Using Java CompletionStage in Asynchronous Programming

DEV4798

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Safe Harbor Statement

Introduction to CompletionStage

What are java.util.concurrent.CompletionStage and java.util.concurrent.CompletableFuture?

CompletableFuture:
The Promises of Java
[DEV5375]

Venkat Subramaniam
Wednesday, October 24

Hands-on Lab: The Asynchronous Java Database Access Driver [HOL4799]

Douglas Surber
Wednesday, October 24

java.util.concurrent.CompletionStage

`public interface CompletionStage<T>`

- A stage of a possibly asynchronous computation, that performs an action or computes a value when another `CompletionStage` completes. A stage completes upon termination of its computation, but this may in turn trigger other dependent stages.

-
  ```
  stage.thenApply(x -> square(x))
       .thenAccept(x -> System.out.print(x))
       .thenRun(() -> System.out.println());
  ```

java.util.concurrent.CompletableFuture

`public class CompletableFuture<T> implements Future<T>, CompletionStage<T>`

- Both a `CompletionStage` and a `Future`
- A `Future` that may be explicitly completed (setting its value and status), and may be used as a `CompletionStage`, supporting dependent functions and actions that trigger upon its completion.

-
  ```
  CompletableFuture future = ...;
  future.complete(value);
  future.get();
  ```

Example

```
supplyAsync(Supplier supplier), thenApply(Function function)
```

```
CompletionStage task = CompleteableFuture.supplyAsync(() -> 10);
CompletionStage squareTask = task.thenApply( v -> v * v );
```

`supplyAsync(Supplier supplier)`

`java.util.concurrent.CompleteableFuture`

public static <U> CompletableFuture<U> supplyAsync(Supplier<U> supplier)

Returns a new CompletableFuture that is asynchronously completed by a task running in the ForkJoinPool.commonPool() with the value obtained by calling the given Supplier.

Type Parameters: U - the function's return type

Parameters: supplier - a function returning the value to be used to complete the returned CompletableFuture

Returns: the new CompletableFuture

`thenApply(Function<? super T,? extends U> fn)`

`java.util.concurrent.CompletionStage`

`<U> CompletionStage<U> thenApply(Function<? super T,? extends U> fn)`

Returns a new CompletionStage that, when this stage completes normally, is executed with this stage's result as the argument to the supplied function.

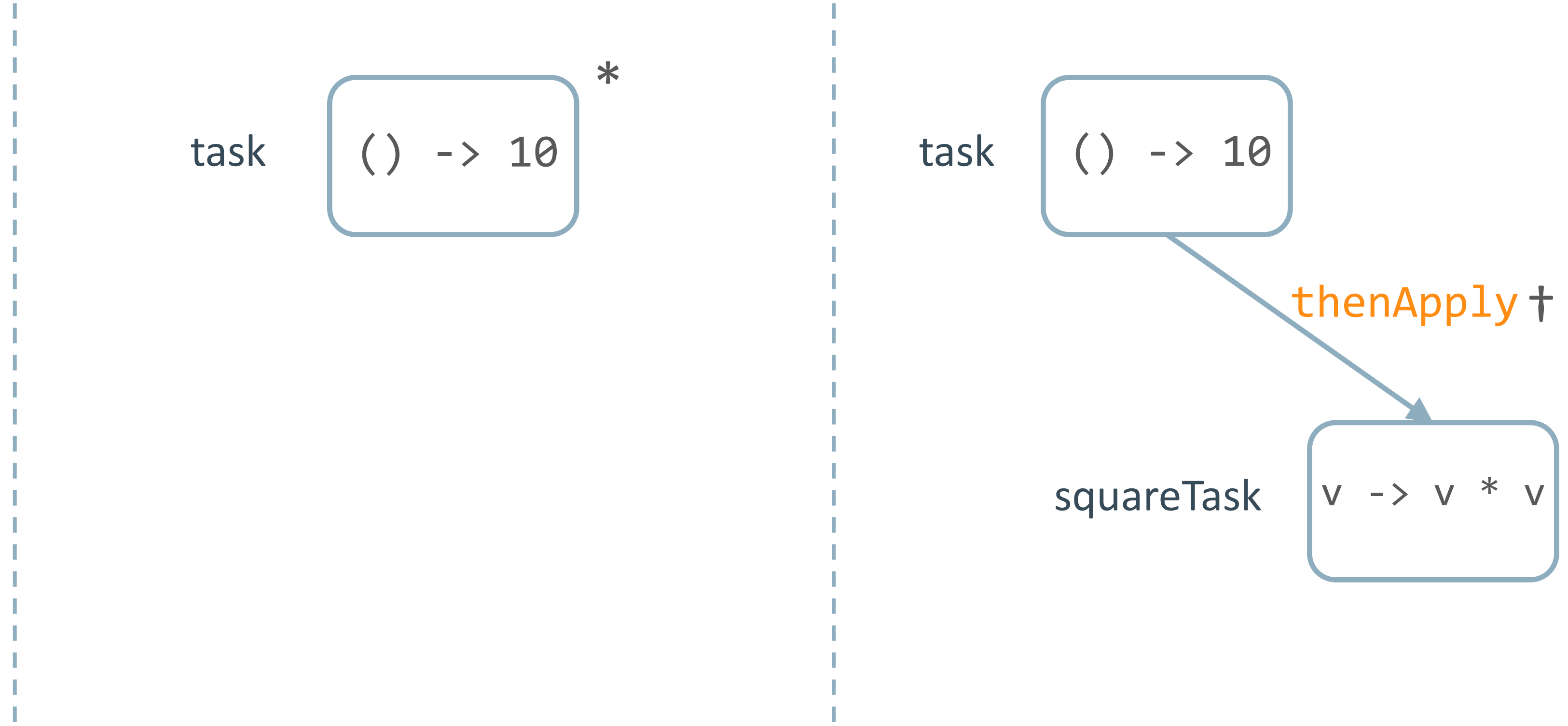
Type Parameters: U - the function's return type

Parameters: fn - the function to use to compute the value of the returned CompletionStage

Returns: the new CompletionStage

Example

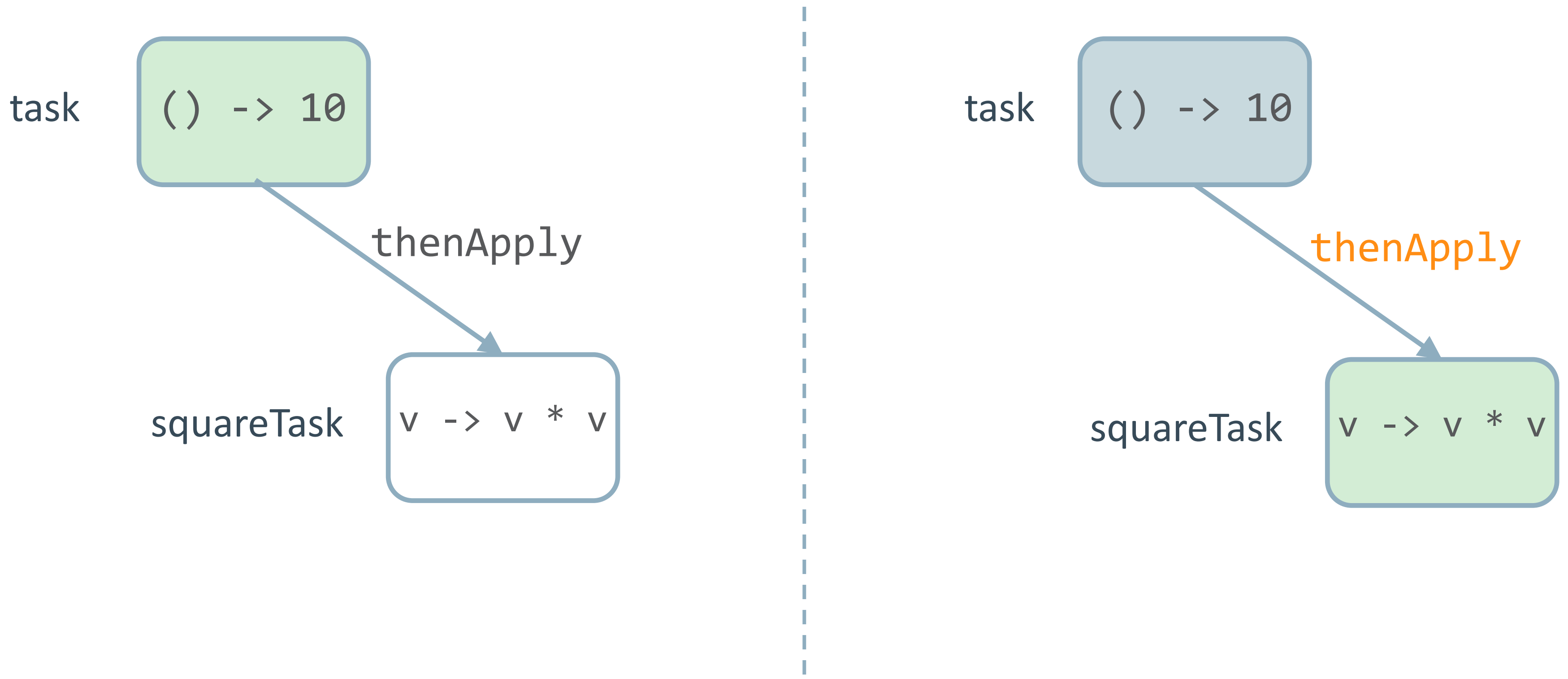
```
CompletionStage task = CompleteableFuture.supplyAsync( () -> 10 );
CompletionStage squareTask = task.thenApply( v -> v * v);
```



* CompletionStage

† dependency

Example Execution



Introduction to AoJ

What are AoJ and ADBA?

Asynchronous Database Access (ADBA)

Proposed Java Standard

- What: Java standard database access API that <u>never blocks user threads</u>
- Who: Developed by the JDBC Community, JDBC Expert Group and Oracle
- When: Targeted for a near future release, Java 14 perhaps
- Why: Async apps have better scalability
  - Fewer threads means less thread scheduling, less thread contention
  - Database access is slow so blocked threads leave resources idle for a long time
- http://hg.openjdk.java.net/jdk/sandbox/file/JDK-8188051-branch/src/jdk.incubator.adba/share/classes

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ADBA Example

Select some items from a table

```
public CompletionStage<List<Item>> itemsForAnswer(DataSource ds, int answer) {
  String sql = "select id, name, answer from tab where answer = :target";
  try (Session session = ds.getSession()) {
    return session.<List<Item>>rowOperation(sql)
            .set("target", answer, AdbaType.NUMERIC)
            .collect(Collectors.mapping(
                    row -> new Item(row.at("id").get(Integer.class),
                                    row.at("name").get(String.class),
                                    row.at("answer").get(Integer.class)),
                    Collectors.toList()))
            .submit()
            .getCompletionStage();
  }
}
```

ADBA over JDBC (AoJ)

Open Source implementation of ADBA using any JDBC as a backend

```
DataSource ds = DataSourceFactory
      .newFactory("com.oracle.adbaoverjdbc.DataSourceFactory")
      .builder()
      .url("jdbc:derby:/myDB")
      .username("scott")
      .password("tiger")
      .build();
```

- https://github.com/oracle/oracle-db-examples/tree/master/java/AoJ

Using CompletionStage

ADBA Example

Select some items from a table

```
public CompletionStage<List<Item>> itemsForAnswer(DataSource ds, int answer) {
  String sql = "select id, name, answer from tab where answer = :target";
  try (Session session = ds.getSession()) {
    return session.<List<Item>>rowOperation(sql)
            .set("target", answer, AdbaType.NUMERIC)
            .collect(Collectors.mapping(
                    row -> new Item(row.at("id").get(Integer.class),
                                    row.at("name").get(String.class),
                                    row.at("answer").get(Integer.class)),
                    Collectors.toList()))
            .submit()
            .getCompletionStage();
  }
}
```

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submit()

com.oracle.adbaoverjdbc.Operation

```
public Submission<T> submit() {
      if (isImmutable()) {
            throw new IllegalStateException("TODO");
      }
      immutable();
      return group.submit(this);
}
```

submit(Operation op)

com.oracle.adbaoverjdbc.OperationGroup

```
Submission<S> submit(Operation<S> op) {
      memberTail =
            op.attachCompletionHandler(op.follows(memberTail,
                                                  getExecutor()));
      return Submission.submit(this::cancel, memberTail);
}
```

attachCompletionHandler

com.oracle.adbaoverjdbc.OperationGroup

```
final CompletionStage<T>
attachCompletionHandler(CompletionStage<T> result) {
     return result.handle((r, t) -> {
          Throwable ex = unwrapException(t);
          checkAbort(ex);
          if (t == null)
               return handleResult(r);
          else
               throw handleError(ex);
     });
}
```

handle(BiFunction<?, Throwable, ?> fn)

`java.util.concurrent.CompletionStage`

<U> CompletionStage<U> handle(BiFunction<? super T, Throwable, ? extends U> fn)

Returns a new CompletionStage that, when this stage completes either normally or exceptionally, is executed with this stage's result and exception as arguments to the supplied function. When this stage is complete, the given function is invoked with the result (or null if none) and the exception (or null if none) of this stage as arguments, and the function's result is used to complete the returned stage.

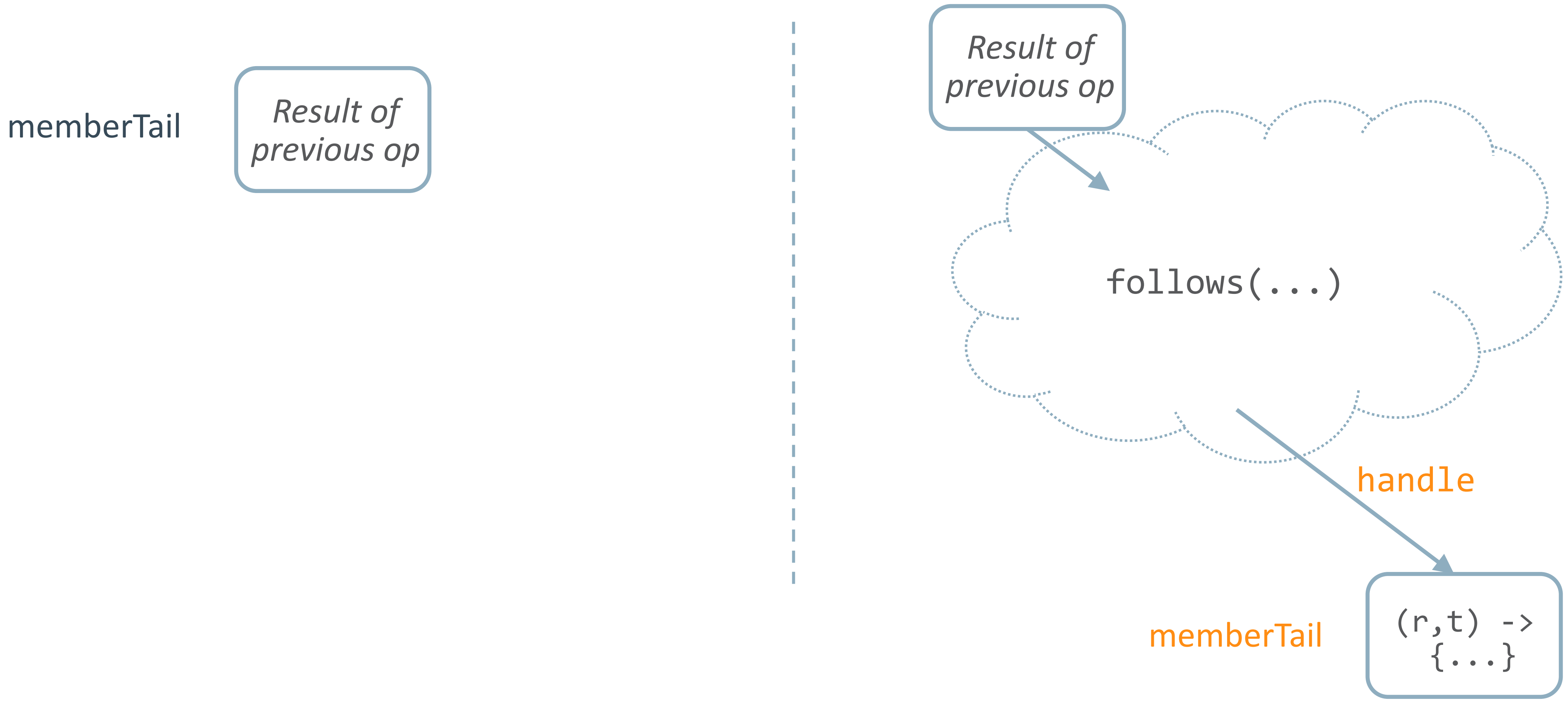
Type Parameters: U - the function's return type

Parameters: fn - the function to use to compute the value of the returned CompletionStage

Returns: the new CompletionStage

attachCompletionHandler

```
memberTail = follows(...).handle( (r, t) -> { ... } )
```



(r, t) -> { ... }

com.oracle.adbaoverjdbc.OperationGroup

```
final CompletionStage<T>
attachCompletionHandler(CompletionStage<T> result) {
     return result.handle((r, t) -> {
          Throwable ex = unwrapException(t);
          checkAbort(ex);
          if (t == null)
               return handleResult(r);
          else
               throw handleError(ex);
     });
}
```

submit(Operation op)

com.oracle.adbaoverjdbc.OperationGroup

```
Submission<S> submit(Operation<S> op) {
     memberTail =
          op.attachCompletionHandler(op.follows(memberTail,
                                                 getExecutor()));
     return Submission.submit(this::cancel, memberTail);
}
```

follows(CompletionStage<?> predecessor, Executor executor)

com.oracle.adbaoverjdbc.RowOperation

```
CompletionStage<T> follows(CompletionStage<?> predecessor,
                           Executor executor) {
     predecessor = attachFutureParameters(predecessor);
     return predecessor
          .thenRunAsync(this::executeQuery, executor)
          .thenCompose(this::moreRows);
}
```

thenRunAsync(Runnable action)

`java.util.concurrent.CompletionStage`

CompletionStage<Void> thenRunAsync(Runnable action)

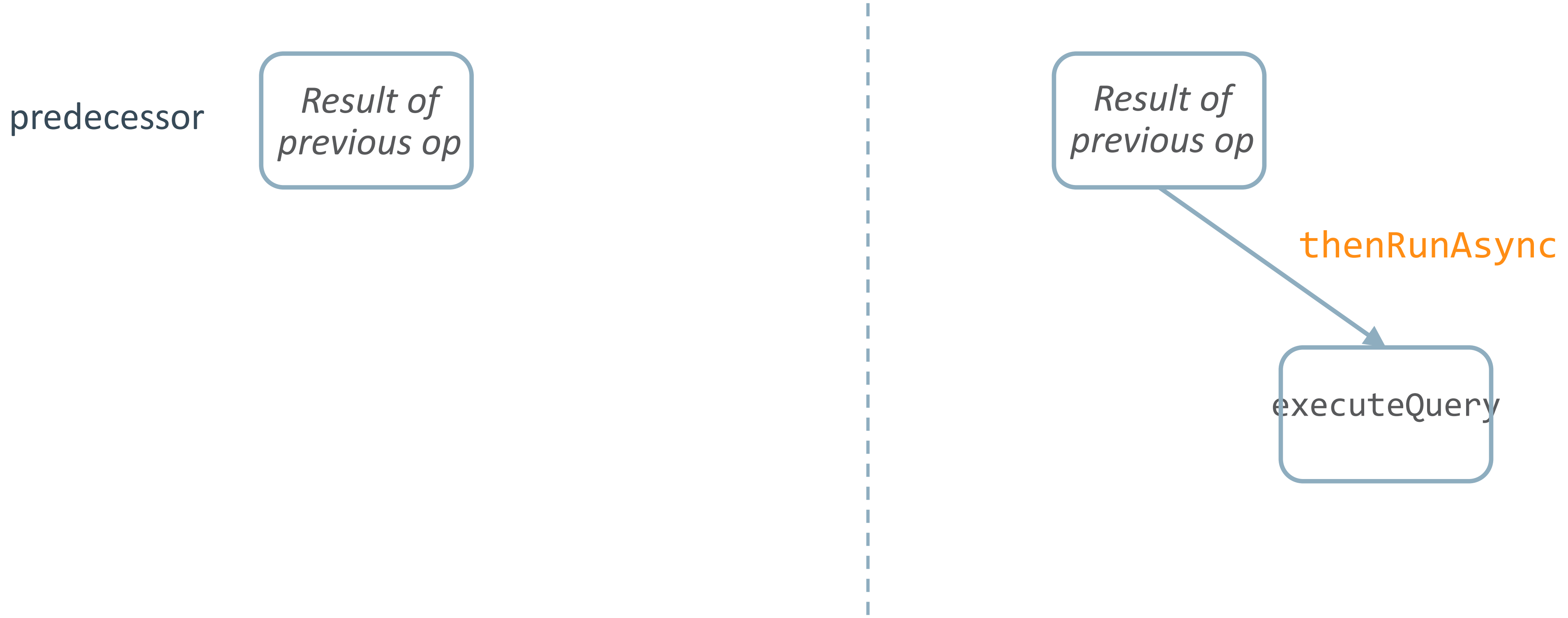
Returns a new CompletionStage that, when this stage completes normally, executes the given action using this stage's default asynchronous execution facility.

Parameters: action - the action to perform before completing the returned CompletionStage

Returns: the new CompletionStage

follows(. . .)

```
predecessor.thenRunAsync(this::executeQuery, executor)
```



follows(CompletionStage<?> predecessor, Executor executor)

com.oracle.adbaoverjdbc.RowOperation

```
CompletionStage<T> follows(CompletionStage<?> predecessor,
                           Executor executor) {
     predecessor = attachFutureParameters(predecessor);
     return predecessor
          .thenRunAsync(this::executeQuery, executor)
          .thenCompose(this::moreRows);
}
```

thenCompose(Function<?, CompletionStage>, Executor executor)

`java.util.concurrent.CompletionStage`

<U> CompletionStage<U> thenCompose(Function<? super T,? extends CompletionStage<U>> fn)

Returns a new CompletionStage that is completed with the same value as the CompletionStage returned by the given function.When this stage completes normally, the given function is invoked with this stage's result as the argument, returning another CompletionStage. When that stage completes normally, the CompletionStage returned by this method is completed with the same value.

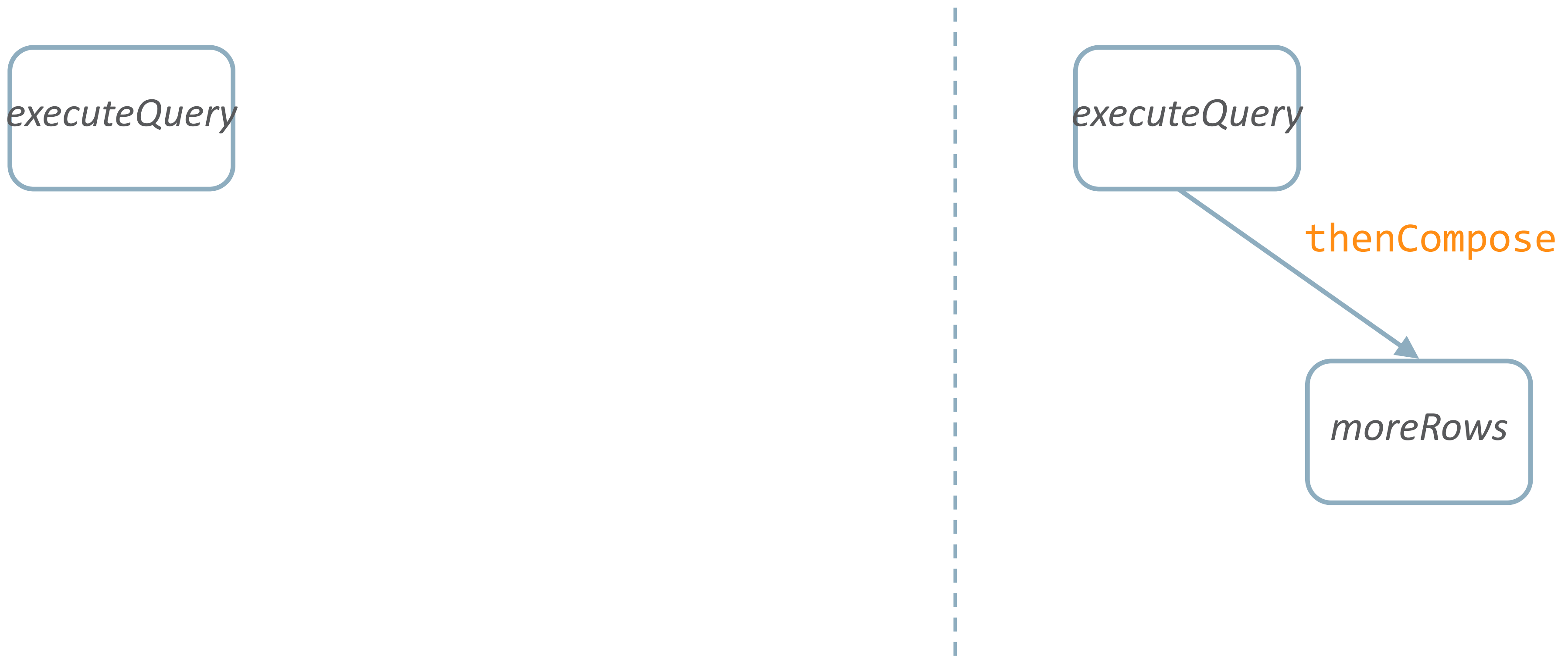
Type Parameters: U - the type of the returned CompletionStage's result

Parameters: fn - the function to use to compute another CompletionStage

Returns: the new CompletionStage

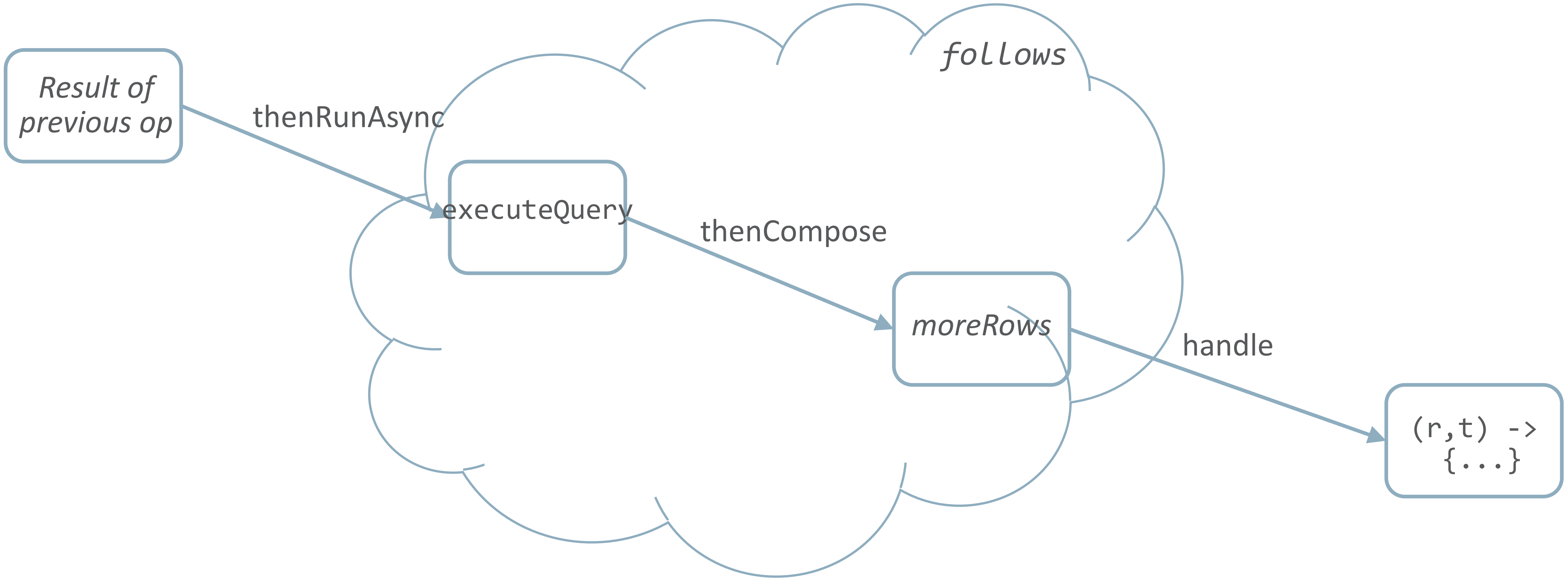
follows(. . .)

`thenCompose(this::moreRows)`



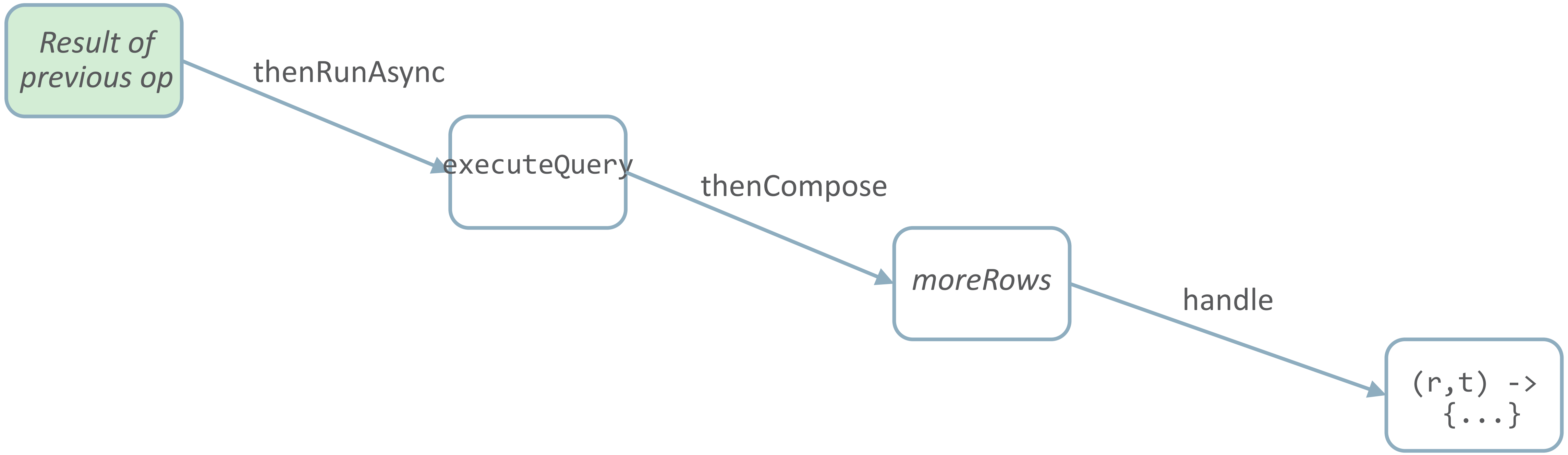
submit(Operation op, Executor executor)

`com.oracle.adbaoverjdbc.OperationGroup`



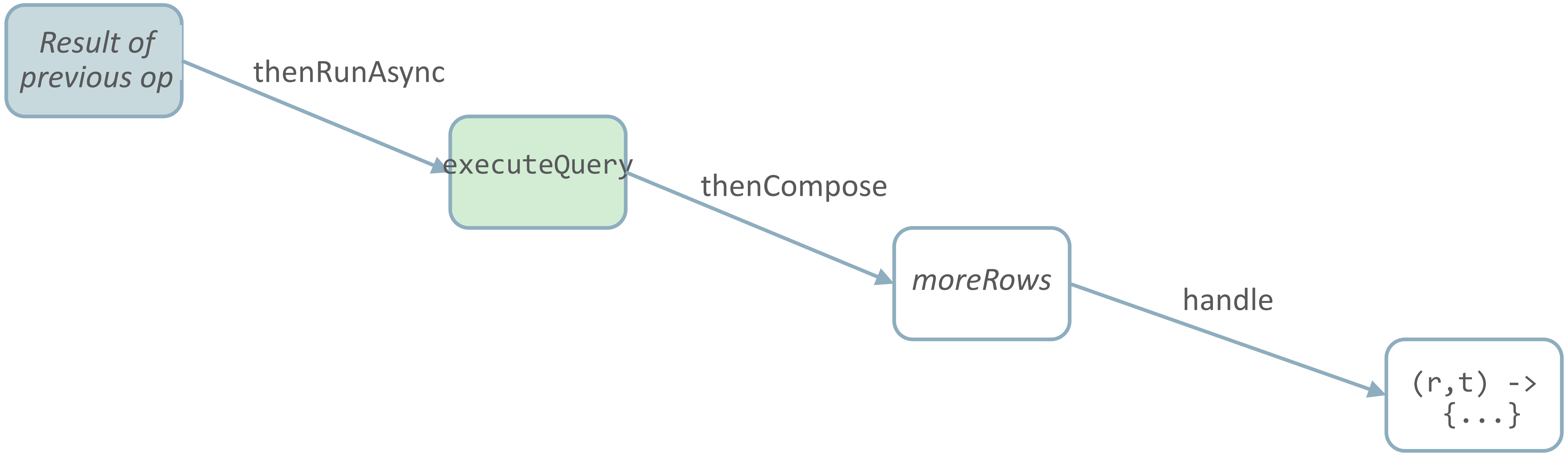
Executing RowOperation

Previous Operation



Executing RowOperation

executeQuery



moreRows(Object x)

com.oracle.adbaoverjdbc.RowOperation

```
protected CompletionStage<T> moreRows(Object x) {
      checkCanceled();
      if (rowsRemain) {
            return CompletableFuture
                  .runAsync(this::handleFetchRows, getExecutor())
                  .thenCompose(this::moreRows);
      }
      else {
            return CompletableFuture
                  .supplyAsync(this::completeQuery, getExecutor());
      }
}
```

runAsync(Runnable action, Executor executor)

`java.util.concurrent.CompletionStage`

public static CompletableFuture<Void> runAsync(Runnable runnable, Executor executor)

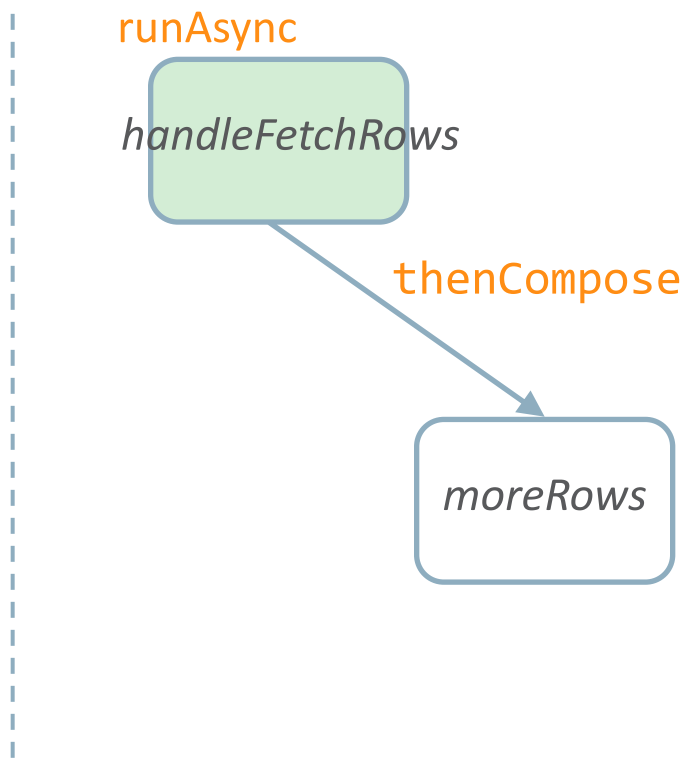
Returns a new CompletableFuture that is asynchronously completed by a task running in the given executor after it runs the given action.

Parameters: runnable - the action to run before completing the returned CompletableFuture
executor - the executor to use for asynchronous execution

Returns: the new CompletableFuture

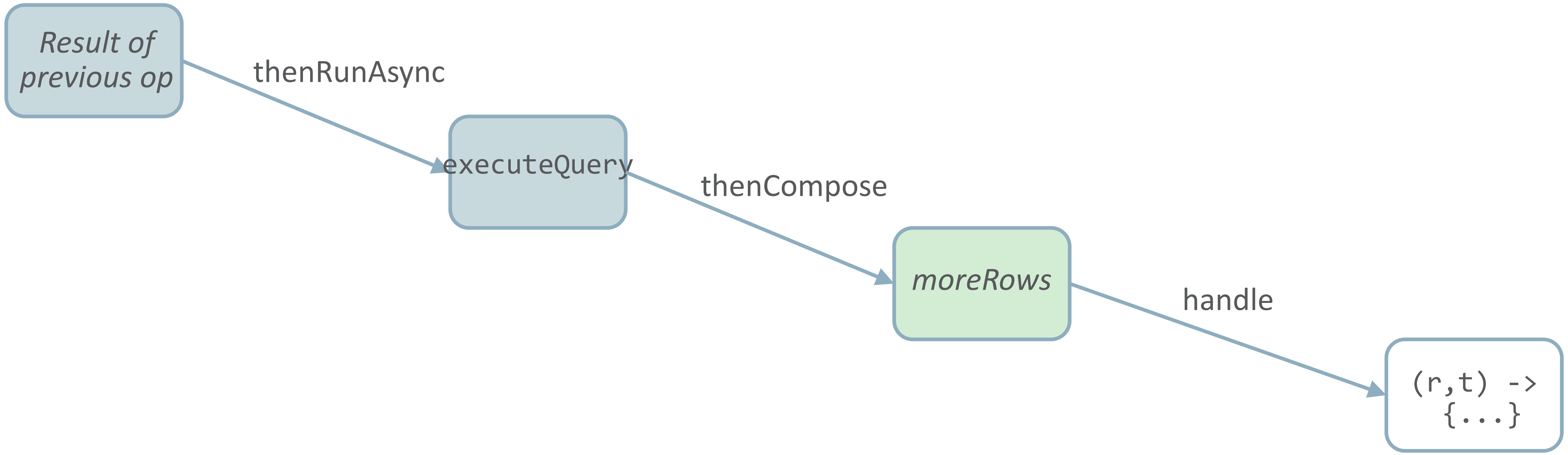
moreRows(...)

```
runAsync(this::handleFetchRows).thenCompose(this::moreRows)
```



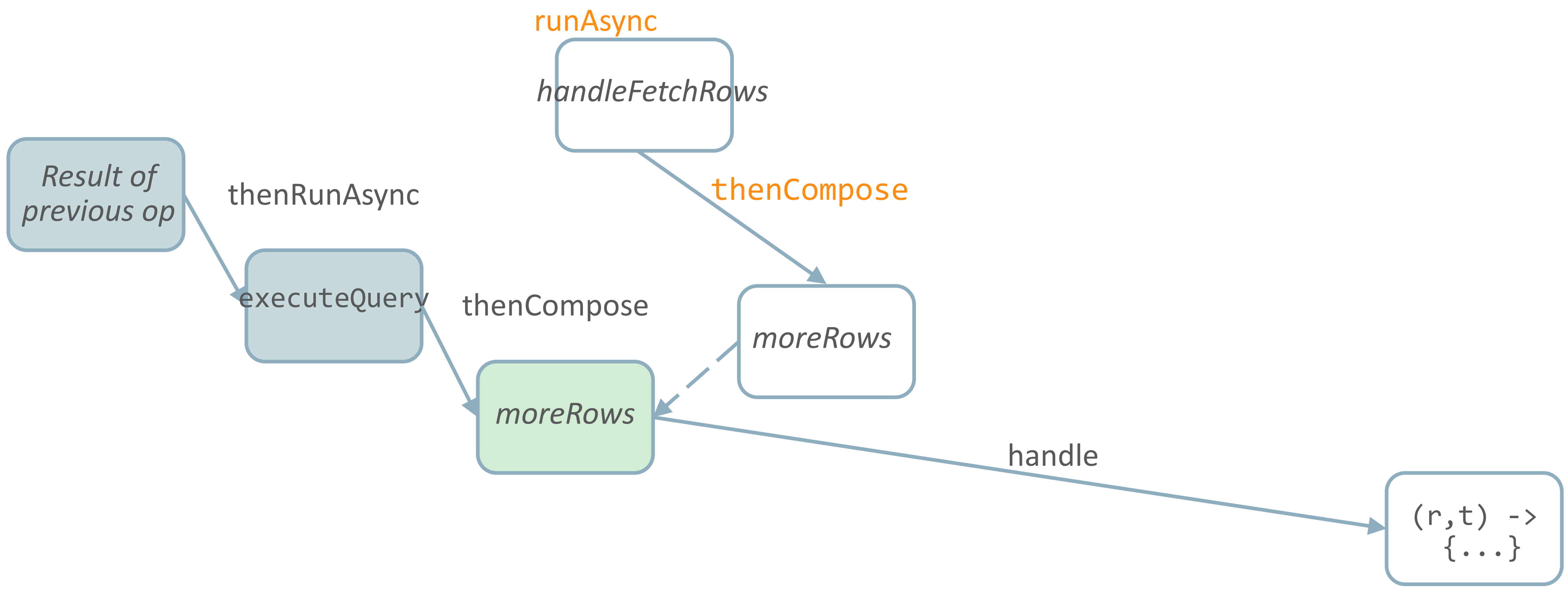
Executing RowOperation

Before `moreRows(Object x)`



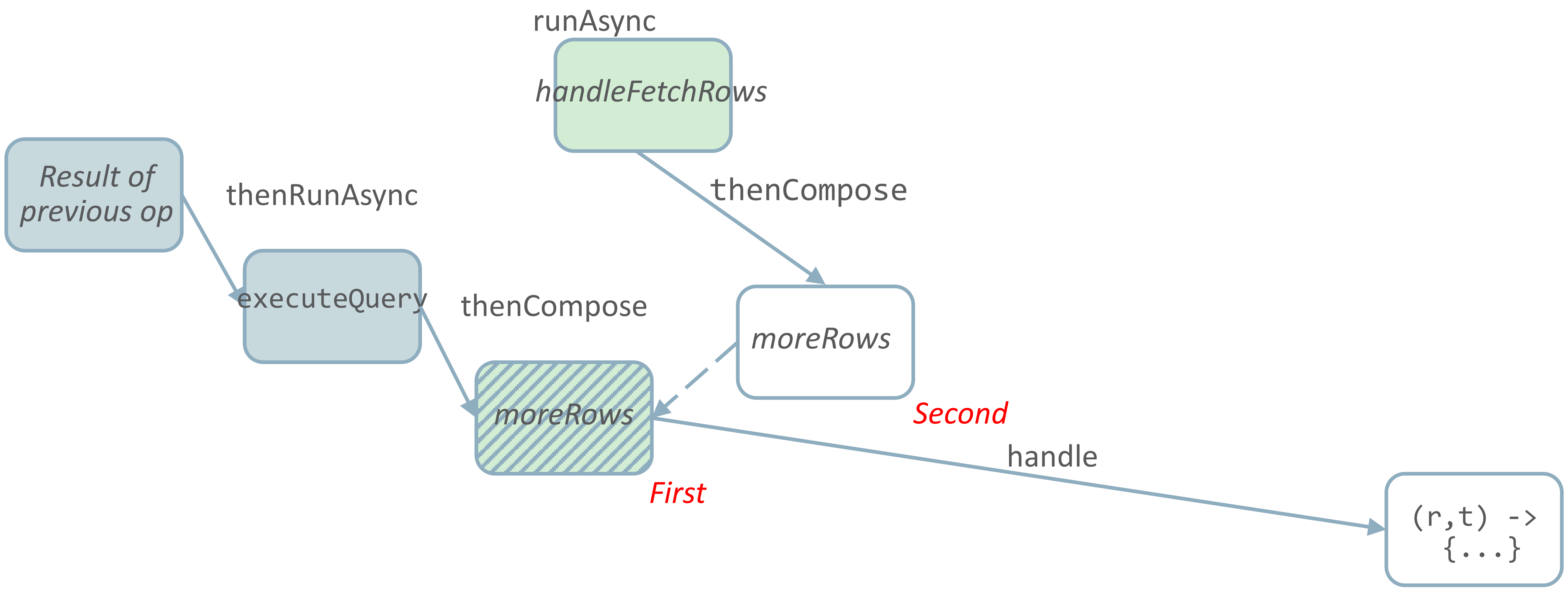
Executing RowOperation

`runAsync(this::handleFetchRows).thenCompose(this::moreRows)`



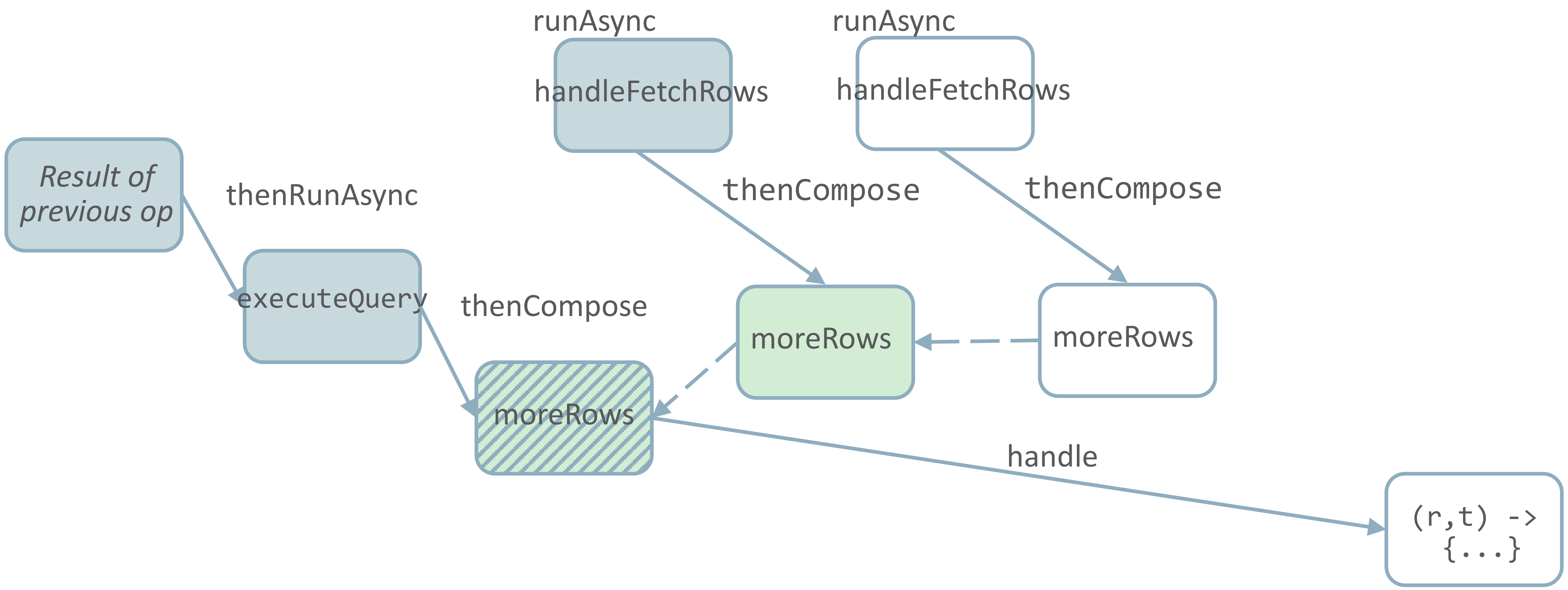
Executing moreRows

`runAsync(this::handleFetchRows).thenCompose(this::moreRows)`



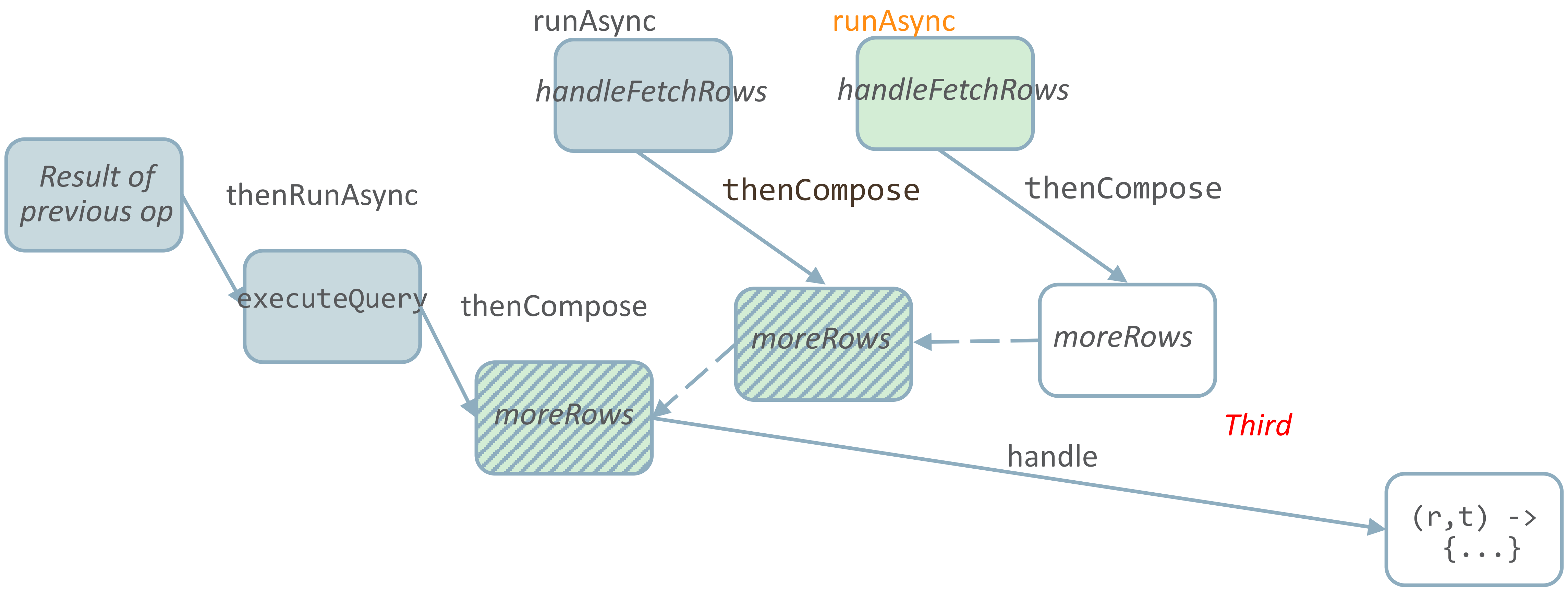
Executing moreRows

`runAsync(this::handleFetchRows).thenCompose(this::moreRows)`



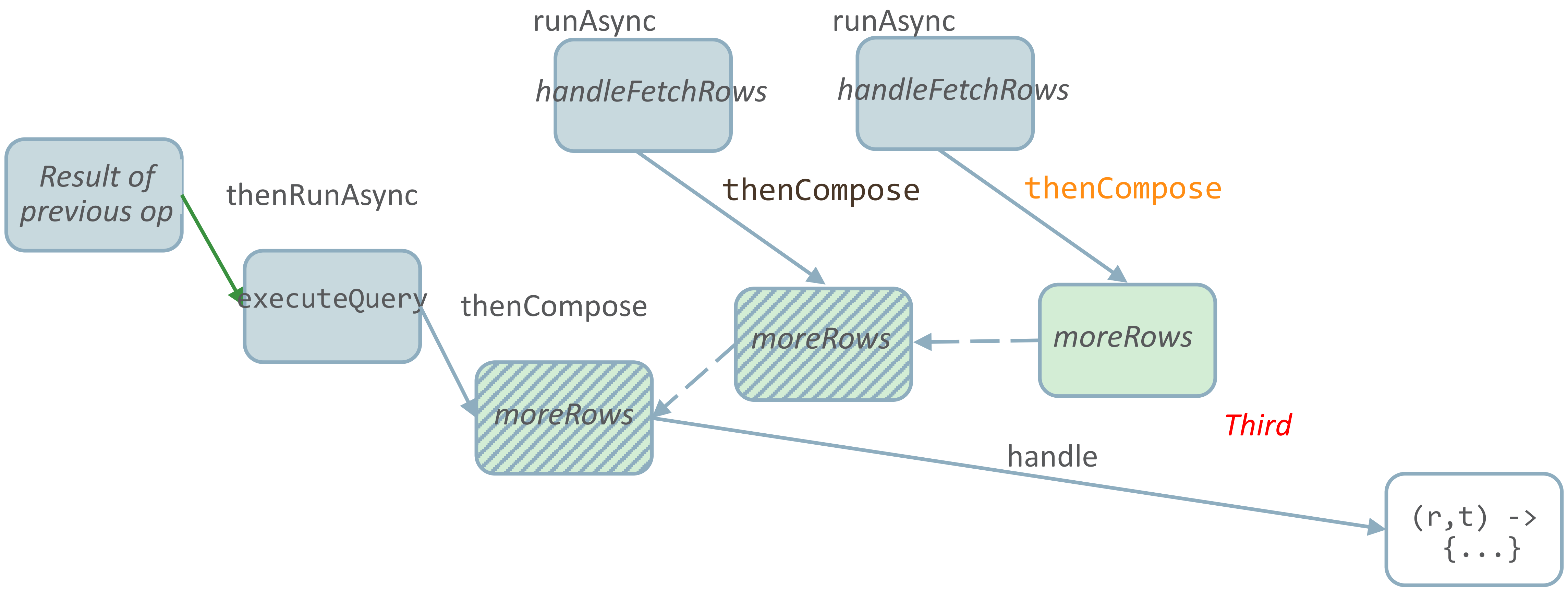
Executing moreRows

`runAsync(this::handleFetchRows)`



Executing moreRows

`.thenCompose(this::moreRows)`



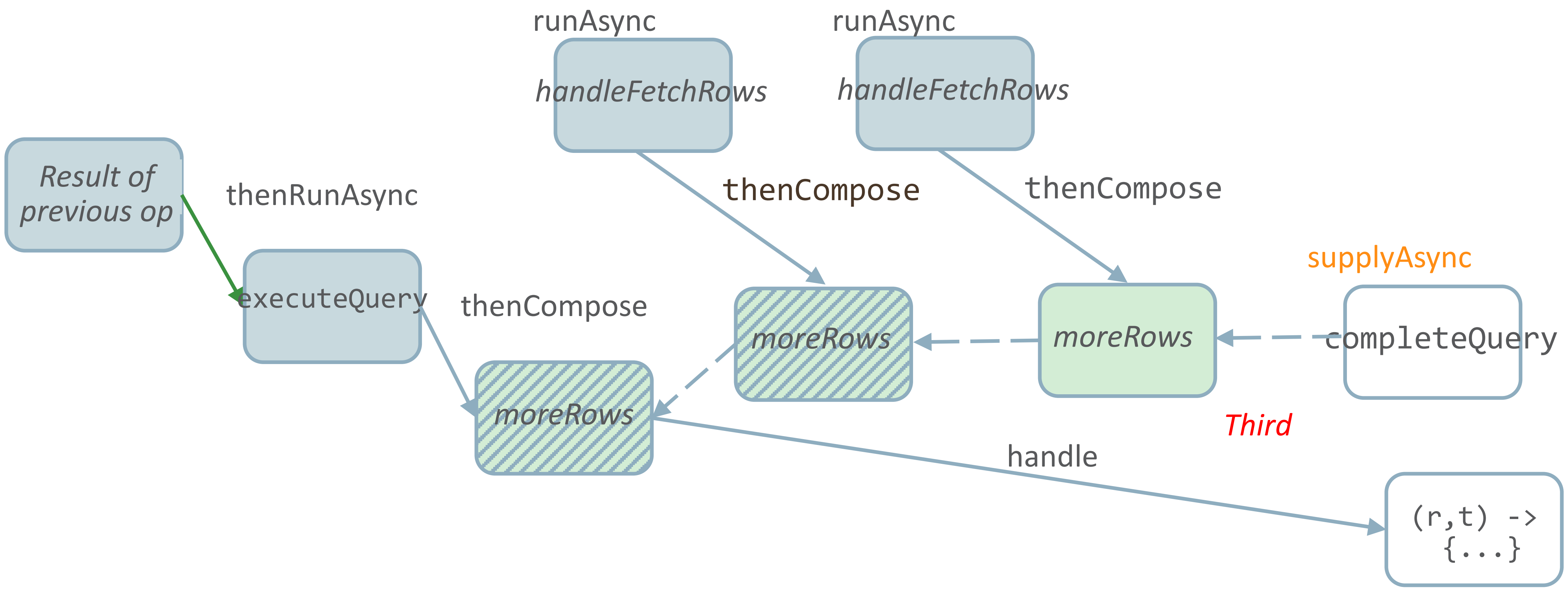
moreRows(Object x)

com.oracle.adbaoverjdbc.RowOperation

```
protected CompletionStage<T> moreRows(Object x) {
     checkCanceled();
     if (rowsRemain) {
          return CompletableFuture
               .runAsync(this::handleFetchRows, getExecutor())
               .thenCompose(this::moreRows, getExecutor());
     }
     else {
          return CompletableFuture
               .supplyAsync(this::completeQuery, getExecutor());
     }
}
```

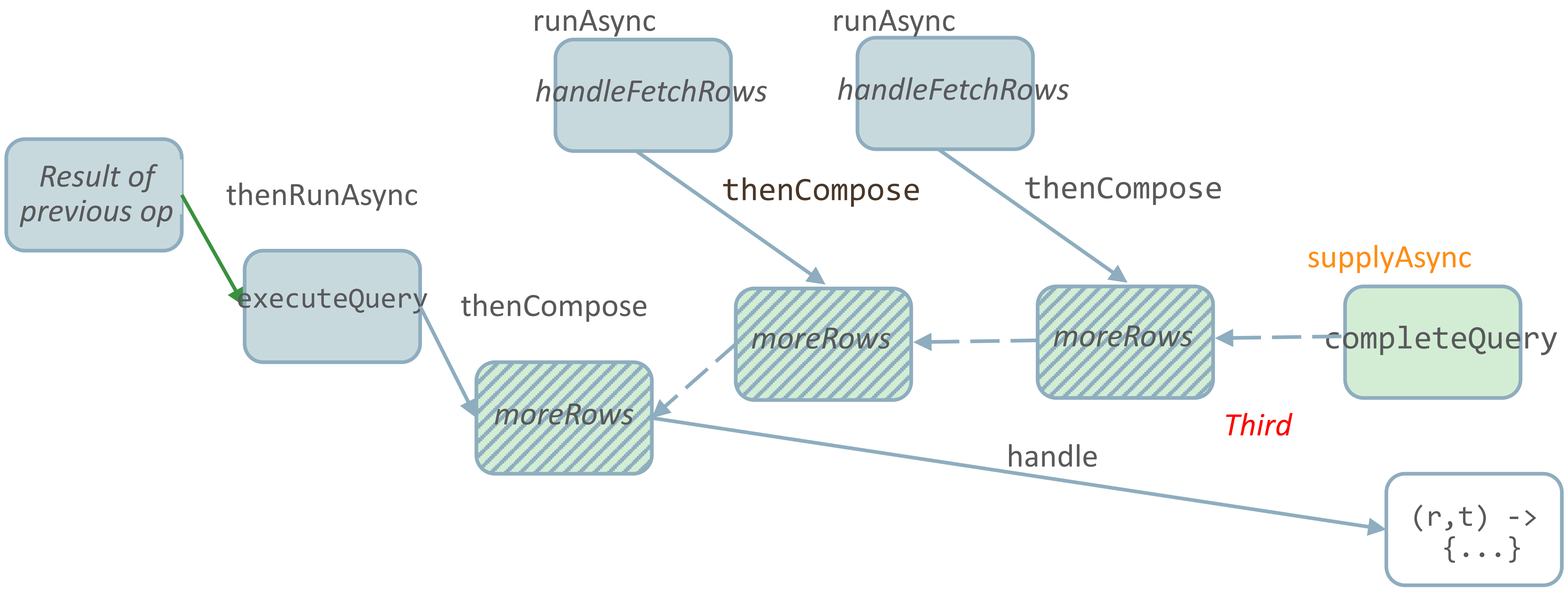
Executing moreRows when no more rows

```
.supplyAsync(this::completeQuery)
```



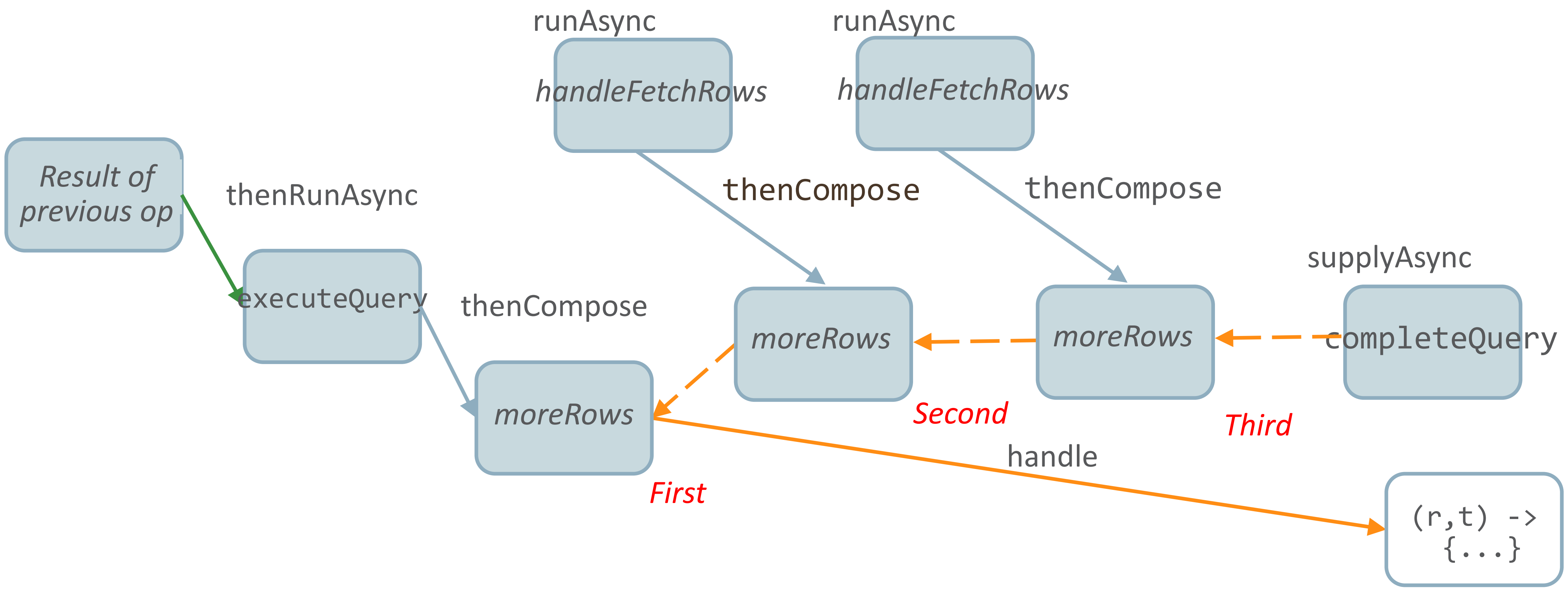
Executing completeQuery

```
.supplyAsync(this::completeQuery)
```



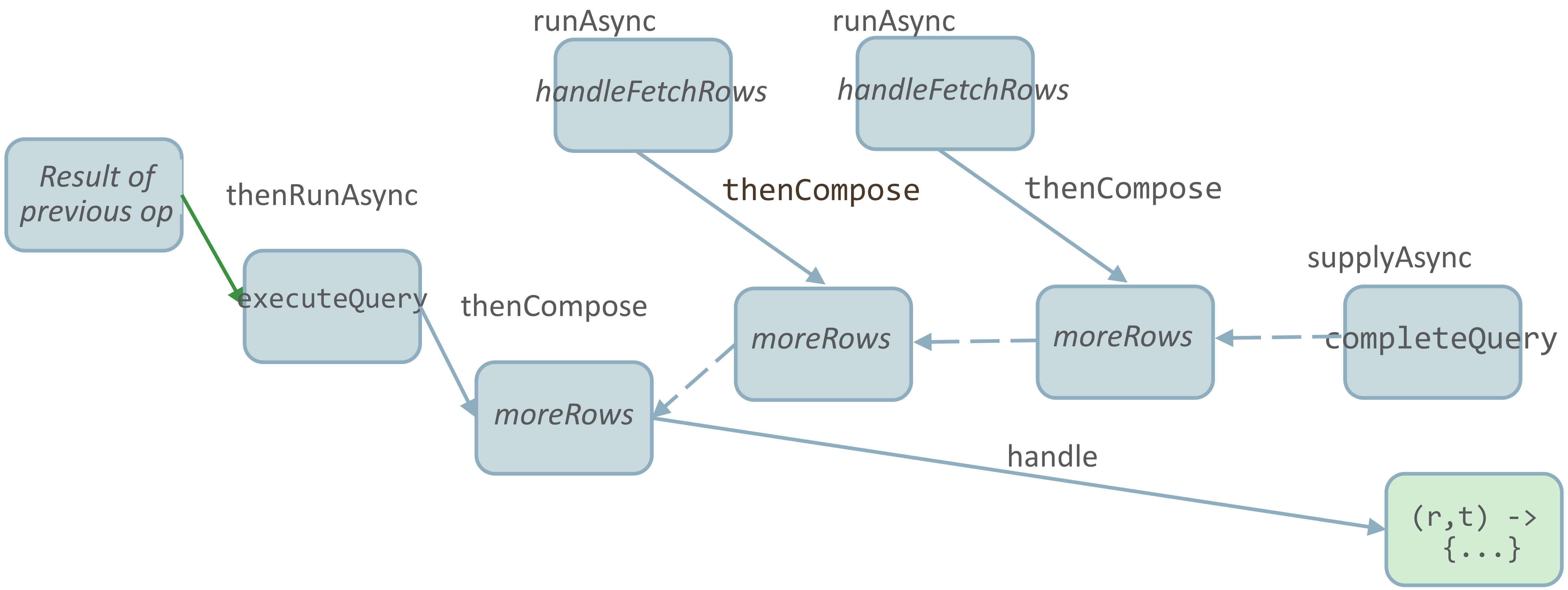
Query complete

`Result of completeQuery propagates back`



Executing completionHandler

```
.handle( (r, t) -> { ... } )
```



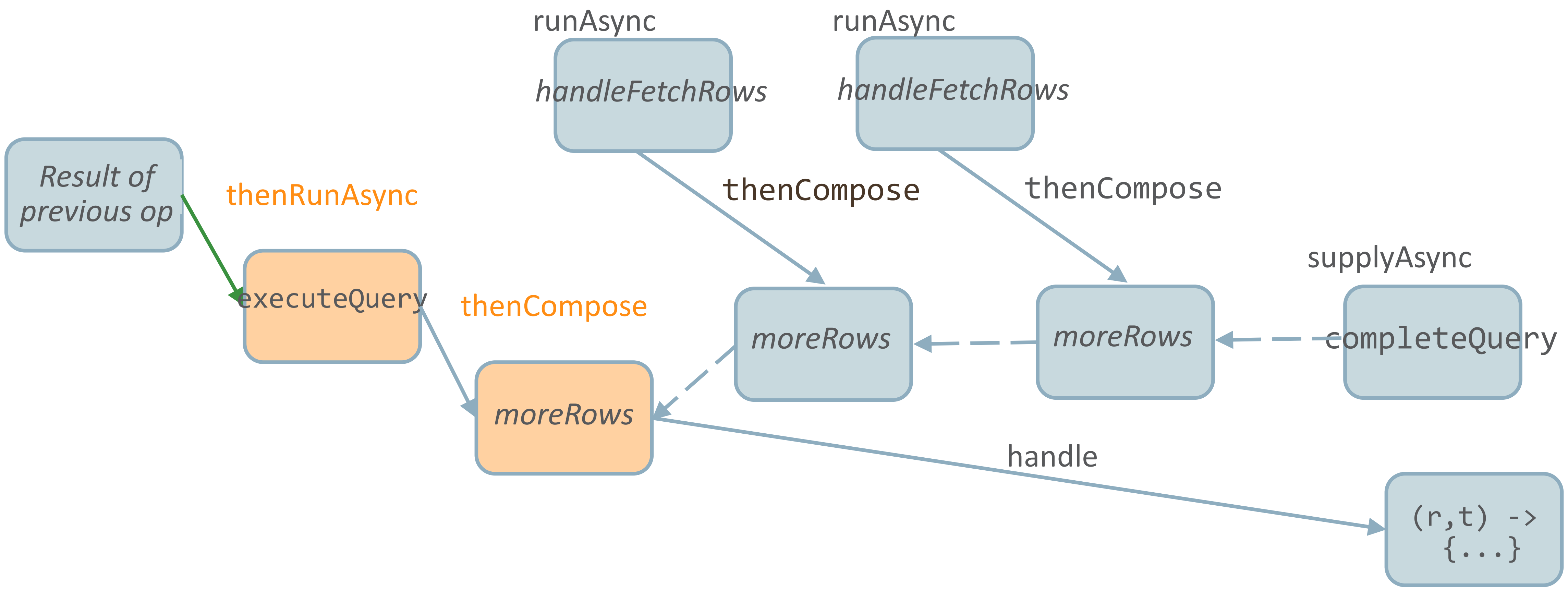
Summary

follows(CompletionStage<?> predecessor,
Executor executor)

com.oracle.adbaoverjdbc.RowOperation

```
CompletionStage<T> follows(CompletionStage<?> predecessor,
                             Executor executor) {
     predecessor = attachFutureParameters(predecessor);
     return predecessor
          .thenRunAsync(this::executeQuery, executor)
          .thenCompose(this::moreRows);
}
```

`follows(CompletionStage<?> predecessor, Executor executor)`

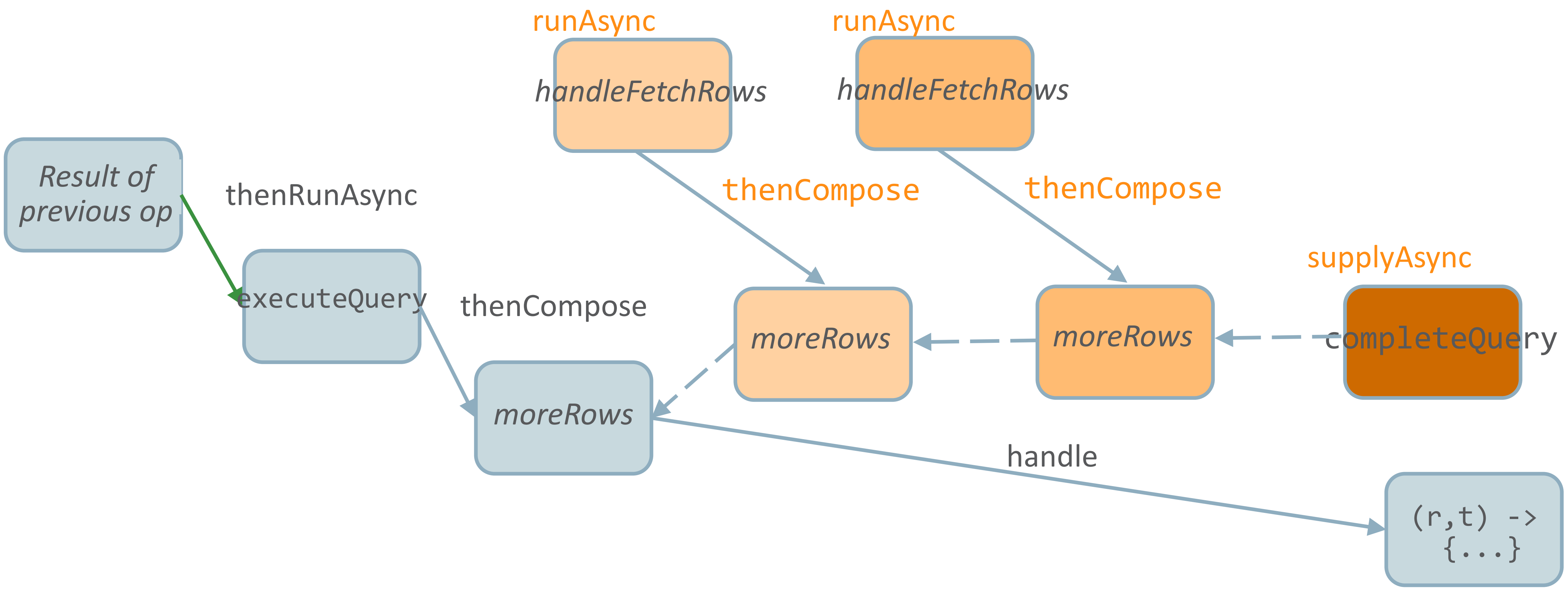


moreRows(Object x)

com.oracle.adbaoverjdbc.RowOperation

```
protected CompletionStage<T> moreRows(Object x) {
      checkCanceled();
      if (rowsRemain) {
            return CompletableFuture
                  .runAsync(this::handleFetchRows, getExecutor())
                  .thenCompose(this::moreRows, getExecutor());
      }
      if {
            return CompletableFuture
                  .supplyAsync(this::completeQuery, getExecutor());
      }
}
```

moreRows(Object x)



attachCompletionHandler

com.oracle.adbaoverjdbc.OperationGroup

```
final CompletionStage<T>
attachCompletionHandler(CompletionStage<T> result) {
     return result.handle((r, t) -> {
          Throwable ex = unwrapException(t);
          checkAbort(ex);
          if (t == null)
               return handleResult(r);
          else
               throw handleError(ex);
     });
}
```

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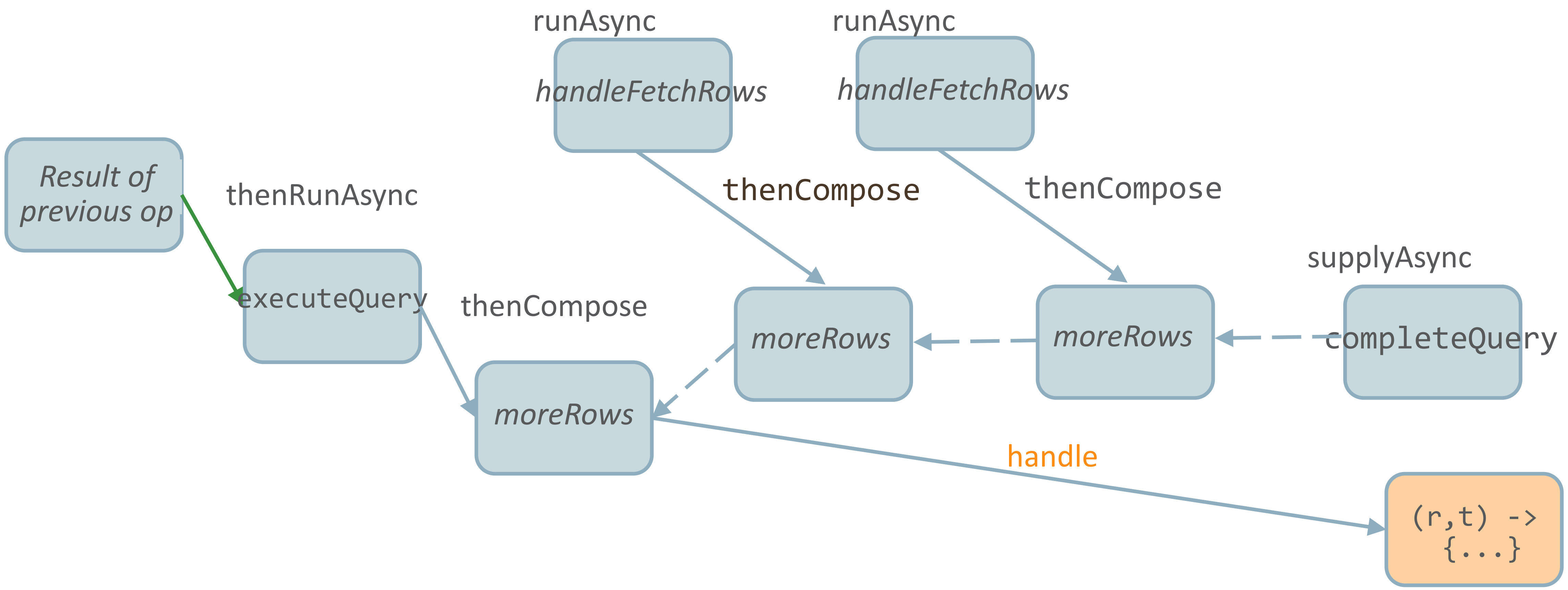
Executing completionHandler

`.handle( (r, t) -> { ... } )`



Methods used to implement the example code

```
CompletionStage
<U> CompletionStage<U> handle (BiFunction<? super T, Throwable, ? extends U> fn)
<U> CompletionStage<U> thenApply(Function<? super T,? extends U> fn)
<U> CompletionStage<U> thenCompose (Function<? super T,? extends CompletionStage<U>> fn)
CompletionStage<Void> thenRunAsync (Runnable action, Executor executor)

CompletableFuture
public static CompletableFuture<Void> runAsync (Runnable runnable, Executor executor)
public static <U> CompletableFuture<U> supplyAsync (Supplier<U> supplier)
```

Q & A