


# Creating Enterprise Reactive Apps

## Part One

- 
1. Project Reactor and Spring WebFlux
  2. Implementing a reactive data layer
  3. Implementing a reactive service layer
  4. Testing the reactive service layer

# 1. Project Reactor and Spring WebFlux

- Overview of Project Reactor
- Overview of Spring WebFlux
- Overview of the demo application
- Adding support for Spring WebFlux
- Adding support for Reactive MongoDB
- Test dependencies

# Overview of Project Reactor

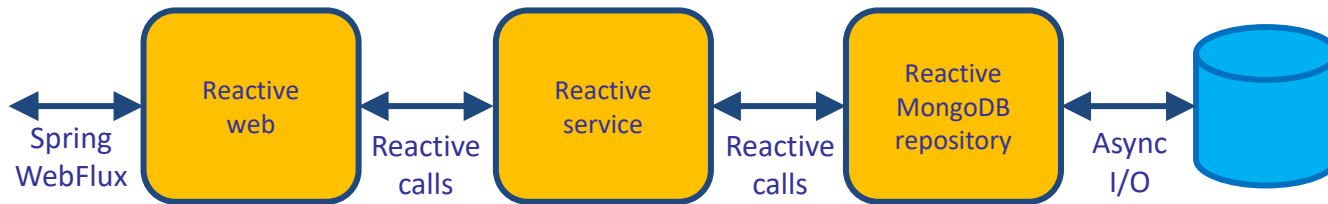
- The previous chapter covered Reactive Streams, available since Java 9
  - Specifies 4 interfaces...
  - `Publisher`, `Subscriber`, `Subscription`, `Processor`
- Project Reactor is an open-source library from Pivotal that builds on Reactive Streams, see <https://projectreactor.io/>
  - Provides 2 specializations of `Publisher<T>...`
  - `Mono<T>` is a publisher that produces 0 or 1 value
  - `Flux<T>` is a publisher that produces 0 or more values
- Recommended usage:
  - Method params - use `Publisher<T>` for substitutability
  - Method results - use `Mono<T>` or `Flux<T>` for specificity

# Overview of Spring WebFlux

- Spring Boot 2 introduced support for Spring WebFlux
  - Enables you to create reactive web applications
  - Produce and consume HTTP resources, WebSockets, SSE
- Should I use Spring WebFlux or Spring MVC?
  - Use Spring WebFlux for apps that create huge/streaming data
  - Use Spring MVC for CRUD-style applications
- Spring WebFlux doesn't depend on the Servlet APIs
  - It has a new reactive web runtime
  - There are adapters to the Servlet API, if you still want to use it

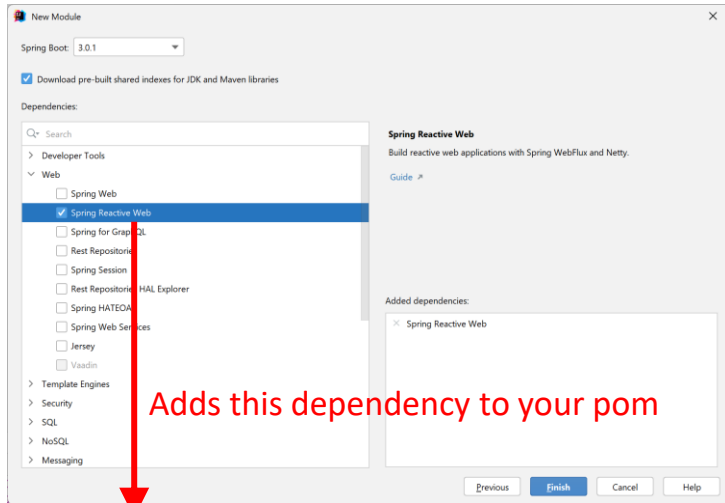
# Overview of the Demo Application

- We're going to see how to build a complete reactive app using Spring WebFlux
  - We'll define a reactive data repository for a MongoDB database
  - We'll define a reactive service layer, to consume the repository
  - We'll define a reactive Web layer, to consume the service
  - The reactive Web layer will be implemented using Spring WebFlux



# Adding Support for Spring WebFlux

- When you create a Spring project using Spring Initializr, add the Spring Reactive Web dependency
  - Uses Netty by default, but you can switch to use Tomcat, Jetty

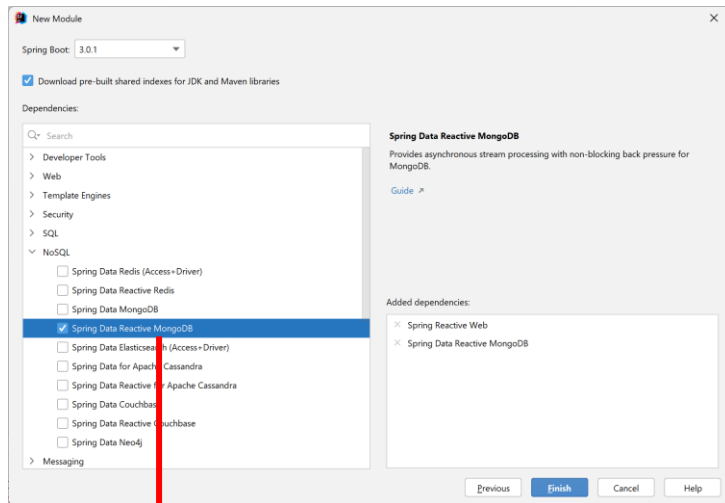


```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-webflux</artifactId>
</dependency>
```

pom.xml

# Adding Support for Reactive MongoDB

- If you want to use reactive data access, e.g. a MongoDB database, then add the appropriate dependency



Adds this dependency to your pom

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-data-mongodb-reactive</artifactId>
</dependency>
```

pom.xml

# Test Dependencies

- Your pom file will contain two sets of test dependencies
  - JUnit tests
  - Project Reactor tests

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-test</artifactId>
  <scope>test</scope>
</dependency>

<dependency>
  <groupId>io.projectreactor</groupId>
  <artifactId>reactor-test</artifactId>
  <scope>test</scope>
</dependency>
```

pom.xml



## 2. Implementing a Reactive Data Layer

- Overview
- MongoDB documents
- Defining a reactive data repository
- Seeding the MongoDB database
- Setting the active profile
- Running the application
- Reminder of the big picture

# Overview

- To obtain the true value of reactive systems, it really helps if the database driver itself supports async I/O 😊
  - Otherwise you won't be able to scale-out reads without scaling-out threads, which is exactly what you want to avoid
- Spring Data has several reactive data repositories
  - Reactive MongoDB
  - Reactive Redis
  - Reactive Cassandra
  - Etc.
- You just need to add the appropriate Spring Boot starter to your project - we added Spring Data Reactive MongoDB

# MongoDB Documents (1 of 2)

- MongoDB is a document-oriented database
  - A MongoDB document is a BSON object (effectively binary JSON)
  - MongoDB documents contain fieldname/value pairs

```
var financialTransaction = {  
  _id:    ObjectId("21aa914e0405a59ce30a94a2"),    // Unique ID for this object.  
  amount: 5000,  
  when:   new Date('Jul 2, 1997')  
}
```

# MongoDB Documents (2 of 2)

- In work with MongoDB documents in Java:
  - Define a class and annotate with `@Document`
  - Define fields as appropriate, plus an ID field annotated with

```
import org.springframework.data.mongodb.core.mapping.Document;
import org.springframework.data.annotation.Id;
...

@Document
@Data
@AllArgsConstructor
@NoArgsConstructor
public class Tx {

    @Id
    private String id;

    private double amount;
    private LocalDateTime when;
}
```

`Tx.java`

- Conceptually similar to defining entity classes in JPA

# Defining a Reactive Data Repository (1 of 4)

- Spring Data is a data-access abstraction mechanism in Spring Boot
  - Makes it much easier to access a wide range of data stores
- It provides the `CrudRepository` interface that specifies **synchronous I/O** operations
  - Sub-interfaces available for many types of data source
  - E.g. `MongoRepository`
- It provides the `ReactiveCrudRepository` interface that specifies **asynchronous I/O** operations
  - Sub-interfaces available for many types of data source
  - E.g. `ReactiveMongoRepository`

# Defining a Reactive Data Repository (2 of 4)

- **ReactiveCrudRepository**
  - Specifies CRUD operations in an agnostic manner
- All methods are reactive
  - They return a Publisher...
  - Either `Mono` (0-1 result)
  - Or `Flux` (\* results)
- In your client code:
  - Call a method
  - Subscribe to returned publisher
  - Obtain result(s) reactively

Modifier and Type	Method and Description
reactor.core.publisher.Mono<Long>	<b>count()</b> Returns the number of entities available.
reactor.core.publisher.Mono<Void>	<b>delete(T entity)</b> Deletes a given entity.
reactor.core.publisher.Mono<Void>	<b>deleteAll()</b> Deletes all entities managed by the repository.
reactor.core.publisher.Mono<Void>	<b>deleteAll(Iterable&lt;? extends T&gt; entities)</b> Deletes the given entities.
reactor.core.publisher.Mono<Void>	<b>deleteAll(org.reactivestreams.Publisher&lt;? extends T&gt; entityStream)</b> Deletes the given entities supplied by a Publisher.
reactor.core.publisher.Mono<Void>	<b>deleteById(ID id)</b> Deletes the entity with the given id.
reactor.core.publisher.Mono<Void>	<b>deleteById(org.reactivestreams.Publisher&lt;ID&gt; id)</b> Deletes the entity with the given id supplied by a Publisher.
reactor.core.publisher.Mono<Boolean>	<b>existsById(ID id)</b> Returns whether an entity with the given id exists.
reactor.core.publisher.Mono<Boolean>	<b>existsById(org.reactivestreams.Publisher&lt;ID&gt; id)</b> Returns whether an entity with the given id, supplied by a Publisher, exists.
reactor.core.publisher.Flux<T>	<b>findAll()</b> Returns all instances of the type.
reactor.core.publisher.Flux<T>	<b>findAllById(Iterable&lt;ID&gt; ids)</b> Returns all instances of the type T with the given IDs.
reactor.core.publisher.Flux<T>	<b>findAllById(org.reactivestreams.Publisher&lt;ID&gt; idStream)</b> Returns all instances of the type T with the given IDs supplied by a Publisher.
reactor.core.publisher.Mono<T>	<b>findById(ID id)</b> Retrieves an entity by its id.
reactor.core.publisher.Mono<T>	<b>findById(org.reactivestreams.Publisher&lt;ID&gt; id)</b> Retrieves an entity by its id supplied by a Publisher.
<S extends T> reactor.core.publisher.Mono<S>	<b>save(S entity)</b> Saves a given entity.
<S extends T> reactor.core.publisher.Flux<S>	<b>saveAll(Iterable&lt;S&gt; entities)</b> Saves all given entities.
<S extends T> reactor.core.publisher.Flux<S>	<b>saveAll(org.reactivestreams.Publisher&lt;S&gt; entityStream)</b> Saves all given entities.

# Defining a Reactive Data Repository (3 of 4)

- **ReactiveMongoRepository**

- Inherits the basic methods from the previous slide and adds a few more...

Modifier and Type	Method and Description
<S extends T> reactor.core.publisher.Flux<S>	findAll(Example<S> example)
<S extends T> reactor.core.publisher.Flux<S>	findAll(Example<S> example, Sort sort)
<S extends T> reactor.core.publisher.Flux<S>	insert(Iterable<S> entities) Inserts the given entities.
<S extends T> reactor.core.publisher.Flux<S>	insert(org.reactivestreams.Publisher<S> entities) Inserts the given entities.
<S extends T> reactor.core.publisher.Mono<S>	insert(S entity) Inserts the given entity.

#### Methods inherited from interface org.springframework.data.repository.reactive.ReactiveSortingRepository

findAll

#### Methods inherited from interface org.springframework.data.repository.reactive.ReactiveCrudRepository

count, delete, deleteAll, deleteAll, deleteAll, deleteById, deleteById, existsById, existsById, findAll, findAllById, findAllById, findById, findById, save, saveAll, saveAll

#### Methods inherited from interface org.springframework.data.repository.query.ReactiveQueryByExampleExecutor

count, exists, findOne

# Defining a Reactive Data Repository (4 of 4)

- To define a reactive MongoDB repository in your app:
  - Define an interface that extends `ReactiveMongoRepository`
  - Specify the document type and the ID type
  - Optionally define custom finder methods

```
import org.springframework.data.mongodb.repository.ReactiveMongoRepository;  
  
interface TxRepository extends ReactiveMongoRepository<Tx, String> {  
}
```

`TxRepository.java`

- This is what a custom finder method might look like
  - This method finds all documents in the MongoDB database that have a `when` attribute equal to the specified value

```
Flux<Tx> findByWhen(LocalDateTime when);
```



# Seeding the MongoDB Database (1 of 3)

- For demo purposes, it's handy to seed the MongoDB database with some sample Tx documents
  - See following slides for explanations of this code...

```
@Log4j2
@Component
@Profile("onlyForDemoPurposes")
public class SeedDb implements ApplicationListener<ApplicationReadyEvent> {

    private final TxRepository repo;

    public SeedDb(TxRepository repo) { this.repo = repo; }

    @Override
    public void onApplicationEvent(ApplicationReadyEvent event) {
        repo.deleteAll()
            .thenMany(Flux.just(100.0, 200.0, 300.0)
                .map(amount -> new Tx(UUID.randomUUID().toString(),
                    amount,
                    LocalDateTime.now()))
                .flatMap(tx -> repo.save(tx))
            )
            .thenMany(repo.findAll())
            .subscribe(tx -> log.info("Tx document successfully inserted: " + tx));
    }
}
```

# Seeding the MongoDB Database (2 of 3)

```
@Log4j2
@Component
@Profile("onlyForDemoPurposes")
public class SeedDb implements ApplicationListener<ApplicationReadyEvent> {

    private final TxRepository repo;

    public SeedDb(TxRepository repo) { this.repo = repo; }

    ...
}
```

- We only want database seeding when we're in "demo" mode, not when we're in production mode
- The `ApplicationListener` interface enables us to handle lifecycle events (`ApplicationReadyEvent` is the final event)
- If a component has only a single constructor, you can omit `@Autowired` to inject dependencies into the constructor

# Seeding the MongoDB Database (3 of 3)

```
repo.deleteAll()  
  .thenMany(Flux.just(100.0, 200.0, 300.0)  
    .map(amount -> new Tx(UUID.randomUUID().toString(),  
      amount,  
      LocalDateTime.now()))  
    .flatMap(tx -> repo.save(tx))  
  )  
  .thenMany(repo.findAll())  
  .subscribe(tx -> log.info("Tx document successfully inserted: " + tx));
```

- `deleteAll()` returns a `Mono` (i.e. a publisher), and publishers support chained processing via `thenMany()`
- `Flux.just()` is a factory method that creates a new publisher with a static list of items (numbers here)
- `map()` receives each number and maps it to a `Tx` object
- `flatMap()` saves each `Tx` object to the MongoDB database
- `thenMany()` finds all the docs, as a sanity check
- `subscribe()` is necessary because publishers are lazy, i.e. you must subscribe to them to trigger their execution

# Setting the Active Profile

- The SeedDb component only kicks in if the active profile includes "onlyForDemoPurposes"

```
@Log4j2
@Component
@Profile("onlyForDemoPurposes")
public class SeedDb implements ApplicationListener<ApplicationReadyEvent> {
    ...
}
```

SeedDb.java

- There are lots of ways to set an active profile
  - E.g. in the application.properties file

```
spring.profiles.active=onlyForDemoPurposes
```

application.properties

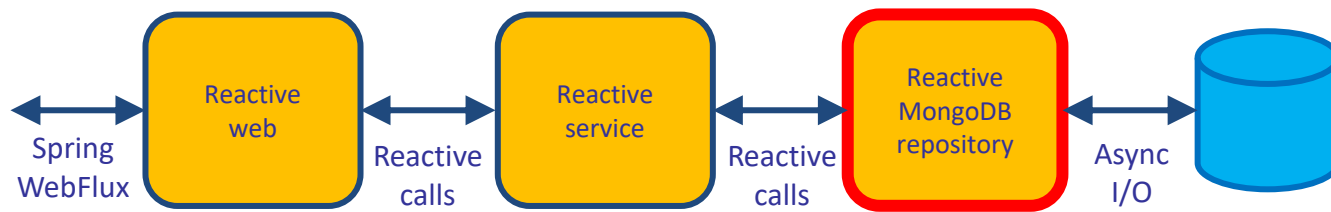
# Running the Application

- Run the Spring Boot application class
  - i.e. Application
- See the following log messages in the console

```
2020-02-06 23:02:39.884 INFO 15004 --- [main] demo.webflux.DemowebfluxApplication : Started DemowebfluxApplication in 3.882 seconds
2020-02-06 23:02:40.007 INFO 15004 --- [localhost:27017] org.mongodb.driver.connection : Opened connection [connectionId{localValue:1,
2020-02-06 23:02:40.011 INFO 15004 --- [localhost:27017] org.mongodb.driver.cluster : Monitor thread successfully connected to serve
2020-02-06 23:02:40.086 INFO 15004 --- [ntLoopGroup-2-2] org.mongodb.driver.connection : Opened connection [connectionId{localValue:3,
2020-02-06 23:02:40.238 INFO 15004 --- [ntLoopGroup-2-3] org.mongodb.driver.connection : Opened connection [connectionId{localValue:4, s
2020-02-06 23:02:40.266 INFO 15004 --- [ntLoopGroup-2-4] org.mongodb.driver.connection : Opened connection [connectionId{localValue:5, se
2020-02-06 23:02:40.376 INFO 15004 --- [ntLoopGroup-2-4] demo.webflux.SeedDb : Tx document successfully inserted: Tx{id=1fdaa86
2020-02-06 23:02:40.378 INFO 15004 --- [ntLoopGroup-2-4] demo.webflux.SeedDb : Tx document successfully inserted: Tx{id=ed7eb1
2020-02-06 23:02:40.379 INFO 15004 --- [ntLoopGroup-2-4] demo.webflux.SeedDb : Tx document successfully inserted: Tx{id=86ca87
```

# Reminder of the Big Picture

- Here's a reminder of the structure of the demo app
  - This section has shown how to implement the reactive MongoDB repository layer, to do async I/O to a MongoDB database

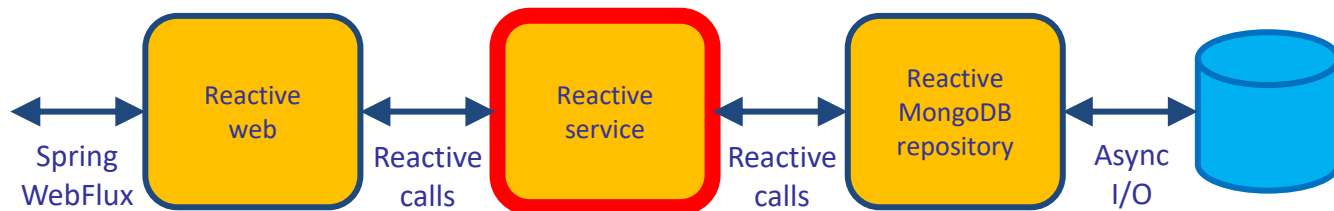


# 3. Implementing a Reactive Service Layer

- Overview
- Defining a service class
- Implementing service operations

# Overview

- In the previous section we implemented a reactive MongoDB repository
  - Performs async (non-blocking) I/O on a MongoDB database
- In this section we implement a reactive Spring service
  - A business component that consumes the reactive repository





# Defining a Service Class

- The service class is a regular Spring component, and we autowire two components:
  - `TxRepository` - to do reactive data access
  - `ApplicationEventPublisher` - to publish Spring events

```
import org.springframework.context.ApplicationEventPublisher;

@Log4j2
@Service
public class TxService {

    private final TxRepository repo;
    private final ApplicationEventPublisher pub;

    TxService(TxRepository repo, ApplicationEventPublisher pub) {
        this.repo = repo;
        this.pub = pub;
    }
    ...
}
```

`TxService.java`

# Implementing Service Operations (1 of 4)

- In our demo, the service is a skinny wrapper over the repo
  - It shows how to consume reactive repository operations
- Our service has a couple of "getter" methods
  - `getAll()` returns many items reactively, i.e. a `Flux<Tx>`
  - `findById()` returns one item reactively, i.e. a `Mono<Tx>`

```
public class TxService {  
  
    public Flux<Tx> getAll() {  
        return repo.findAll();  
    }  
  
    public Mono<Tx> findById(String id) {  
        return repo.findById(id);  
    }  
  
    ...  
}
```

`TxService.java`

# Implementing Service Operations (2 of 4)

- Our service has a method to create a financial transaction
  - Calls repository's `save ()` method, which returns `Mono<Tx>`
  - `Mono` and `Flux` have many hook methods, e.g. `doOnSuccess ()`
  - `doOnSuccess ()` takes a `Consumer<Tx>` to process the result

```
public Mono<Tx> create(double amount) {  
    checkAmount(amount);  
    return repo.save(new Tx(null, amount, LocalDateTime.now()))  
        .doOnSuccess(tx -> pub.publishEvent(new TxCreatedEvent(tx)));  
}
```

- Our service also publishes an event if the tx value is high

```
private void checkAmount(double amount) {  
    if (amount > 1_000_000) {  
        pub.publishEvent(new TxHighValueEvent(amount));  
    }  
}
```

`TxService.java`

# Implementing Service Operations (3 of 4)

- Our service has a method to update a financial transaction
  - Calls repository's `findById()` method, returns a `Mono<T>`
  - We call `map()` on the `Mono<Tx>` to update it locally
  - Then we call `flatMap()` to save it to the database reactively

```
public Mono<Tx> update(String id, double amount, LocalDateTime when) {  
    checkAmount(amount);  
    return repo.findById(id)  
        .map(t -> new Tx(t.getId(), amount, when))  
        .flatMap(t -> repo.save(t).thenReturn(t));  
}
```

`TxService.java`

- Use `map()` for sync operation, returns result immediately
  - `map( Function<T, R> )`
- Use `flatMap()` for async operation, returns a publisher
  - `flatMap( Function<T, Publisher<R>> )`

# Implementing Service Operations (4 of 4)

- Our service has a method to delete a financial transaction
  - Similar idea to previous slide
  - What does it return?

```
public Mono<Tx> delete(String id) {  
    return repo.findById(id)  
        .flatMap(t -> repo.deleteById(t.getId()).thenReturn(t));  
}
```

`TxService.java`

## 4. Testing the Reactive Service Layer

- Overview
- Test dependencies
- Defining a test class
- Autowiring dependencies into the test class
- How to define reactive tests
- Defining reactive tests
- Exercise

# Overview

- In this section we'll see how to test the functions in our reactive service class
- The service methods are reactive
  - i.e. they return publishers (Mono or Flux)
  - So we need a way to test results asynchronously
- Project Reactor provides a test API that allows us to test reactive publishers
  - We can subscribe to a publisher and specify expectations about the results it will publish

# Test Dependencies

- Here's a reminder of the test dependencies in the pom file
  - JUnit 5
  - Project Reactor tests

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-test</artifactId>
  <scope>test</scope>
</dependency>

<dependency>
  <groupId>io.projectreactor</groupId>
  <artifactId>reactor-test</artifactId>
  <scope>test</scope>
</dependency>
```

pom.xml



# Defining a Test Class

- Here's a test class for our reactive service

```
@Log4j2
@DataMongoTest
@Import(TxService.class)
public class TxServiceModificationsTest {
    ...
}
```

`TxServiceModificationsTest.java`

- @DataMongoTest and @Import create a *test slice*
  - They add components into the application context
- Specifically...
  - @DataMongoTest adds MongoDB-related components
  - @Import adds a TxService component

# Autowiring Dependencies into the Test Class

- You can autowire dependencies into the test class

```
@Log4j2
@DataMongoTest
@Import(TxService.class)
public class TxServiceModificationsTest {

    private final TxService service;
    private final TxRepository repo;

    public TxServiceModificationsTest(@Autowired TxService service,
                                      @Autowired TxRepository repo) {
        this.service = service;
        this.repo = repo;
    }
    ...
}
```

TxServiceModificationsTest.java

# How to Define Reactive Tests

- To define a reactive test:
  - Invoke a reactive method-under-test (i.e. it returns a publisher)
  - Then use `StepVerifier` to verify it publishes expected results
- Here's the general way to use a `StepVerifier`:
  - Call `StepVerifier.create()` to set up a `StepVerifier`
  - Call `expectXxx()` to specify what you expect to be published
  - Call `verifyXxx()` to trigger the expected results were published

```
Publisher<XXX> resultPublisher = someReactiveMethod();

StepVerifier.create(resultPublisher)
    .expectNext(next-expected-published-result)
    .expectNextMatches(predicate-to-test-next-published-result)
    .expectNextCount(expected-number-of-published-items)
    .verifyComplete();
```

*general syntax*

# Defining Reactive Tests (1 of 3)

- Here's a reactive test for the service `create()` method

```
@Test
public void createTx_returnsCreatedTxWithId() {

    Mono<Tx> createdTx = service.create(1234);

    StepVerifier
        .create(createdTx)
        .expectNextMatches(tx -> tx.getId() != null && tx.getId().length() != 0)
        .verifyComplete();
}
```

`TxServiceModificationsTest.java`

# Defining Reactive Tests (2 of 3)

- Here's a reactive test for the service `update()` method

```
@Test
public void updateTx_txUpdated() {

    Mono<Tx> updatedTx = service.create(4321)
        .flatMap(tx -> service.update(tx.getId(),
                                     8888,
                                     LocalDateTime.now()));

    StepVerifier
        .create(updatedTx)
        .expectNextMatches(tx -> tx.getAmount() == 8888)
        .verifyComplete();
}
```

`TxServiceModificationsTest.java`

# Defining Reactive Tests (3 of 3)

- Here's a reactive test for the service `delete()` method

```
@Test
public void deleteTx_txDeleted() {

    Mono<Tx> deletedTx = service.create(5678)
                           .flatMap(tx -> service.delete(tx.getId()));

    StepVerifier
        .create(deletedTx)
        .expectNextMatches(tx -> tx.getAmount() == 5678)
        .verifyComplete();
}
```

`TxServiceModificationsTest.java`

# Exercise

- Take a look at the test in here:
  - `TxServiceQueryTest.java`
- What does it do?

A large, light gray play button icon is positioned on the left side of the slide. It consists of a white right-pointing triangle centered within a series of concentric circles in varying shades of gray.

# Summary

- Project Reactor and Spring WebFlux
- Implementing a reactive data layer
- Implementing a reactive service layer
- Testing the reactive service layer

