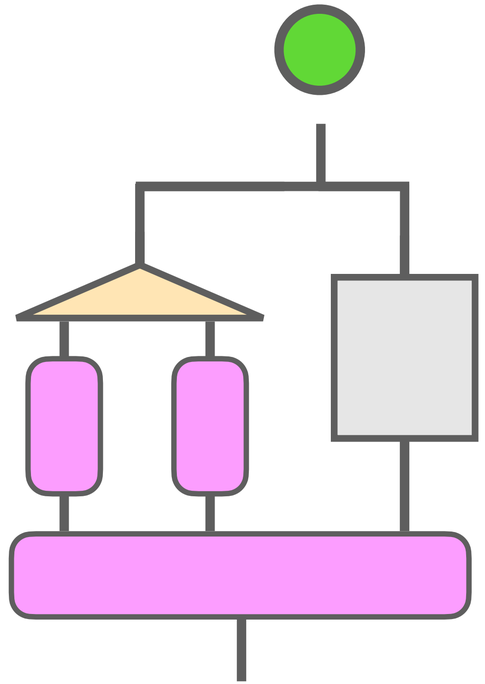
available input

- data
- persistable

continuation

- data
- persistable

Durable Execution



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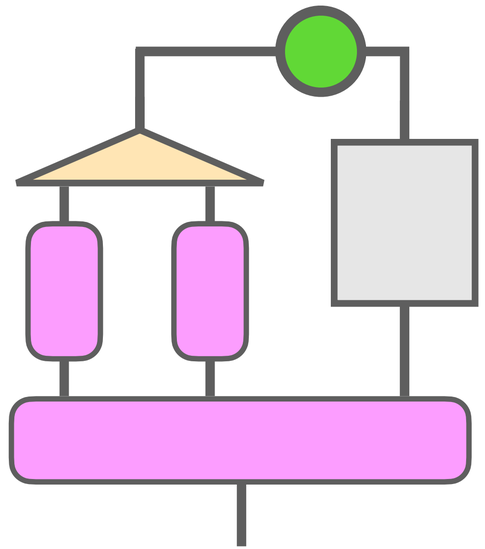
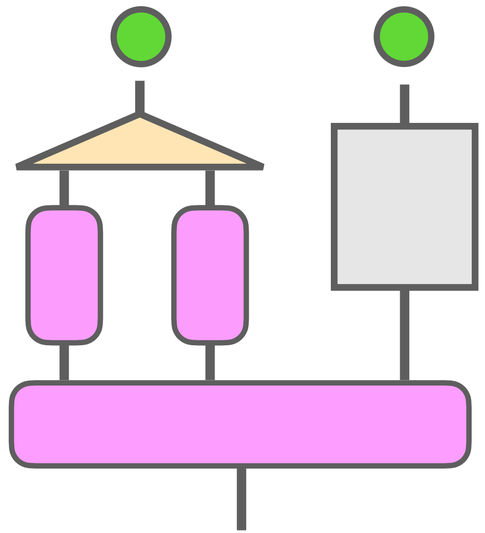


Durable Execution



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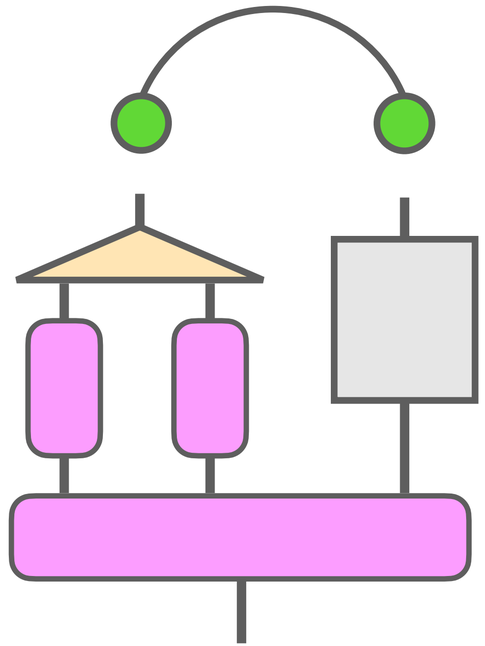

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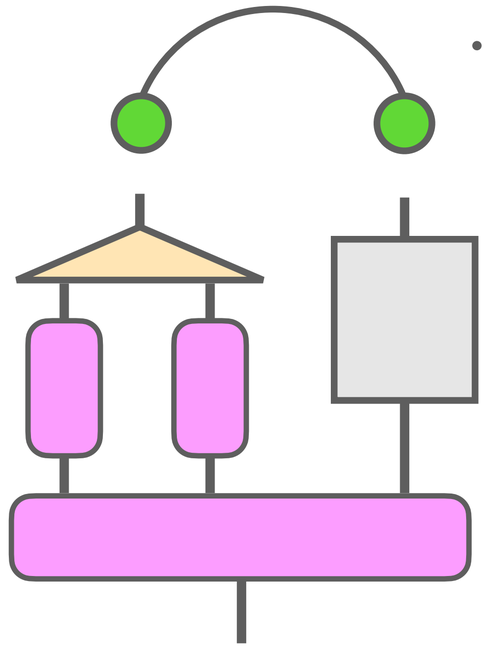
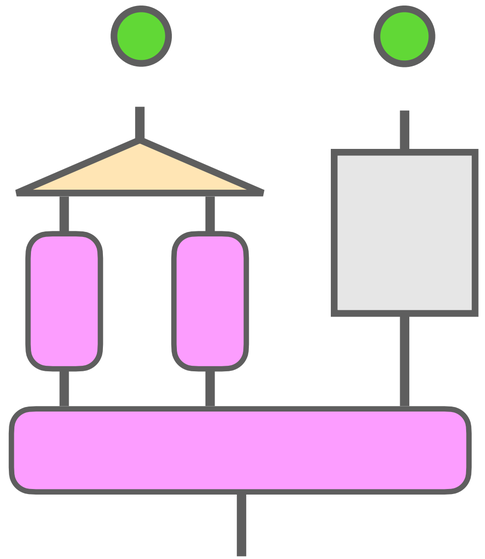


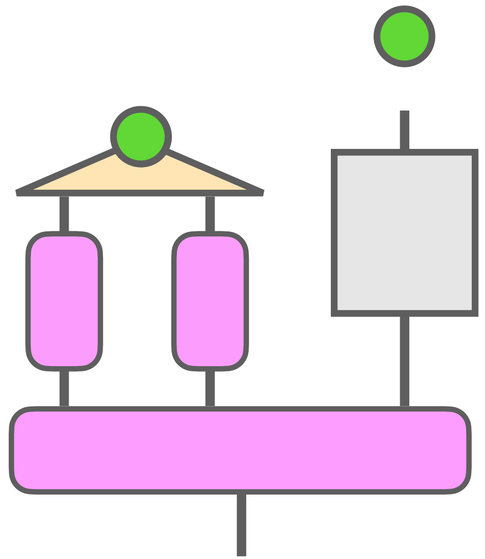
available inputs
- data
- persistable

continuation
- data
- persistable

Durable Execution



Durable Execution



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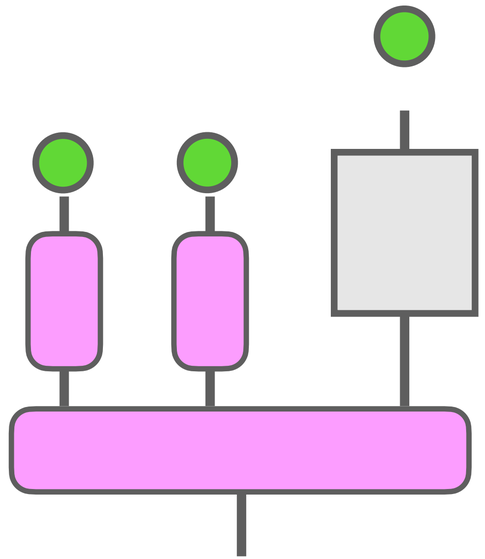
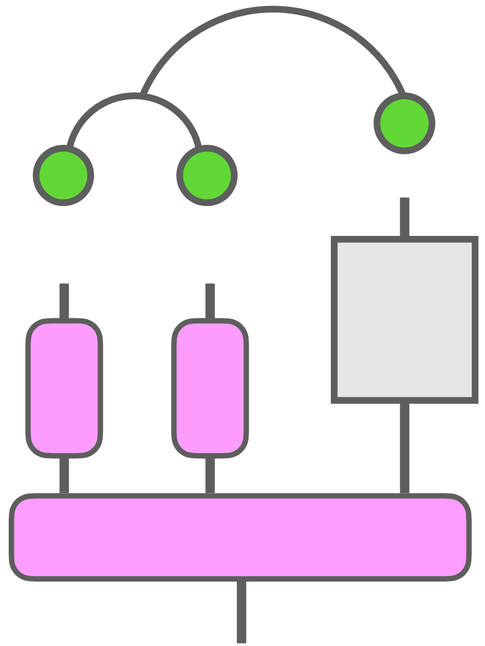


Durable Execution



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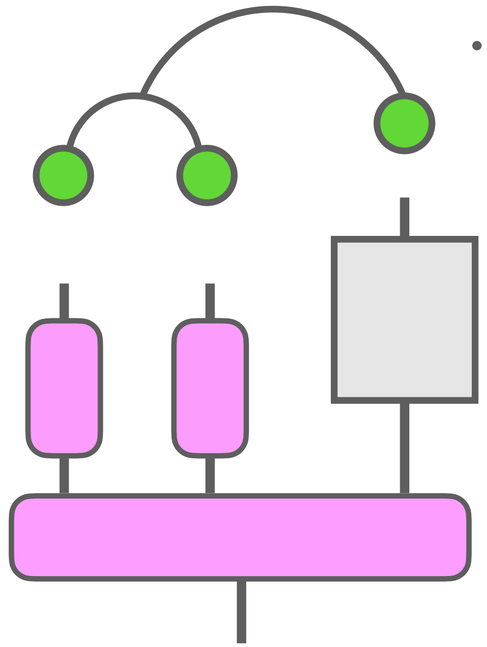


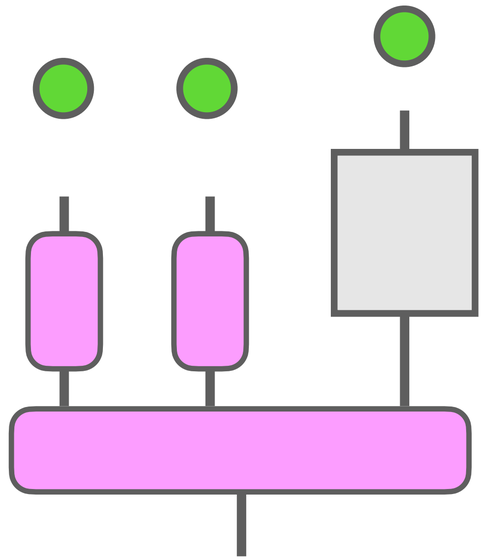
available inputs

- data
- persistable

continuation

- data
- persistable

Durable Execution



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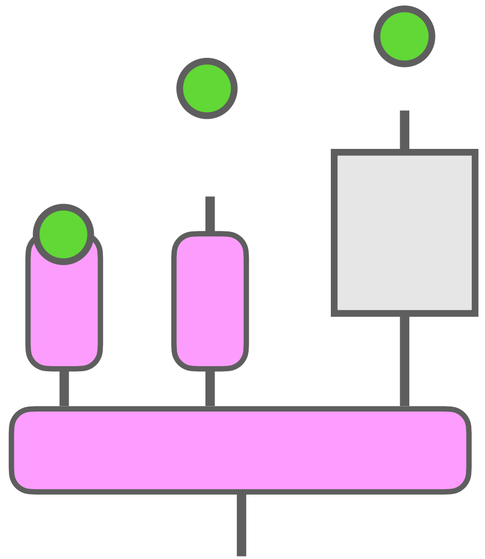

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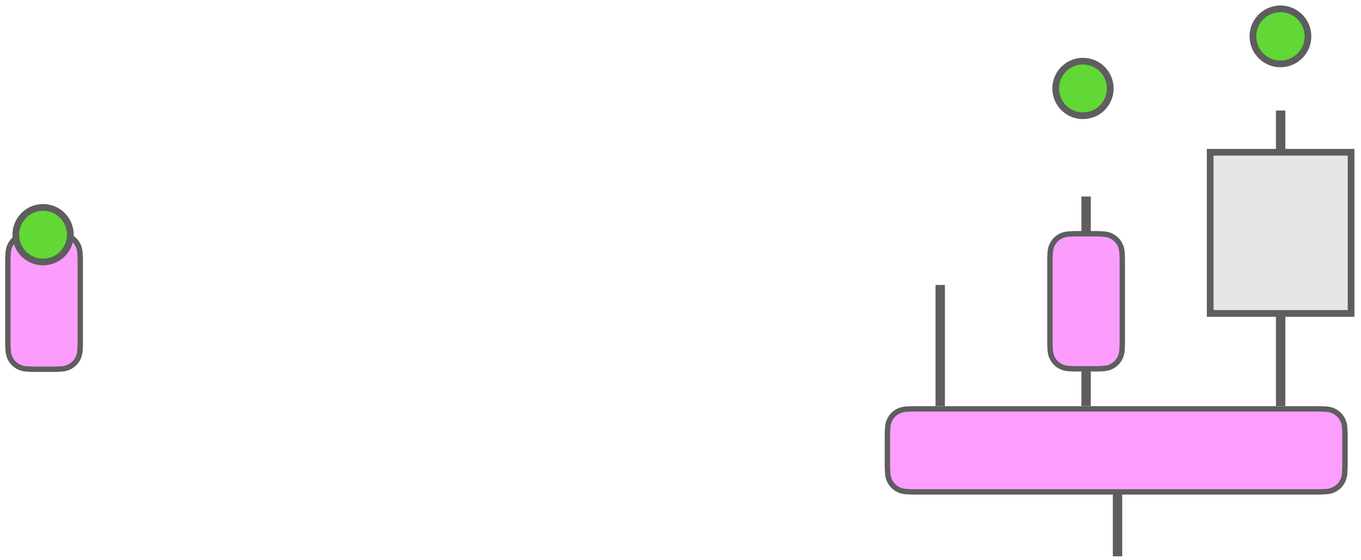

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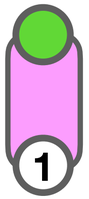

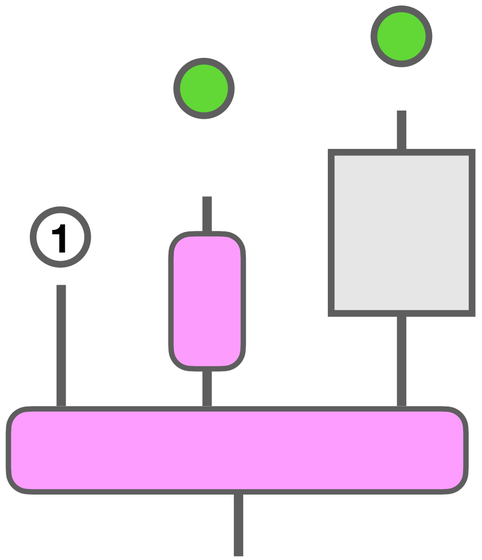

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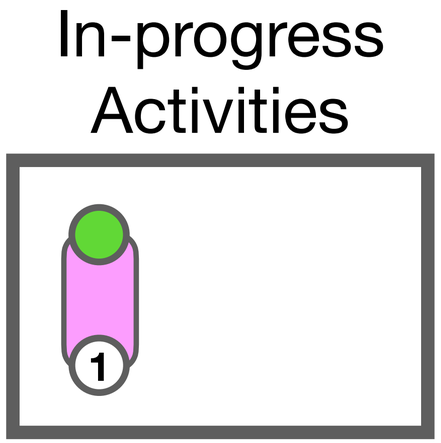
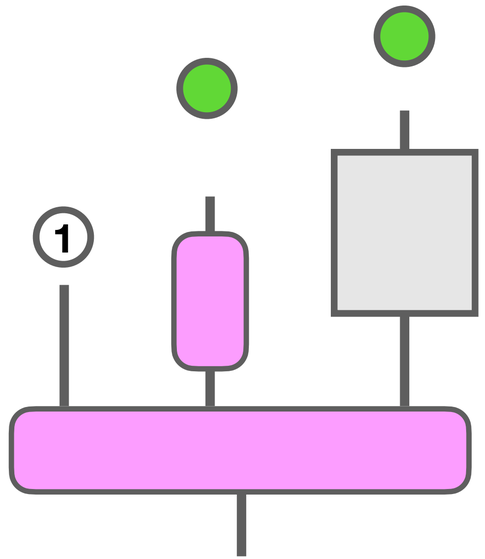
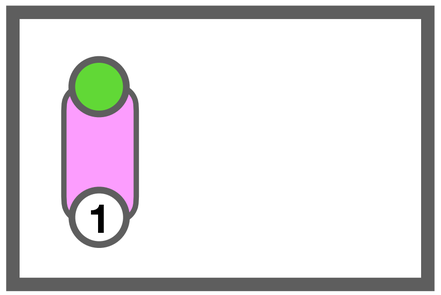


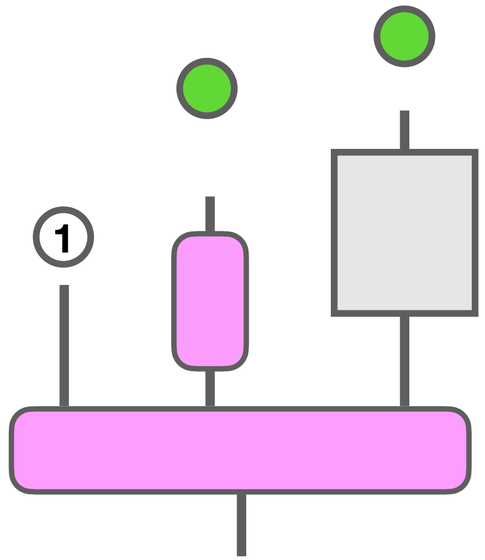


Durable Execution

In-progress Activities

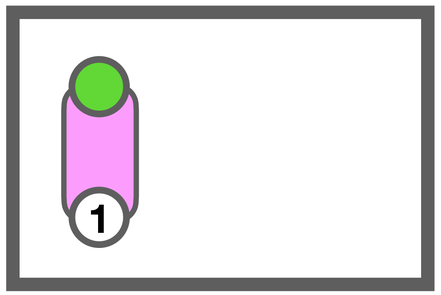


- persisted recipes
- restartable

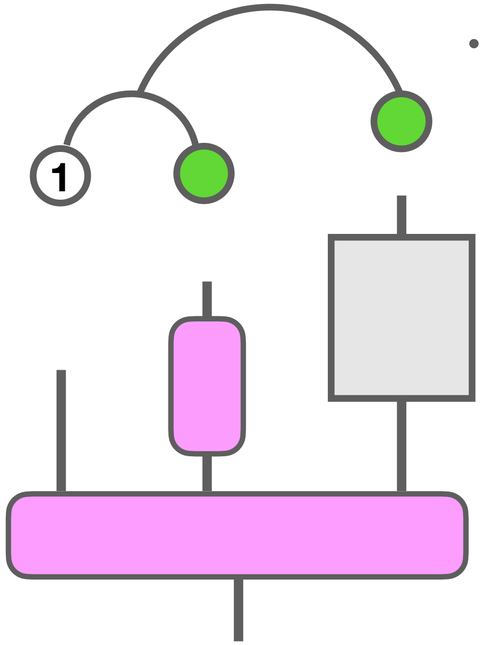


Durable Execution

In-progress Activities



- persisted recipes
- restartable



inputs

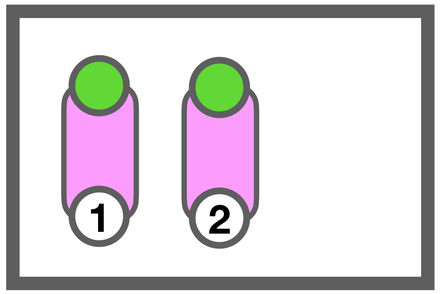
- available or *promised*
- persistable

continuation

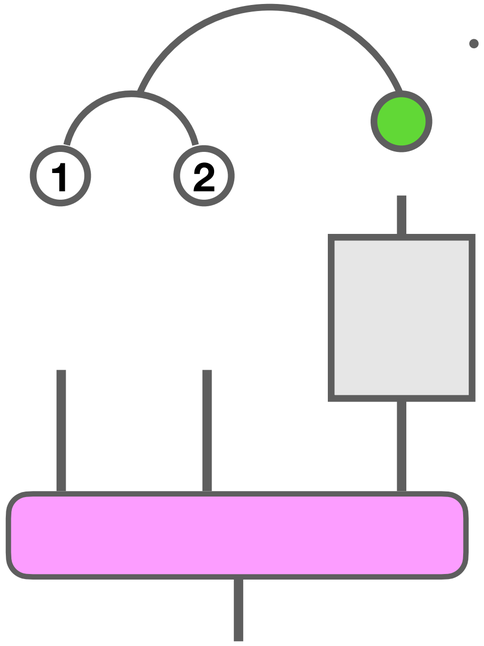
- data
- persistable

Durable Execution

In-progress Activities



- persisted recipes
- restartable



inputs

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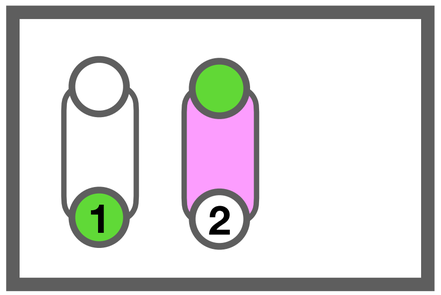
- persistable

continuation

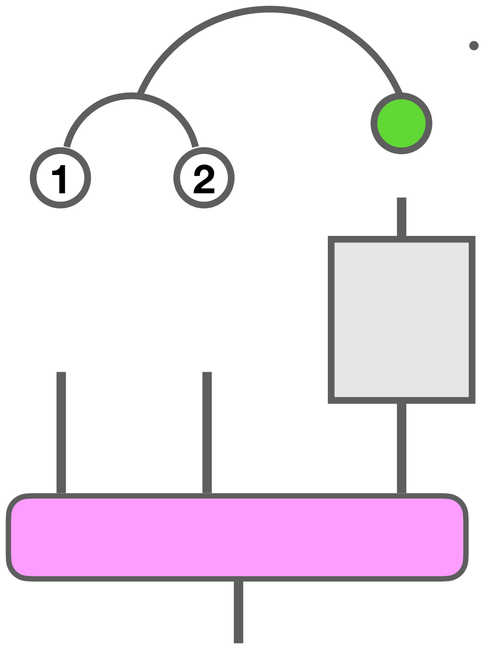
- data
- persistable

Durable Execution

In-progress Activities



- persisted recipes
- restartable



inputs

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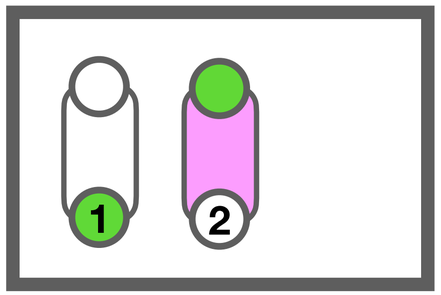
- persistable

continuation

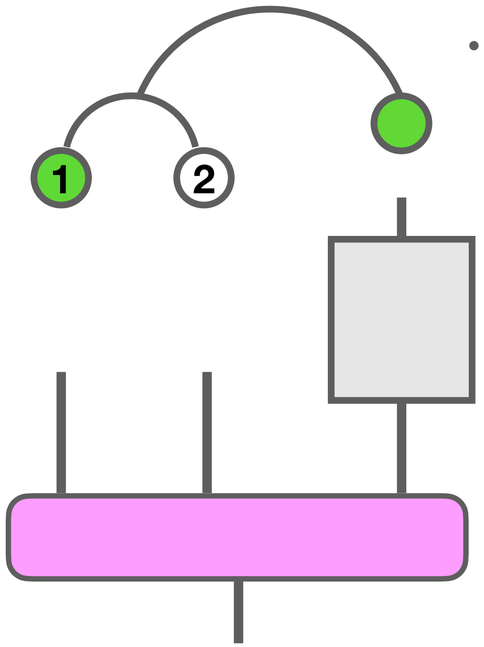
- data
- persistable

Durable Execution

In-progress Activities



- persisted recipes
- restartable



inputs

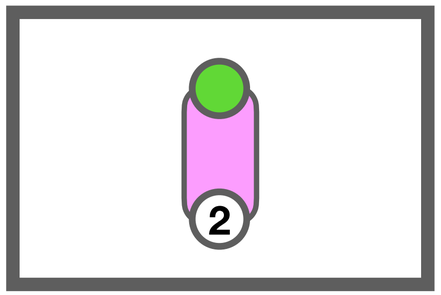
- available or *promised*
- persistable

continuation

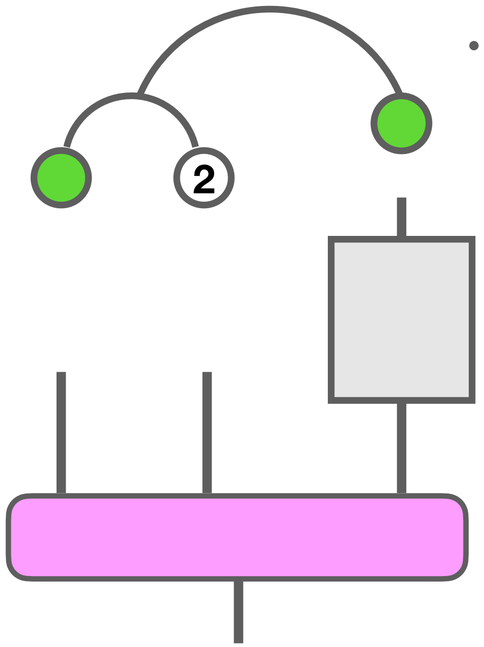
- data
- persistable

Durable Execution

In-progress Activities



- persisted recipes
- restartable



inputs

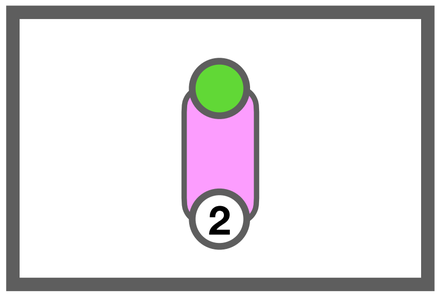
- available or *promised*
- persistable

continuation

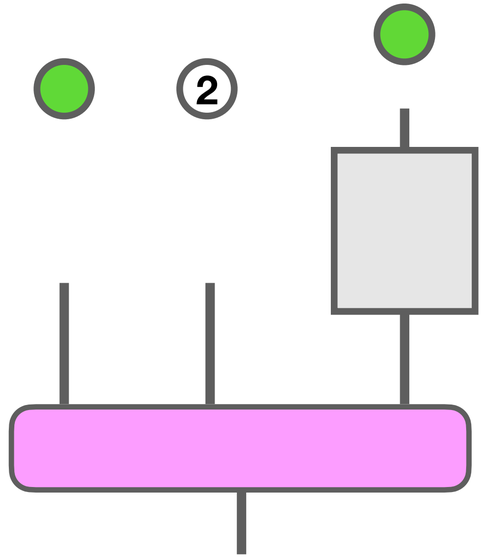
- data
- persistable

Durable Execution

In-progress Activities

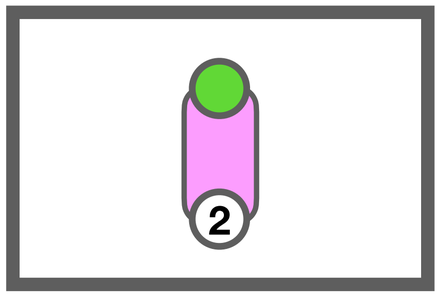


- persisted recipes
- restartable

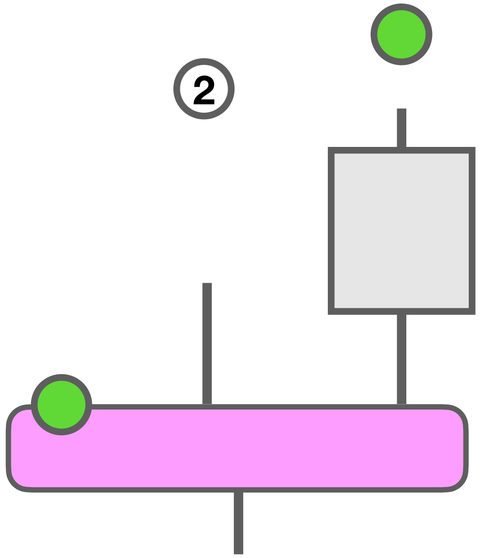


Durable Execution

In-progress Activities

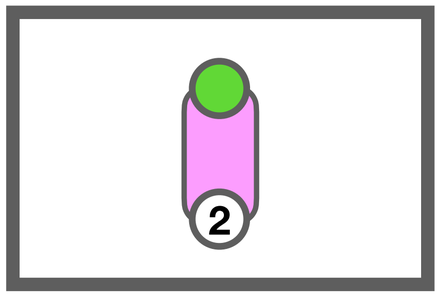


- persisted recipes
- restartable

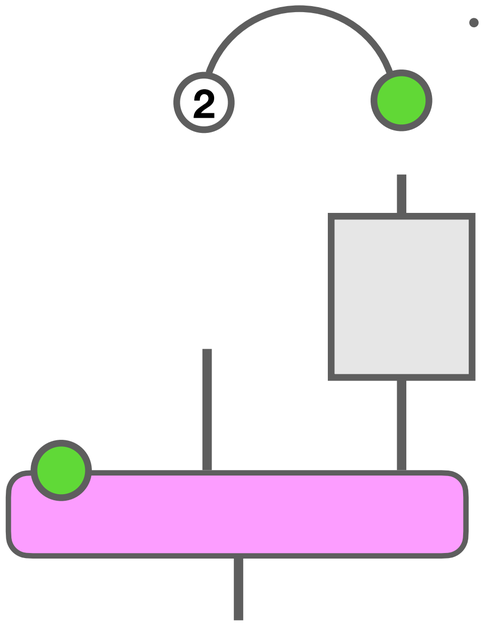


Durable Execution

In-progress Activities



- persisted recipes
- restartable



inputs

- available or *promised*
- persistable

continuation

- with *captured* values
- persistable

Durable Execution

Durable Execution

- **execution** state always **as data**

Durable Execution

- **execution** state always **as data**
- introspectable

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types
- Persistence

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types
- Persistence
  - storage format

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types
- Persistence
  - storage format
    - graph?

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types
- Persistence
  - storage format
    - graph?
    - single document?

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types
- Persistence
  - storage format
    - graph?
    - single document?
- Orchestration

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types
- Persistence
  - storage format
    - graph?
    - single document?
- Orchestration
  - coordinator, workers, scheduler, …

Durable Execution

- **execution** state always **as data**
- introspectable
- opens possibilities
  - visualize
  - visualize mid-execution
  - edit mid-execution

Omitted “details”

- Serialization
  - pluggable for custom data types
- Persistence
  - storage format
    - graph?
    - single document?
- Orchestration
  - coordinator, workers, scheduler, …
- Externally completable promises

Distinctly Scala in Action

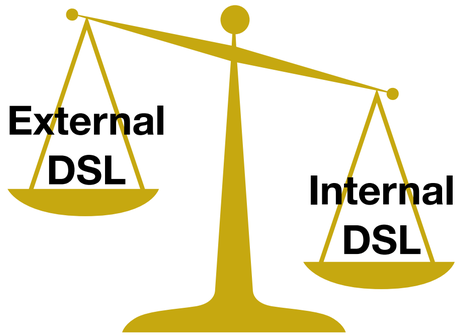
- Extension Methods `flow(expr) , expr switch {…}`
- Extractors `case id ** history =>`
- Context Functions

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

- Givens
- Opaque Types `Expr`
- Polymorphic Functions `sum: [X,Y] => (Flow[X, R], Flow[Y, R]) => Flow[X ++ Y, R]`
- lightweight Macros (source position, var names)
- Path-dependent types (not seen here, but heavily used in the library)

Take Aways

- **Programs-as-data** open new possibilities
- Does not take much to represent expressive control flows
- **Variables problematic**
  - Avoid internally to make some **illegal programs unrepresentable**
  - **Affordable** translation to point-free via canned implementation
- Expanding the case for internal DSLs



Thank you!

https://github.com/TomasMikula/libretto/tree/main/lambda-examples