Pivotal

Reactive Spring Application

Introducing Reactive Programming

Objectives

After completing this lesson, you should be able to

- Describe the basic concepts of Reactive Programming
- Write a “reactive” Spring application

Agenda

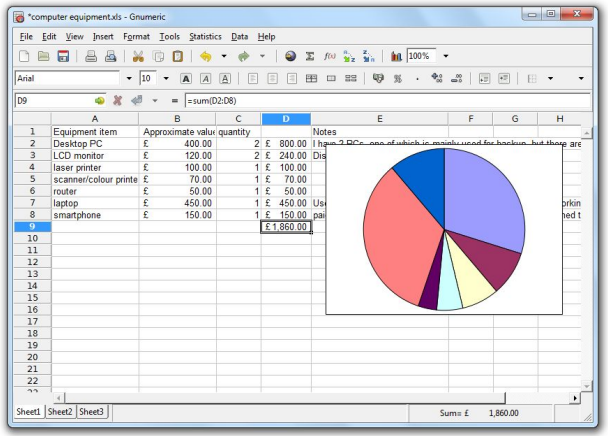
- **What is Reactive Programming?**
- Reactive Features
- Reactive Stream Implementations
- Reactive Spring Features
- Lab

What is Reactive Programming?

- Programming with *asynchronous* data streams
  - Everything (almost) can be seen as a stream
    - Messages, variables, user input, data structures, ...
  - **Stream:** Ongoing events ordered in time
    - Series of user clicks through our web app
    - Calls to a web server over time
    - Separate values returned from a function
    - Rows returned from a DB query
  - **Event:** (almost) anything
    - User clicks, calls to a web server, function returning a result, row returned from a DB query

Familiar Example 1: Spreadsheets

- Spreadsheets
  - Formula cells in a spreadsheet automatically “react” to changes in the cells used by the formula
  - Spreadsheet recalculates whenever such cells are modified



Familiar Example 2: User Interfaces

- Implementing a GUI
  - Must respond to mouse/keyboard events
  - Setup *Listeners*
  - Respond to events by running handlers *asynchronously*

- JavaScript (AJAX, SPA) web-pages
  - Make a REST request to back-end server
  - Define a *call-back* for when data is returned
  - Call-back invoked *asynchronously*

Why Reactive?

projectreactor.io

- New applications and environments
  - Distributed multi-process applications
    - Cloud, PaaS, Microservices
- Challenges
  - Latency inevitable
  - Redundancy and recovery
  - Scale out, not up
- Imperative (traditional) logic becomes *very* complicated
  - Too many nested callbacks

Reactive Programming Examples

- Reactive is good for
  - Time series processing without storing state
  - Non-blocking processing - threads do not need to wait for calls to complete
  - Speed / Throughput - Far more efficient use of threads and memory
  - Building complex event-driven systems without “callback-hell”
- It is not appropriate or necessary for all applications
  - Considerable learning-curve

Agenda

- What is Reactive Programming?
- **Reactive Features**
- Reactive Stream Implementations
- Reactive Spring Features
- Lab
- Optional/Advanced ...

Reactive Programming

- Non-blocking applications
  - Asynchronous, event-driven
  - Scale using a *minimal* number of threads
  - Flow control (*backpressure*)
  - Stream processing
- Implications
  - Major shift from *imperative* style logic to a *declarative pipeline* of asynchronous logic
  - Intelligent routing and consumption of events
  - Comparable to **`CompletableFuture`** in Java 8 and composing follow-up actions via lambda expressions

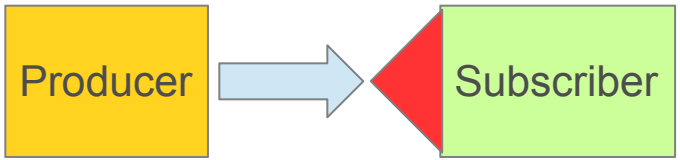
Asynchronous Components

- Similar to messaging systems
  - Independent components (tasks)
    - Respond to incoming events
    - Pass on results by generating events
  - *But components do not get their own thread*
    - Thread selects and runs components that are ready
    - Then switches to next ready-to-run component
    - Switching components *much* cheaper than thread-switching
- Analogous concepts
  - Actors, Coroutines, C.S.P.

CSP = Communicating Sequential Processes

Back-Pressure

- Controls data flow through the reactive pipeline
  - Ensures producers don't overwhelm subscribers (consumers)
  - *Options:* Ignore excess events or block until ready
- *Example*
  - Pipeline of reactive components from the HTTP socket to database
    - Too many HTTP requests, data repository slows down or stops until capacity frees up



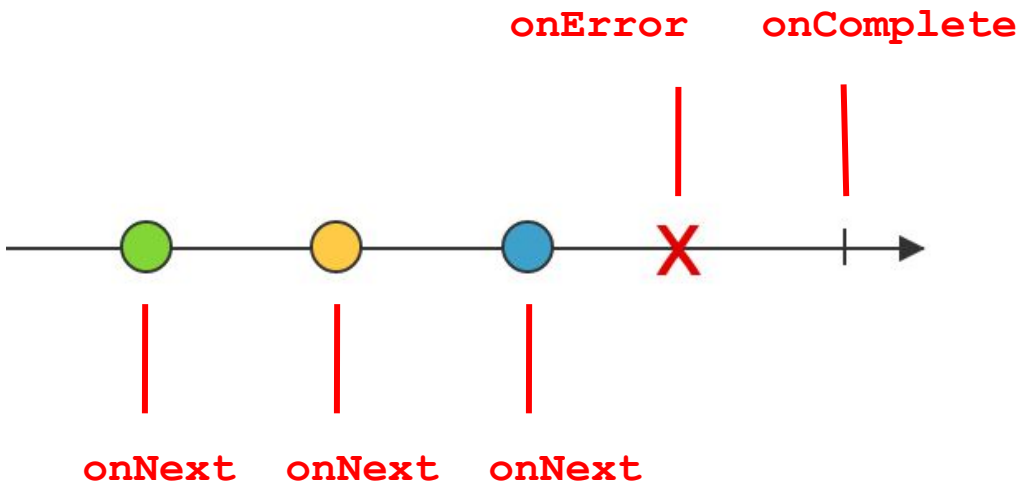
Back Pressure

Agenda

- What is Reactive Programming?
- Reactive Features
- **Reactive Stream Implementations**
- Reactive Spring Features
- Lab
- Optional/Advanced ...

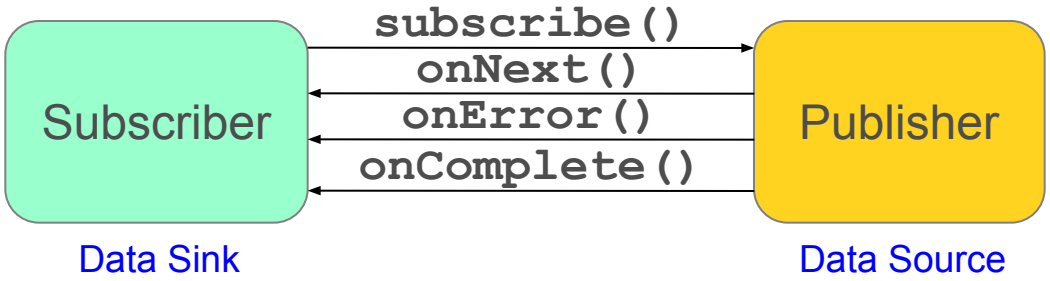
Handle Stream of Events Asynchronously

- Reactive Streams
  - Specification of *Interfaces*
  - Needs an implementation



Reactive Streams

- Require a publisher and a subscriber
  - Like messaging
- Publisher provides data & specifies how to process it
  - Produces a “stream” of 0, 1 or more data items
- Subscriber actually processes the events in the stream
  - *Nothing happens without a subscriber*



Reactive Stream Implementations

- Flow classes
  - Part of Java 9 JDK
- Project Reactor from Pivotal
  - Supported by Spring 5
    - http://projectreactor.io
- RxJava
  - Rx has several implementations

- Spring supports Reactor and RxJava
  - *Doesn't require Java 9*

Stream Types

- A sequence of zero or more events
  - *Reactor* calls this *Flux*
  - *RxJava* calls this *Observable*

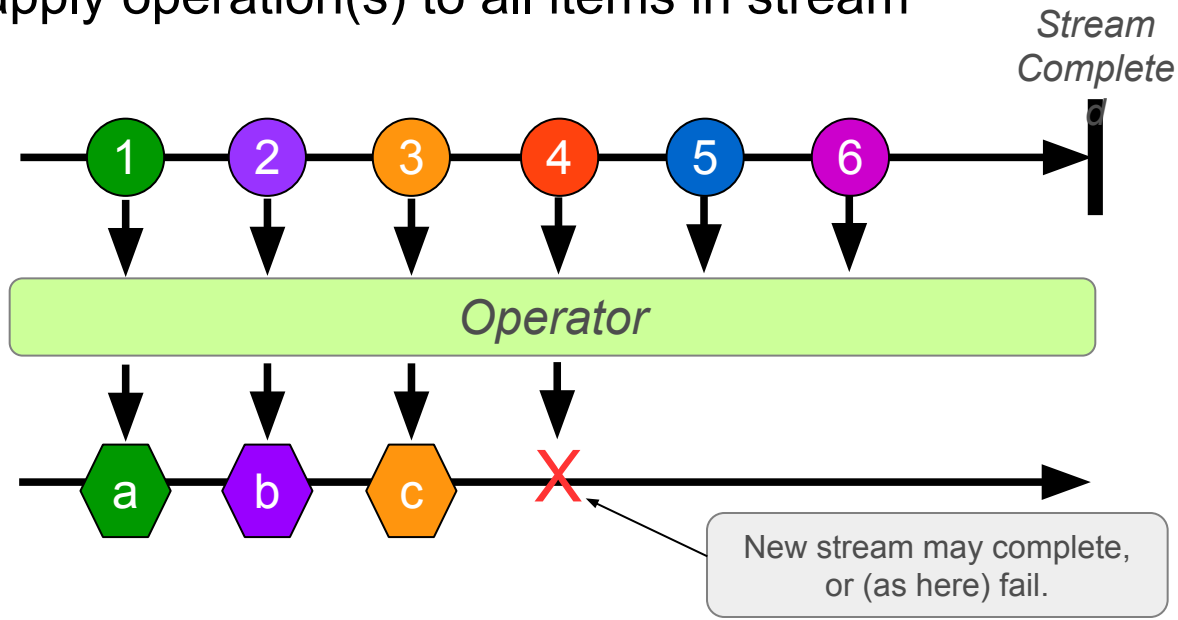
- Common special case
  - Stream of 0 or 1 events
    - *Reactor* calls this *Mono*
    - *RxJava* calls this *Single*

- *All are publishers of events*

Flux: Sequence of [0 .. N]

Flux, Observable *are* Publishers

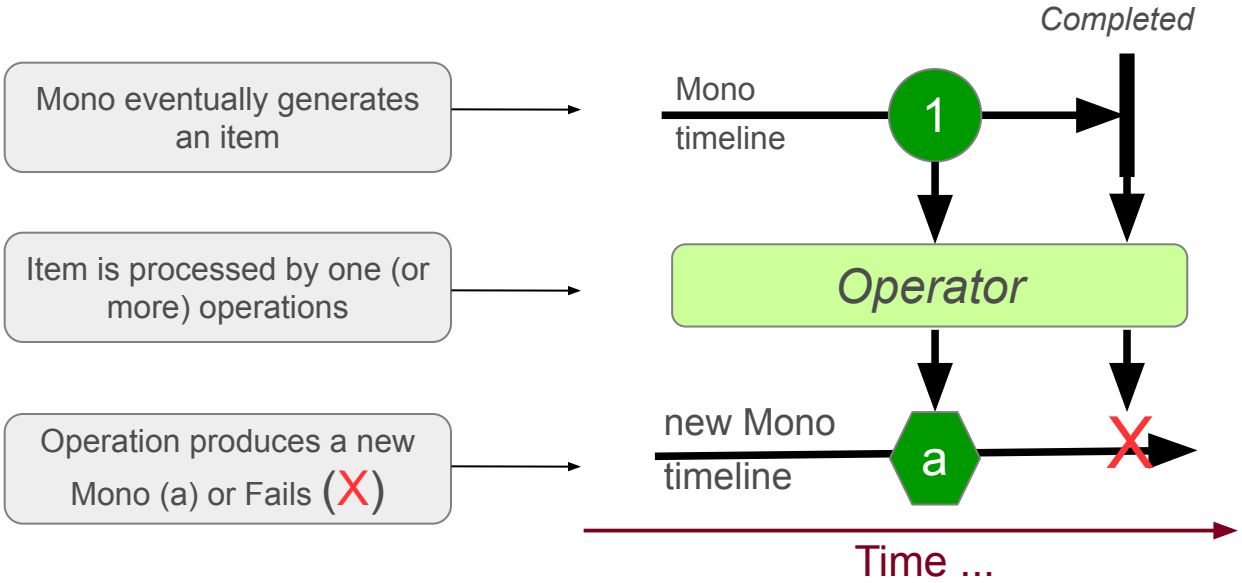
- Return continuous stream of events with failure handling
  - *Flux* (Reactor) or *Observable* (RxJava)
  - Can apply operation(s) to all items in stream



Mono: Sequence of [0 .. 1]

Mono and Single *are* Publishers

- Used to return a single result (or fail doing so)
  - *Mono* (Reactor) or *Single* (RxJava)



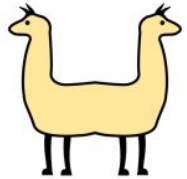
Subscribing to a Stream

Reactor Syntax

- Two options
  - Implement a **`Subscriber<T>`**
    - **`onSubscribe`**, **`onNext`**, **`onError`**, **`onComplete`**
  - Provide a **`Consumer`**
    - Has a single **`accept(T)`** – equivalent to **`onNext`**
      - Can pass a lambda

```
Flux.just( "red", "green", "blue" )  // The producer
      .log()                                  // Stream operator: log item
      .map(String::toUpperCase)       // Stream operator: convert to upper case
      .subscribe(System.out::println);      // Subscribe, Consumer prints each item
```

Java Streams are *not* Reactive



pushmi-pullyu

- Java Streams
  - Subscriber actively *pulls* in data, blocks if not available

```
List<Shop> shops = customer.getVendors();
List<BigDecimal> discountedPrices =
    shops.stream()  // Fetches data from list
        .map(Shop::getPrice)
        .map(Discount::applyDiscount)
        .collect(Collectors.toList());
```

- Reactive Streams
  - Data is sent (pushed) to subscriber via *callbacks*
  - By “pushing-back” we get back-pressure

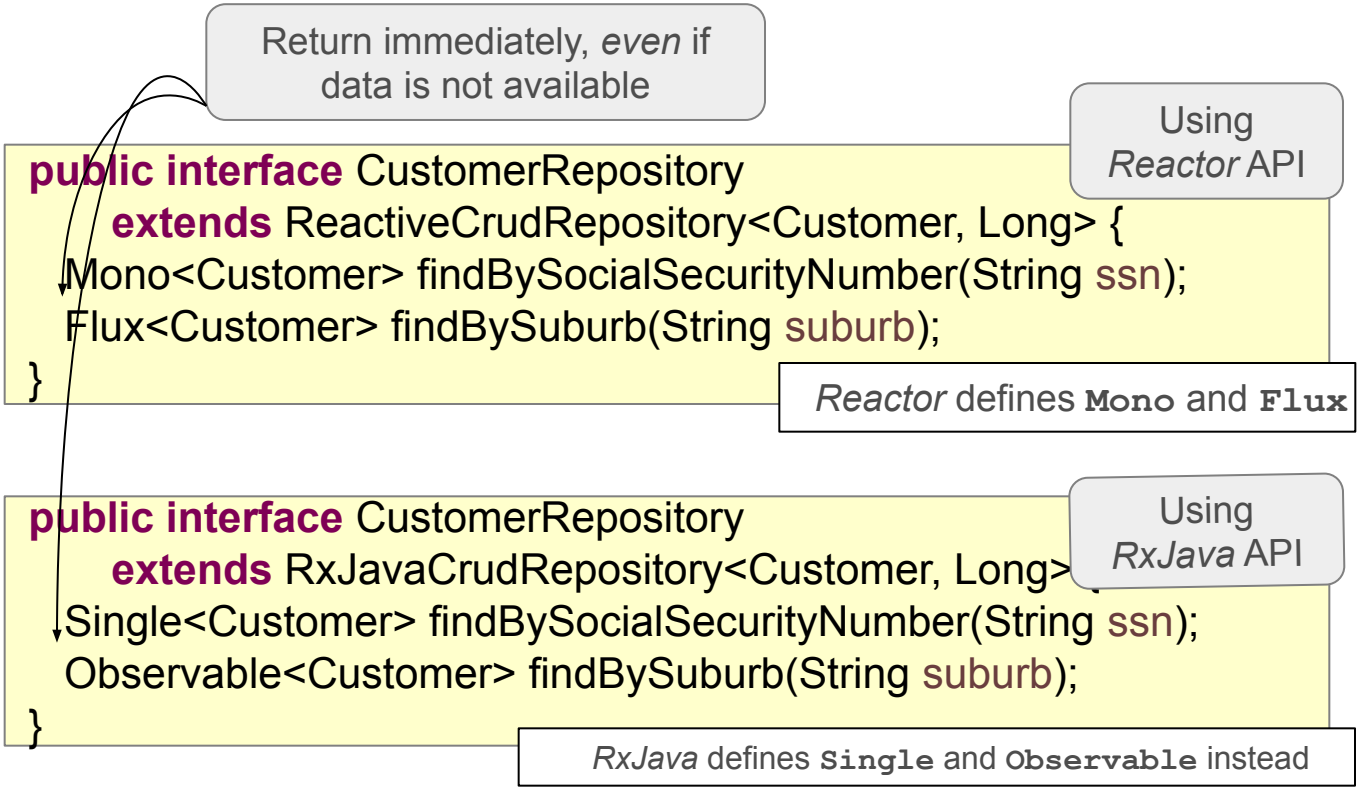
Agenda

- What is Reactive Programming?
- Reactive Features
- Reactive Stream Implementations
- **Reactive Spring Features**
- Lab
- Optional/Advanced ...

Reactive Features in Spring

- Spring Data Reactive Repositories
  - Returns query results as a Stream
- Web Client
  - Reactive alternative to **`RestTemplate`**
- **`WebFlux`**
  - Reactive **`@Controllers`**

Reactive Spring Data Repository



WebClient – 1

The Mono is processed in the *same* thread

- Asynchronous alternative to RestTemplate
  - HTTP response is handled by *different* thread to HTTP request

```
WebClient client = WebClient.create(ACCOUNT_SERVER_URL);
Mono<Account> result = client.get()
    .uri("/accounts/{id}", id)
    .accept(MediaType.APPLICATION_JSON)
    .retrieve()     // Send request
    .bodyToMono(Account.class);

Account account = result.block();       // Wait for account to be returned
```

HTTP GET for account **{id}**

Response (a Mono) so block until available

WebClient – Processing Alternative 1

Mono or Flux is processed in a *different* thread

- Alternative ways of processing the Mono (or Flux)
  - Note you *must* **`subscribe()`** to do *anything*

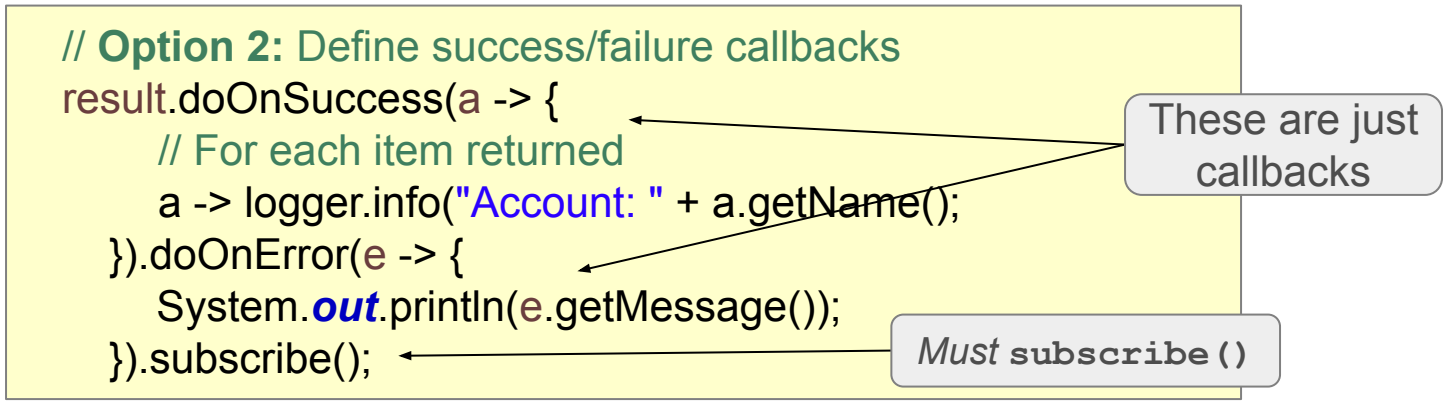
Pass lambda to **`subscribe()`**

```
// Option 1: Subscribe using  lambda
result.subscribe(a -> {
   // For each item returned, log it
   logger.info("Account: " + a.getName()
});
```

WebClient – Processing Alternative 2

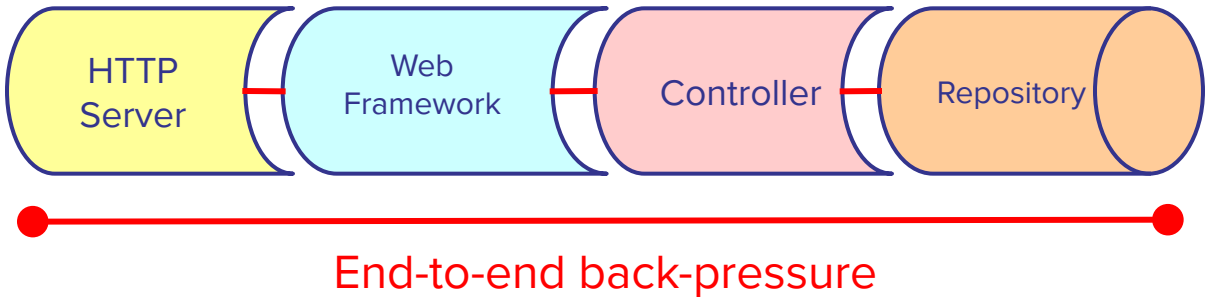
- Provide success & error callback processing
  - Note you still *must* **`subscribe()`** to do *anything*

```
// Option 2: Define success/failure callbacks
result.doOnSuccess(a -> {
        // For each item returned
        a -> logger.info("Account: " + a.getName();
    }).doOnError(e -> {
        System.out.println(e.getMessage());
    }).subscribe();
```



Spring WebFlux

- Consider incoming HTTP Requests as a stream
  - Process in usual way
  - Controllers return Reactive Streams
- A *Reactive Web Pipeline*



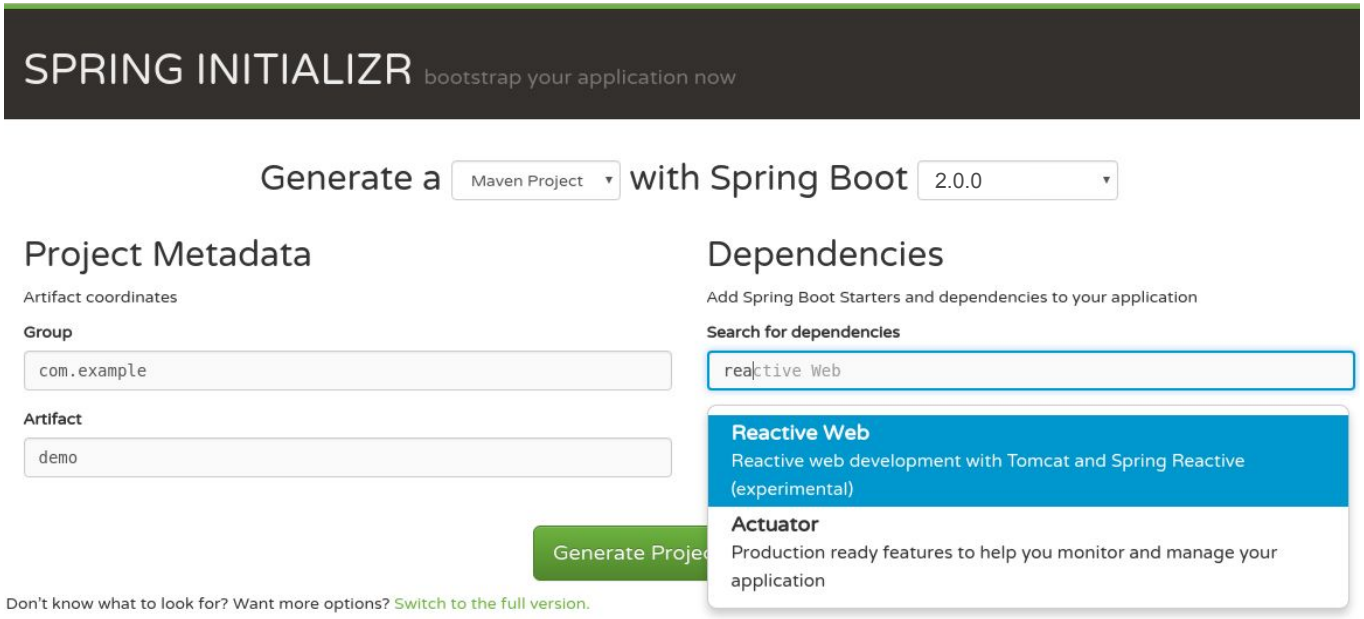
Reactive Web Controller

Using *Reactor* API

```
@Controller
public class CustomerController {
    private final CustomerRepository customerRepository;   // Reactive repository

    @Autowired
    public CustomerController (CustomerRepository customerRepository) {
        this.customerRepository = customerRepository;
    }

    @GetMapping("/customers/{id}")
    public Mono<Customer> getCustomer(@PathVariable Long id) {
        return customerRepository.findById(id);    // Or return Single<Customer>
    }

    @GetMapping("/customers")
    public Flux<Customer> getCustomer() {      // Or return Observable<Customer>
        return customerRepository.findAll();
    }
```

Getting Started

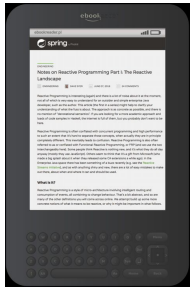
- Support in Spring Boot 2.0 and Spring Initializr



References

- Reactive Programming
  - Spring Blog article by Dave Syer
    - Part 1Part 1, Part 2Part 1, Part 2, Part 3
  - An Introduction to Reactive by André Staltz
  - Project Reactor documentation

- WebFlux
  - Article by Rossen Stoynchev (Spring MVC lead)
  - WebFlux in Spring reference documentation

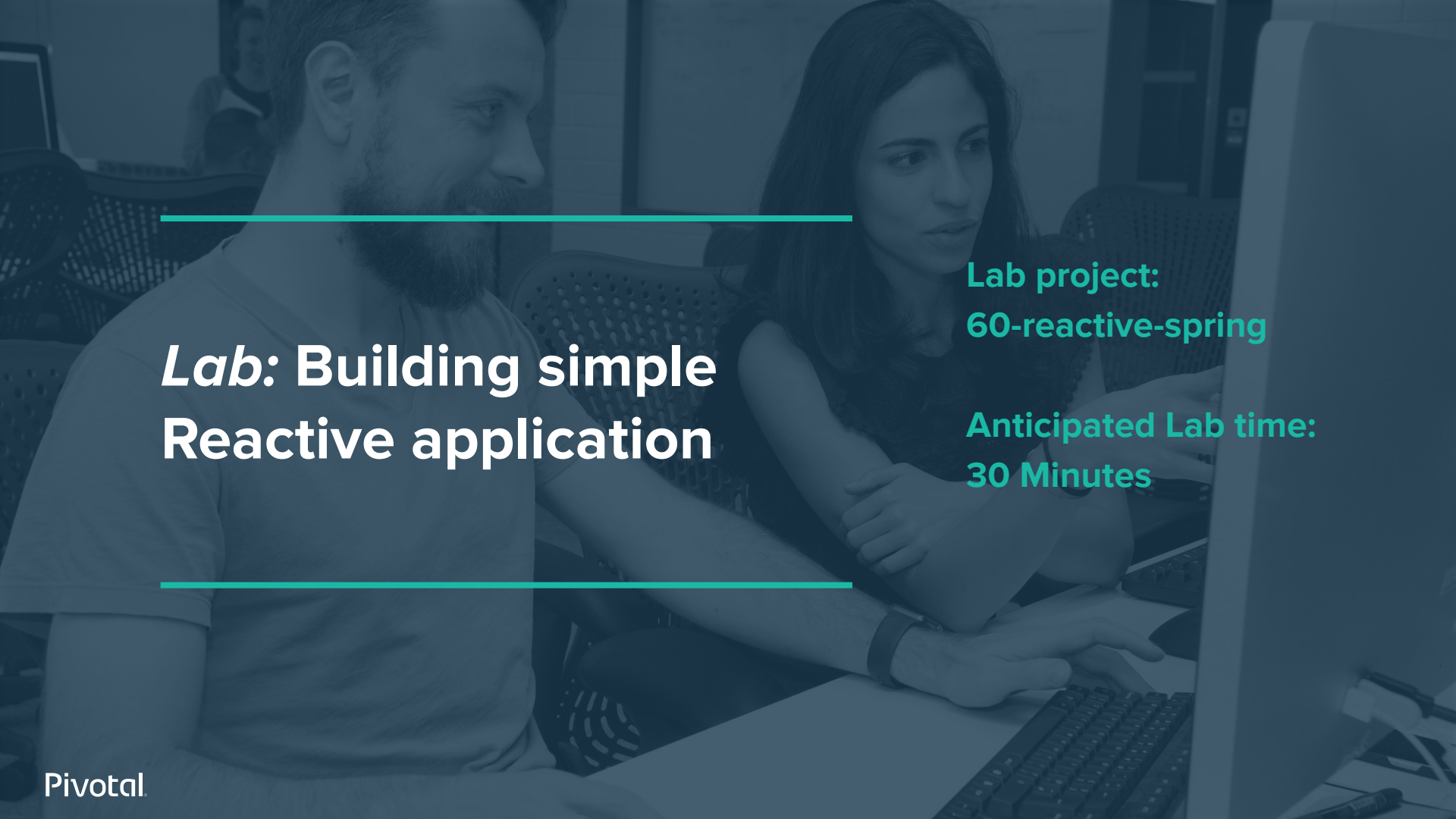


Summary

- What is Reactive Programming?
  - What are
    - Mono, Flux, Single, Observable?
- How does Spring incorporate Reactive Features?
  - Reactive Repositories
  - Web Client
  - Web Flux

projectreactor.io

RxJava



Lab: Building simple Reactive application

Lab project:
60-reactive-spring

Anticipated Lab time:
30 Minutes

Spring 5 – Web Stack