# Web on Reactive Stack

Version 5.0.10.RELEASE

# Table of Contents

This part of the documentation covers support for reactive stack, web applications built on a Reactive Streams API to run on non-blocking servers such as Netty, Undertow, and Servlet 3.1+ containers. Individual chapters cover the Spring WebFlux framework, the reactive WebClient, support for Testing, and Reactive Libraries. For Servlet stack, web applications, please see Web on Servlet Stack.

# Chapter 1. Spring WebFlux

## 1.1. Introduction

The original web framework included in the Spring Framework, Spring Web MVC, was purpose built for the Servlet API and Servlet containers. The reactive stack, web framework, Spring WebFlux, was added later in version 5.0. It is fully non-blocking, supports Reactive Streams back pressure, and runs on servers such as Netty, Undertow, and Servlet 3.1+ containers.

Both web frameworks mirror the names of their source modules spring-webmvc and spring-webflux and co-exist side by side in the Spring Framework. Each module is optional. Applications may use one or the other module, or in some cases both — e.g. Spring MVC controllers with the reactive `WebClient`.

### 1.1.1. Motivation

Why was Spring WebFlux created?

Part of the answer is the need for a non-blocking web stack to handle concurrency with a small number of threads and scale with less hardware resources. Servlet 3.1 did provide an API for non-blocking I/O. However, using it leads away from the rest of the Servlet API where contracts are synchronous (`Filter`, `Servlet`) or blocking (`getParameter`, `getPart`). This was the motivation for a new common API to serve as a foundation across any non-blocking runtime. That is important because of servers such as Netty that are well established in the async, non-blocking space.

The other part of the answer is functional programming. Much like the addition of annotations in Java 5 created opportunities — e.g. annotated REST controllers or unit tests, the addition of lambda expressions in Java 8 created opportunities for functional APIs in Java. This is a boon for non-blocking applications and continuation style APIs — as popularized by `CompletableFuture` and ReactiveX, that allow declarative composition of asynchronous logic. At the programming model level Java 8 enabled Spring WebFlux to offer functional web endpoints alongside with annotated controllers.

### 1.1.2. Define "reactive"

We touched on non-blocking and functional but what does reactive mean?

The term "reactive" refers to programming models that are built around reacting to change — network component reacting to I/O events, UI controller reacting to mouse events, etc. In that sense non-blocking is reactive because instead of being blocked we are now in the mode of reacting to notifications as operations complete or data becomes available.

There is also another important mechanism that we on the Spring team associate with "reactive" and that is non-blocking back pressure. In synchronous, imperative code, blocking calls serve as a natural form of back pressure that forces the caller to wait. In non-blocking code it becomes important to control the rate of events so that a fast producer does not overwhelm its destination.

Reactive Streams is a small spec, also adopted in Java 9, that defines the interaction between

asynchronous components with back pressure. For example a data repository — acting as Publisher, can produce data that an HTTP server — acting as Subscriber, can then write to the response. The main purpose of Reactive Streams is to allow the subscriber to control how fast or how slow the publisher will produce data.

**Common question: what if a publisher can't slow down?**
The purpose of Reactive Streams is only to establish the mechanism and a boundary. If a publisher can't slow down then it has to decide whether to buffer, drop, or fail.

### 1.1.3. Reactive API

Reactive Streams plays an important role for interoperability. It is of interest to libraries and infrastructure components but less useful as an application API because it is too low level. What applications need is a higher level and richer, functional API to compose async logic — similar to the Java 8 `Stream` API but not only for collections. This is the role that reactive libraries play.

Reactor is the reactive library of choice for Spring WebFlux. It provides the Mono and Flux API types to work on data sequences of 0..1 and 0..N through a rich set of operators aligned with the ReactiveX vocabulary of operators. Reactor is a Reactive Streams library and therefore all of its operators support non-blocking back pressure. Reactor has a strong focus on server-side Java. It is developed in close collaboration with Spring.

WebFlux requires Reactor as a core dependency but it is interoperable with other reactive libraries via Reactive Streams. As a general rule WebFlux APIs accept a plain `Publisher` as input, adapt it to Reactor types internally, use those, and then return either `Flux` or `Mono` as output. So you can pass any `Publisher` as input and you can apply operations on the output, but you'll need to adapt the output for use with another reactive library. Whenever feasible — e.g. annotated controllers, WebFlux adapts transparently to the use of RxJava or other reactive library. See Reactive Libraries for more details.

### 1.1.4. Programming models

The `spring-web` module contains the reactive foundation that underlies Spring WebFlux including HTTP abstractions, Reactive Streams adapters for supported servers, codecs, and a core WebHandler API comparable to the Servlet API but with non-blocking contracts.

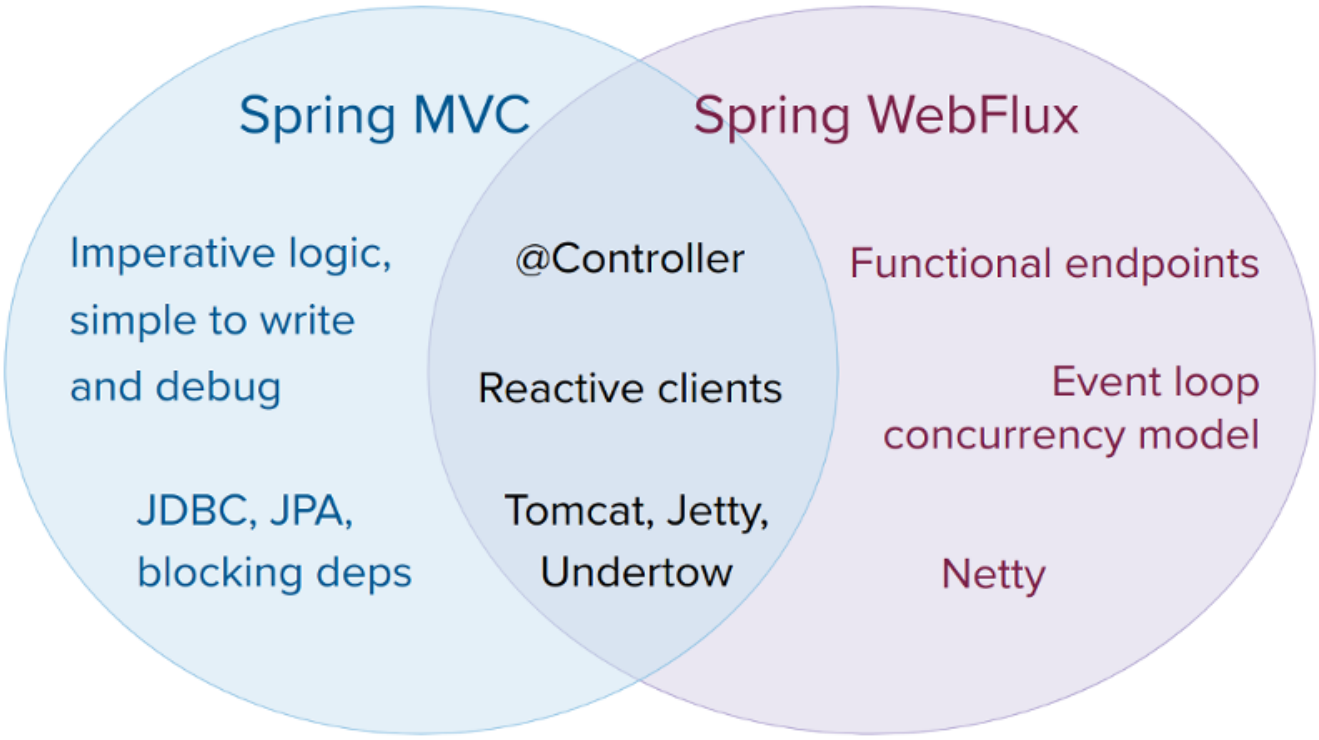
On that foundation Spring WebFlux provides a choice of two programming models:

- Annotated Controllers — consistent with Spring MVC, and based on the same annotations from the `spring-web` module. Both Spring MVC and WebFlux controllers support reactive (Reactor, RxJava) return types and as a result it is not easy to tell them apart. One notable difference is that WebFlux also supports reactive `@RequestBody` arguments.
- Functional Endpoints — lambda-based, lightweight, functional programming model. Think of this as a small library or a set of utilities that an application can use to route and handle requests. The big difference with annotated controllers is that the application is in charge of request handling from start to finish vs declaring intent through annotations and being called back.

### 1.1.5. Applicability

Spring MVC or WebFlux?

A natural question to ask but one that sets up an unsound dichotomy. It's actually both working together to expand the range of available options. The two are designed for continuity and consistency with each other, they are available side by side, and feedback from each side benefits both sides. The diagram below shows how the two relate, what they have in common, and what each supports uniquely:




Below are some specific points to consider:

- If you have a Spring MVC application that works fine, there is no need to change. Imperative programming is the easiest way to write, understand, and debug code. You have maximum choice of libraries since historically most are blocking.
- If you are already shopping for a non-blocking web stack, Spring WebFlux offers the same execution model benefits as others in this space and also provides a choice of servers — Netty, Tomcat, Jetty, Undertow, Servlet 3.1+ containers, a choice of programming models — annotated controllers and functional web endpoints, and a choice of reactive libraries — Reactor, RxJava, or other.
- If you are interested in a lightweight, functional web framework for use with Java 8 lambdas or Kotlin then use the Spring WebFlux functional web endpoints. That can also be a good choice for smaller applications or microservices with less complex requirements that can benefit from greater transparency and control.
- In a microservice architecture you can have a mix of applications with either Spring MVC or Spring WebFlux controllers, or with Spring WebFlux functional endpoints. Having support for the same annotation-based programming model in both frameworks makes it easier to re-use knowledge while also selecting the right tool for the right job.
- A simple way to evaluate an application is to check its dependencies. If you have blocking

persistence APIs (JPA, JDBC), or networking APIs to use, then Spring MVC is the best choice for common architectures at least. It is technically feasible with both Reactor and RxJava to perform blocking calls on a separate thread but you wouldn't be making the most of a non-blocking web stack.

- If you have a Spring MVC application with calls to remote services, try the reactive `WebClient`. You can return reactive types (Reactor, RxJava, or other) directly from Spring MVC controller methods. The greater the latency per call, or the interdependency among calls, the more dramatic the benefits. Spring MVC controllers can call other reactive components too.
- If you have a large team, keep in mind the steep learning curve in the shift to non-blocking, functional, and declarative programming. A practical way to start without a full switch is to use the reactive `WebClient`. Beyond that start small and measure the benefits. We expect that for a wide range of applications the shift is unnecessary. If you are unsure what benefits to look for, start by learning about how non-blocking I/O works (e.g. concurrency on single-threaded Node.js) and its effects.

### 1.1.6. Servers

Spring WebFlux is supported on Tomcat, Jetty, Servlet 3.1+ containers, as well as on non-Servlet runtimes such as Netty and Undertow. All servers are adapted to a low-level, common API so that higher level programming models can be supported across servers.

Spring WebFlux does not have built-in support to start or stop a server. However it is easy to assemble an application from Spring configuration, and WebFlux infrastructure, and run it with a few lines of code.

Spring Boot has a WebFlux starter that automates these steps. By default the starter uses Netty but it is easy to switch to Tomcat, Jetty, or Undertow simply by changing your Maven or Gradle dependencies. Spring Boot defaults to Netty because it is more widely used in the async, non-blocking space, and provides a client and a server share resources.

Tomcat and Jetty can be used with both Spring MVC and WebFlux. Keep in mind however that the way they're used is very different. Spring MVC relies on Servlet blocking I/O and allows applications to use the Servlet API directly if they need to. Spring WebFlux relies on Servlet 3.1 non-blocking I/O and uses the Servlet API behind a low-level adapter and not exposed for direct use.

For Undertow, Spring WebFlux uses Undertow APIs directly without the Servlet API.

### 1.1.7. Performance vs scale

Performance has many characteristics and meanings. Reactive and non-blocking generally do not make applications run faster. They can, in some cases, for example if using the `WebClient` to execute remote calls in parallel. On the whole it requires more work to do things the non-blocking way and that can increase slightly the required processing time.

The key expected benefit of reactive and non-blocking is the ability to scale with a small, fixed number of threads and less memory. That makes applications more resilient under load because they scale in a more predictable way. In order to observe those benefits however you need to have some latency including a mix of slow and unpredictable network I/O. That's where the reactive

stack begins to show its strengths and the differences can be dramatic.

### 1.1.8. Concurrency Model

Both Spring MVC and Spring WebFlux support annotated controllers, but there is a key difference in the concurrency model and default assumptions for blocking and threads.

In Spring MVC, and servlet applications in general, it is assumed that applications *may block* the current thread, e.g. for remote calls, and for this reason servlet containers use a large thread pool, to absorb potential blocking during request handling.

In Spring WebFlux, and non-blocking servers in general, it is assumed that applications *will not block*, and therefore non-blocking servers use a small, fixed-size thread pool (event loop workers) to handle requests.

To "scale" and "small number of threads" may sound contradictory but to never block the current thread, and rely on callbacks instead, means you don't need extra threads as there are no blocking calls to absorb.

*Invoking a Blocking API*

What if you do need to use a blocking library? Both Reactor and RxJava provide the `publishOn` operator to continue processing on a different thread. That means there is an easy escape latch. Keep in mind however that blocking APIs are not a good fit for this concurrency model.

*Mutable State*

In Reactor and RxJava, logic is declared through operators, and at runtime, a reactive pipeline is formed where data is processed sequentially, in distinct stages. A key benefit of that is that it frees applications from having to protect mutable state because application code within that pipeline is never invoked concurrently.

*Threading Model*

What threads should you expect to see on a server running with Spring WebFlux?

- On a "vanilla" Spring WebFlux server (e.g. no data access, nor other optional dependencies), you can expect one thread for the server, and several others for request processing (typically as many as the number of CPU cores). Servlet containers, however, may start with more threads (e.g. 10 on Tomcat), in support of both servlet, blocking I/O and servlet 3.1, non-blocking I/O usage.
- The reactive `WebClient` operates in event loop style. So you'll see a small, fixed number of processing threads related to that, e.g. "reactor-http-nio-" with the Reactor Netty connector. However if Reactor Netty is used for both client and server, the two will share event loop resources by default.
- Reactor and RxJava provide thread pool abstractions, called Schedulers, to use with the `publishOn` operator that is used to switch processing to a different thread pool. The schedulers have names that suggest a specific concurrency strategy, e.g. "parallel" for CPU-bound work with a limited number of threads, or "elastic" for I/O-bound work with a large number of

threads. If you see such threads it means some code is using a specific thread pool `Scheduler` strategy.

- Data access libraries and other 3rd party dependencies may also create and use threads of their own.

*Configuring*

The Spring Framework does not provide support for starting and stopping servers. To configure the threading model for a server, you'll need to use server-specific config APIs, or if using Spring Boot, check the Spring Boot configuration options for each server. The WebClient can be configured directly. For all other libraries, refer to their respective documentation.

# 1.2. Reactive Core

The `spring-web` module contains abstractions and infrastructure to build reactive web applications. For server side processing this is organized in two distinct levels:

- HttpHandler — basic, common API for HTTP request handling with non-blocking I/O and (Reactive Streams) back pressure, along with adapters for each supported server.
- WebHandler API — slightly higher level, but still general purpose API for server request handling, which underlies higher level programming models such as annotated controllers and functional endpoints.

The reactive core also includes Codecs for client and server side use.

## 1.2.1. HttpHandler

HttpHandler is a simple contract with a single method to handle a request and response. It is intentionally minimal as its main purpose is to provide an abstraction over different server APIs for HTTP request handling.

Supported server APIs:

| Server name | Server API used | Reactive Streams support |
|---|---|---|
| Netty | Netty API | Reactor Netty |
| Undertow | Undertow API | spring-web: Undertow to Reactive Streams bridge |
| Tomcat | Servlet 3.1 non-blocking I/O; Tomcat API to read and write ByteBuffers vs byte[] | spring-web: Servlet 3.1 non-blocking I/O to Reactive Streams bridge |
| Jetty | Servlet 3.1 non-blocking I/O; Jetty API to write ByteBuffers vs byte[] | spring-web: Servlet 3.1 non-blocking I/O to Reactive Streams bridge |
| Servlet 3.1 container | Servlet 3.1 non-blocking I/O | spring-web: Servlet 3.1 non-blocking I/O to Reactive Streams bridge |

Server dependencies (and supported versions):

| Server name | Group id | Artifact name |
|---|---|---|
| Reactor Netty | io.projectreactor.ipc | reactor-netty |
| Undertow | io.undertow | undertow-core |
| Tomcat | org.apache.tomcat.embed | tomcat-embed-core |
| Jetty | org.eclipse.jetty | jetty-server, jetty-servlet |

Code snippets to adapt `HttpHandler` to each server API:

**Reactor Netty**

```
HttpHandler handler = ...
ReactorHttpHandlerAdapter adapter = new ReactorHttpHandlerAdapter(handler);
HttpServer.create(host, port).newHandler(adapter).block();
```

**Undertow**

```
HttpHandler handler = ...
UndertowHttpHandlerAdapter adapter = new UndertowHttpHandlerAdapter(handler);
Undertow server = Undertow.builder().addHttpListener(port, host).setHandler(adapter)
.build();
server.start();
```

**Tomcat**

```
HttpHandler handler = ...
Servlet servlet = new TomcatHttpHandlerAdapter(handler);

Tomcat server = new Tomcat();
File base = new File(System.getProperty("java.io.tmpdir"));
Context rootContext = server.addContext("", base.getAbsolutePath());
Tomcat.addServlet(rootContext, "main", servlet);
rootContext.addServletMappingDecoded("/", "main");
server.setHost(host);
server.setPort(port);
server.start();
```

**Jetty**

```
HttpHandler handler = ...
Servlet servlet = new JettyHttpHandlerAdapter(handler);

Server server = new Server();
ServletContextHandler contextHandler = new ServletContextHandler(server, "");
contextHandler.addServlet(new ServletHolder(servlet), "/");
contextHandler.start();

ServerConnector connector = new ServerConnector(server);
connector.setHost(host);
connector.setPort(port);
server.addConnector(connector);
server.start();
```

#### Servlet 3.1+ Container

To deploy as a WAR to any Servlet 3.1+ container, simply extend and include AbstractReactiveWebInitializer in the WAR, which wraps an `HttpHandler` with `ServletHttpHandlerAdapter` and registers that as a `Servlet`.

### 1.2.2. WebHandler API

The WebHandler API is a general purpose, server, web API for processing requests through a chain of WebExceptionHandler, WebFilter, and a target WebHandler components. The chain can be assembled with `WebHttpHandlerBuilder` either by adding components to the builder or by having them detected from a Spring `ApplicationContext`. The builder returns an HttpHandler that can then be used to run on any of the supported servers.

While `HttpHandler` aims to be the most minimal contract across HTTP servers, the WebHandler API provides essential features commonly used to build web applications. For example, the `ServerWebExchange` available to WebHandler API components provides access not only to the request and response, but also to request and session attributes, access to parsed form data, multipart data, and more.

#### Special bean types

The table below lists the components that `WebHttpHandlerBuilder` detects:

| Bean name | Bean type | Count | Description |
|---|---|---|---|
| <any> | `WebExceptionHandler` | 0..N | Provide handling for exceptions from the chain of `WebFilter`'s and the target `WebHandler`. For more details, see Exceptions. |
| <any> | `WebFilter` | 0..N | Apply interception style logic to before and after the rest of the filter chain and the target `WebHandler`. For more details, see Filters. |
| "webHandler" | `WebHandler` | 1 | The handler for the request. |

| Bean name | Bean type | Count | Description |
|---|---|---|---|
| "webSessionManager" | `WebSessionManager` | 0..1 | The manager for `WebSession`'s exposed through a method on `ServerWebExchange`. `DefaultWebSessionManager` by default. |
| "serverCodecConfigurer" | `ServerCodecConfigurer` | 0..1 | For access to `HttpMessageReader`'s for parsing form data and multipart data that's then exposed through methods on `ServerWebExchange`. `ServerCodecConfigurer.create()` by default. |
| "localeContextResolver" | `LocaleContextResolver` | 0..1 | The resolver for `LocaleContext` exposed through a method on `ServerWebExchange`. `AcceptHeaderLocaleContextResolver` by default. |

### Form data

`ServerWebExchange` exposes the following method for access to form data:

```
Mono<MultiValueMap<String, String>> getFormData();
```

The `DefaultServerWebExchange` uses the configured `HttpMessageReader` to parse form data ("application/x-www-form-urlencoded") into a `MultiValueMap`. By default `FormHttpMessageReader` is configured for use via the `ServerCodecConfigurer` bean (see Web Handler API).

### Multipart data

Same in Spring MVC

`ServerWebExchange` exposes the following method for access to multipart data:

```
Mono<MultiValueMap<String, Part>> getMultipartData();
```

The `DefaultServerWebExchange` uses the configured `HttpMessageReader<MultiValueMap<String, Part>>` to parse "multipart/form-data" content into a `MultiValueMap`. At present Synchronoss NIO Multipart is the only 3rd party library supported, and the only library we know for non-blocking parsing of multipart requests. It is enabled through the `ServerCodecConfigurer` bean (see Web Handler API).

To parse multipart data in streaming fashion, use the `Flux<Part>` returned from an `HttpMessageReader<Part>` instead. For example in an annotated controller use of `@RequestPart` implies Map-like access to individual parts by name, and hence requires parsing multipart data in full. By contrast `@RequestBody` can be used to decode the content to `Flux<Part>` without collecting to a `MultiValueMap`.

### 1.2.3. Filters

Same in Spring MVC

In the WebHandler API, a `WebFilter` can be used to apply interception-style logic before and after the rest of the processing chain of filters and the target `WebHandler`. When using the WebFlux Config, registering a `WebFilter` is as simple as declaring it as a Spring bean, and optionally expressing precedence via `@Order` on the bean declaration or by implementing `Ordered`.

The following describe the available `WebFilter` implementations:

#### Forwarded Headers

Same in Spring MVC

As a request goes through proxies such as load balancers the host, port, and scheme may change presenting a challenge for applications that need to create links to resources since the links should reflect the host, port, and scheme of the original request as seen from a client perspective.

RFC 7239 defines the "Forwarded" HTTP header for proxies to use to provide information about the original request. There are also other non-standard headers in use such as "X-Forwarded-Host", "X-Forwarded-Port", and "X-Forwarded-Proto".

`ForwardedHeaderFilter` detects, extracts, and uses information from the "Forwarded" header, or from "X-Forwarded-Host", "X-Forwarded-Port", and "X-Forwarded-Proto". It wraps the request in order to overlay its host, port, and scheme and also "hides" the forwarded headers for subsequent processing.

Note that there are security considerations when using forwarded headers as explained in Section 8 of RFC 7239. At the application level it is difficult to determine whether forwarded headers can be trusted or not. This is why the network upstream should be configured correctly to filter out untrusted forwarded headers from the outside.

Applications that don't have a proxy and don't need to use forwarded headers can configure the `ForwardedHeaderFilter` to remove and ignore such headers.

#### CORS

Same in Spring MVC

Spring WebFlux provides fine-grained support for CORS configuration through annotations on controllers. However when used with Spring Security it is advisable to rely on the built-in `CorsFilter` that must be ordered ahead of Spring Security's chain of filters.

See the section on CORS and the CORS WebFilter for more details.

### 1.2.4. Exceptions

Same in Spring MVC

In the WebHandler API, a `WebExceptionHandler` can be used to to handle exceptions from the chain

of `WebFilter`'s and the target `WebHandler`. When using the WebFlux Config, registering a `WebExceptionHandler` is as simple as declaring it as a Spring bean, and optionally expressing precedence via `@Order` on the bean declaration or by implementing `Ordered`.

Below are the available `WebExceptionHandler` implementations:

| Exception Handler | Description |
|---|---|
| `ResponseStatusExceptionHandler` | Provides handling for exceptions of type ResponseStatusException by setting the response to the HTTP status code of the exception. |
| `WebFluxResponseStatusExceptionHandler` | Extension of `ResponseStatusExceptionHandler` that can also determine the HTTP status code an `@ResponseStatus` annotation on any exception.<br><br>This handler is declared in the WebFlux Config. |

### 1.2.5. Codecs

Same in Spring MVC

HttpMessageReader and HttpMessageWriter are contracts for encoding and decoding HTTP request and response content via non-blocking I/O with (Rective Streams) back pressure.

Encoder and Decoder are contracts for encoding and decoding content, independent of HTTP. They can be wrapped with `EncoderHttpMessageWriter` or `DecoderHttpMessageReader` and used for web processing.

All codecs are for client or server side use. All build on DataBuffer which abstracts byte buffer representations such as the Netty `ByteBuf` or `java.nio.ByteBuffer` (see Data Buffers and Codecs for more details). `ClientCodecConfigurer` and `ServerCodecConfigurer` are typically used to configure and customize the codecs to use in an application.

The `spring-core` module has encoders and decoders for `byte[]`, `ByteBuffer`, `DataBuffer`, `Resource`, and `String`. The `spring-web` module adds encoders and decoders for Jackson JSON, Jackson Smile, JAXB2, along with other web-specific HTTP message readers and writers for form data, multipart requests, and server-sent events.

#### Jackson

The decoder relies on Jackson's non-blocking, byte array parser to parse a stream of byte chunks into a `TokenBuffer` stream, which can then be turned into Objects with Jackson's `ObjectMapper`. JSON and Smile (binary JSON) data formats are currently supported.

The encoder processes a `Publisher<?>` as follows:

- if the `Publisher` is a `Mono` (i.e. single value), the value is encoded when available.
- if media type is `application/stream+json` for JSON or `application/stream+x-jackson-smile` for Smile, each value produced by the `Publisher` is encoded individually (and followed by a new line in JSON).

- otherwise all items from the `Publisher` are gathered in with `Flux#collectToList()` and the resulting collection is encoded as an array.

As a special case to the above rules the `ServerSentEventHttpMessageWriter` feeds items emitted from its input `Publisher` individually into the `Jackson2JsonEncoder` as a `Mono<?>`.

Note that both the Jackson JSON encoder and decoder explicitly back out of rendering elements of type `String`. Instead `String`'s are treated as low level content, (i.e. serialized JSON) and are rendered as-is by the `CharSequenceEncoder`. If you want a `Flux<String>` rendered as a JSON array, you'll have to use `Flux#collectToList()` and provide a `Mono<List<String>>` instead.

**HTTP Streaming**

Same in Spring MVC

When a multi-value, reactive type such as `Flux` is used for response rendering, it may be collected to a `List` and rendered as a whole (e.g. JSON array), or it may be treated as an infinite stream with each item flushed immediately. The determination for which is which is made based on content negotiation and the selected media type which may imply a streaming format (e.g. "text/event-stream", "application/stream+json"), or not (e.g. "application/json").

When streaming to the HTTP response, regardless of the media type (e.g. text/event-stream, application/stream+json), it is important to send data periodically, since the write would fail if the client has disconnected. The send could take the form of an empty (comment-only) SSE event, or any other data that the other side would have to interpret as a heartbeat and ignore.

# 1.3. DispatcherHandler

Same in Spring MVC

Spring WebFlux, like Spring MVC, is designed around the front controller pattern where a central `WebHandler`, the `DispatcherHandler`, provides a shared algorithm for request processing while actual work is performed by configurable, delegate components. This model is flexible and supports diverse workflows.

`DispatcherHandler` discovers the delegate components it needs from Spring configuration. It is also designed to be a Spring bean itself and implements `ApplicationContextAware` for access to the context it runs in. If `DispatcherHandler` is declared with the bean name "webHandler" it is in turn discovered by WebHttpHandlerBuilder which puts together a request processing chain as described in WebHandler API.

Spring configuration in a WebFlux application typically contains:

- `DispatcherHandler` with the bean name "webHandler"
- `WebFilter` and `WebExceptionHandler` beans
- DispatcherHandler special beans
- Others

The configuration is given to `WebHttpHandlerBuilder` to build the processing chain:

```
ApplicationContext context = ...
HttpHandler handler = WebHttpHandlerBuilder.applicationContext(context);
```

The resulting `HttpHandler` is ready for use with a server adapter.

### 1.3.1. Special bean types

Same in Spring MVC

The `DispatcherHandler` delegates to special beans to process requests and render the appropriate responses. By "special beans" we mean Spring-managed, Object instances that implement WebFlux framework contracts. Those usually come with built-in contracts but you can customize their properties, extend then, or replaced.

The table below lists the special beans detected by the `DispatcherHandler`. Note that there are also some other beans detected at a lower level, see Special bean types in the Web Handler API.

| Bean type | Explanation |
|---|---|
| HandlerMapping | Map a request to a handler. The mapping is based on some criteria the details of which vary by `HandlerMapping` implementation — annotated controllers, simple URL pattern mappings, etc.<br><br>The main `HandlerMapping` implementations are `RequestMappingHandlerMapping` for `@RequestMapping` annotated methods, `RouterFunctionMapping` for functional endpoint routes, and `SimpleUrlHandlerMapping` for explicit registrations of URI path patterns and `WebHandler`'s. |
| HandlerAdapter | Help the `DispatcherHandler` to invoke a handler mapped to a request regardless of how the handler is actually invoked. For example invoking an annotated controller requires resolving annotations. The main purpose of a `HandlerAdapter` is to shield the `DispatcherHandler` from such details. |
| HandlerResultHandler | Process the result from the handler invocation and finalize the response. See Result Handling. |

### 1.3.2. WebFlux Config

Same in Spring MVC

Applications can declare the infrastructure beans listed under Web Handler API and DispatcherHandler that are required to process requests. However in most cases the WebFlux Config is the best starting point. It declares the required beans and provides a higher level configuration callback API to customize it.

Spring Boot relies on the WebFlux config to configure Spring WebFlux and also provides many extra convenient options.

### 1.3.3. Processing

Same in Spring MVC

The `DispatcherHandler` processes requests as follows:

- Each `HandlerMapping` is asked to find a matching handler and the first match is used.
- If a handler is found, it is executed through an appropriate `HandlerAdapter` which exposes the return value from the execution as `HandlerResult`.
- The `HandlerResult` is given to an appropriate `HandlerResultHandler` to complete processing by writing to the response directly or using a view to render.

### 1.3.4. Result Handling

The return value from the invocation of a handler, through a `HandlerAdapter`, is wrapped as `HandlerResult`, along with some additional context, and passed to the first `HandlerResultHandler` that claims support for it. The table below shows the available `HandlerResultHandler` implementations all of which are declared in the WebFlux Config:

| Result Handler Type | Return Values | Default Order |
|---|---|---|
| `ResponseEntityResultHandler` | `ResponseEntity`, typically from `@Controller`'s. | 0 |
| `ServerResponseResultHandler` | `ServerResponse`, typically from functional endpoints. | 0 |
| `ResponseBodyResultHandler` | Handle return values from `@ResponseBody` methods or `@RestController` classes. | 100 |
| `ViewResolutionResultHandler` | `CharSequence` or View, Model or `Map`, Rendering, or any other Object is treated as a model attribute.<br><br>Also see View Resolution. | `Integer.MAX_VALUE` |

### 1.3.5. Exceptions

Same in Spring MVC

The `HandlerResult` returned from a `HandlerAdapter` may expose a function for error handling based on some handler-specific mechanism. This error function is called if:

- the handler (e.g. `@Controller`) invocation fails.
- handling of the handler return value through a `HandlerResultHandler` fails.

The error function can change the response, e.g. to an error status, as long as an error signal occurs before the reactive type returned from the handler produces any data items.

This is how `@ExceptionHandler` methods in `@Controller` classes are supported. By contrast, support for the same in Spring MVC is built on a `HandlerExceptionResolver`. This generally shouldn't matter, however, keep in mind that in WebFlux you cannot use a `@ControllerAdvice` to handle exceptions

that occur before a handler is chosen.

See also Exceptions in the Annotated Controller section, or Exceptions in the WebHandler API section.

### 1.3.6. View Resolution

Same in Spring MVC

View resolution enables rendering to a browser with an HTML template and a model without tying you to a specific view technology. In Spring WebFlux, view resolution is supported through a dedicated HandlerResultHandler that uses `ViewResolver`'s to map a String, representing a logical view name, to a `View` instance. The `View` is then used to render the response.

#### Handling

Same in Spring MVC

The `HandlerResult` passed into `ViewResolutionResultHandler` contains the return value from the handler, and also the model that contains attributes added during request handling. The return value is processed as one of the following:

- `String`, `CharSequence` — a logical view name to be resolved to a `View` through the list of configured `ViewResolver`'s.
- `void` — select a default view name based on the request path minus the leading and trailing slash, and resolve it to a `View`. The same also happens when a view name was not provided, e.g. model attribute was returned, or an async return value, e.g. `Mono` completed empty.
- Rendering — API for view resolution scenarios; explore the options in your IDE with code completion.
- `Model`, `Map` — extra model attributes to be added to the model for the request.
- Any other — any other return value (except for simple types, as determined by BeanUtils#isSimpleProperty) is treated as a model attribute to be added to the model. The attribute name is derived from the Class name, using Conventions, unless a handler method `@ModelAttribute` annotation is present.

The model can contain asynchronous, reactive types (e.g. from Reactor, RxJava). Prior to rendering, `AbstractView` resolves such model attributes into concrete values and updates the model. Single-value reactive types are resolved to a single value, or no value (if empty) while multi-value reactive types, e.g. `Flux<T>` are collected and resolved to `List<T>`.

To configure view resolution is as simple as adding a `ViewResolutionResultHandler` bean to your Spring configuration. WebFlux Config provides a dedicated configuration API for view resolution.

See View Technologies for more on the view technologies integrated with Spring WebFlux.

#### Redirecting

Same in Spring MVC

The special `redirect:` prefix in a view name allows you to perform a redirect. The `UrlBasedViewResolver` (and sub-classes) recognize this as an instruction that a redirect is needed. The rest of the view name is the redirect URL.

The net effect is the same as if the controller had returned a `RedirectView` or `Rendering.redirectTo("abc").build()`, but now the controller itself can simply operate in terms of logical view names. A view name such as `redirect:/some/resource` is relative to the current application, while the view name `redirect:http://example.com/arbitrary/path` redirects to an absolute URL.

**Content negotiation**

Same in Spring MVC

`ViewResolutionResultHandler` supports content negotiation. It compares the request media type(s) with the media type(s) supported by each selected `View`. The first `View` that supports the requested media type(s) is used.

In order to support media types such as JSON and XML, Spring WebFlux provides `HttpMessageWriterView` which is a special `View` that renders through an HttpMessageWriter. Typically you would configure these as default views through the WebFlux Config. Default views are always selected and used if they match the requested media type.

# 1.4. Annotated Controllers

Same in Spring MVC

Spring WebFlux provides an annotation-based programming model where `@Controller` and `@RestController` components use annotations to express request mappings, request input, exception handling, and more. Annotated controllers have flexible method signatures and do not have to extend base classes nor implement specific interfaces.

Here is a basic example:

```
@RestController
public class HelloController {

    @GetMapping("/hello")
    public String handle() {
        return "Hello WebFlux";
    }
}
```

In this example the methods returns a String to be written to the response body.

## 1.4.1. @Controller

Same in Spring MVC

You can define controller beans using a standard Spring bean definition. The `@Controller` stereotype allows for auto-detection, aligned with Spring general support for detecting `@Component` classes in the classpath and auto-registering bean definitions for them. It also acts as a stereotype for the annotated class, indicating its role as a web component.

To enable auto-detection of such `@Controller` beans, you can add component scanning to your Java configuration:

```
@Configuration
@ComponentScan("org.example.web")
public class WebConfig {

    // ...
}
```

`@RestController` is a composed annotation that is itself meta-annotated with `@Controller` and `@ResponseBody` indicating a controller whose every method inherits the type-level `@ResponseBody` annotation and therefore writes directly to the response body vs view resolution and rendering with an HTML template.

### 1.4.2. Request Mapping

Same in Spring MVC

The `@RequestMapping` annotation is used to map requests to controllers methods. It has various attributes to match by URL, HTTP method, request parameters, headers, and media types. It can be used at the class-level to express shared mappings or at the method level to narrow down to a specific endpoint mapping.

There are also HTTP method specific shortcut variants of `@RequestMapping`:

- `@GetMapping`
- `@PostMapping`
- `@PutMapping`
- `@DeleteMapping`
- `@PatchMapping`

The above are Custom Annotations that are provided out of the box because arguably most controller methods should be mapped to a specific HTTP method vs using `@RequestMapping` which by default matches to all HTTP methods. At the same an `@RequestMapping` is still needed at the class level to express shared mappings.

Below is an example with type and method level mappings:

```
@RestController
@RequestMapping("/persons")
class PersonController {

    @GetMapping("/{id}")
    public Person getPerson(@PathVariable Long id) {
        // ...
    }

    @PostMapping
    @ResponseStatus(HttpStatus.CREATED)
    public void add(@RequestBody Person person) {
        // ...
    }
}
```

**URI Patterns**

Same in Spring MVC

You can map requests using glob patterns and wildcards:

- ? matches one character
- * matches zero or more characters within a path segment
- ** match zero or more path segments

You can also declare URI variables and access their values with `@PathVariable`:

```
@GetMapping("/owners/{ownerId}/pets/{petId}")
public Pet findPet(@PathVariable Long ownerId, @PathVariable Long petId) {
    // ...
}
```

URI variables can be declared at the class and method level:

```
@Controller
@RequestMapping("/owners/{ownerId}")
public class OwnerController {

    @GetMapping("/pets/{petId}")
    public Pet findPet(@PathVariable Long ownerId, @PathVariable Long petId) {
        // ...
    }
}
```

URI variables are automatically converted to the appropriate type or`TypeMismatchException` is

raised. Simple types — `int`, `long`, `Date`, are supported by default and you can register support for any other data type. See Type Conversion and DataBinder.

URI variables can be named explicitly — e.g. `@PathVariable("customId")`, but you can leave that detail out if the names are the same and your code is compiled with debugging information or with the `-parameters` compiler flag on Java 8.

The syntax `{*varName}` declares a URI variable that matches zero or more remaining path segments. For example `/resources/{*path}` matches all files `/resources/` and the `"path"` variable captures the complete relative path.

The syntax `{varName:regex}` declares a URI variable with a regular expressions with the syntax `{varName:regex}` — e.g. given URL `"/spring-web-3.0.5 .jar"`, the below method extracts the name, version, and file extension:

```
@GetMapping("/{name:[a-z-]+}-{version:\\d\\.\\d\\.\\d}{ext:\\.[a-z]+}")
public void handle(@PathVariable String version, @PathVariable String ext) {
    // ...
}
```

URI path patterns can also have embedded `${…}` placeholders that are resolved on startup via `PropertyPlaceHolderConfigurer` against local, system, environment, and other property sources. This can be used for example to parameterize a base URL based on some external configuration.

Spring WebFlux uses `PathPattern` and the `PathPatternParser` for URI path matching support both of which are located in `spring-web` and expressly designed for use with HTTP URL paths in web applications where a large number of URI path patterns are matched at runtime.

Spring WebFlux does not support suffix pattern matching — unlike Spring MVC, where a mapping such as `/person` also matches to `/person.*`. For URL based content negotiation, if needed, we recommend using a query parameter, which is simpler, more explicit, and less vulnerable to URL path based exploits.

**Pattern Comparison**

Same in Spring MVC

When multiple patterns match a URL, they must be compared to find the best match. This is done with `PathPattern.SPECIFICITY_COMPARATOR` which looks for patterns that more specific.

For every pattern, a score is computed based the number of URI variables and wildcards where a URI variable scores lower than a wildcard. A pattern with a lower total score wins. If two patterns have the same score, then the longer is chosen.

Catch-all patterns, e.g. `**`, `{*varName}`, are excluded from the scoring and are always sorted last instead. If two patterns are both catch-all, the longer is chosen.

### Consumable Media Types

Same in Spring MVC

You can narrow the request mapping based on the `Content-Type` of the request:

```
@PostMapping(path = "/pets", <strong>consumes = "application/json"</strong>)
public void addPet(@RequestBody Pet pet) {
    // ...
}
```

The consumes attribute also supports negation expressions — e.g. `!text/plain` means any content type other than "text/plain".

You can declare a shared consumes attribute at the class level. Unlike most other request mapping attributes however when used at the class level, a method-level consumes attribute overrides rather than extend the class level declaration.

`MediaType` provides constants for commonly used media types — e.g. `APPLICATION_JSON_VALUE`, `APPLICATION_XML_VALUE`.

### Producible Media Types

Same in Spring MVC

You can narrow the request mapping based on the `Accept` request header and the list of content types that a controller method produces:

```
@GetMapping(path = "/pets/{petId}", <strong>produces = "application/json;charset=UTF-
8"</strong>)
@ResponseBody
public Pet getPet(@PathVariable String petId) {
    // ...
}
```

The media type can specify a character set. Negated expressions are supported — e.g. `!text/plain` means any content type other than "text/plain".

For JSON content type, the UTF-8 charset should be specified even if RFC7159 clearly states that "no charset parameter is defined for this registration" because some browsers require it for interpreting correctly UTF-8 special characters.

You can declare a shared produces attribute at the class level. Unlike most other request mapping attributes however when used at the class level, a method-level produces attribute overrides rather than extend the class level declaration.

`MediaType` provides constants for commonly used media types — e.g. `APPLICATION_JSON_UTF8_VALUE`, `APPLICATION_XML_VALUE`.

#### Parameters and Headers

Same in Spring MVC

You can narrow request mappings based on query parameter conditions. You can test for the presence of a query parameter (`"myParam"`), for the absence (`"!myParam"`), or for a specific value (`"myParam=myValue"`):

```
@GetMapping(path = "/pets/{petId}", <strong>params = "myParam=myValue"</strong>)
public void findPet(@PathVariable String petId) {
    // ...
}
```

You can also use the same with request header conditions:

```
@GetMapping(path = "/pets", <strong>headers = "myHeader=myValue"</strong>)
public void findPet(@PathVariable String petId) {
    // ...
}
```

#### HTTP HEAD, OPTIONS

Same in Spring MVC

`@GetMapping` — and also `@RequestMapping(method=HttpMethod.GET)`, support HTTP HEAD transparently for request mapping purposes. Controller methods don't need to change. A response wrapper, applied in the `HttpHandler` server adapter, ensures a `"Content-Length"` header is set to the number of bytes written and without actually writing to the response.

By default HTTP OPTIONS is handled by setting the "Allow" response header to the list of HTTP methods listed in all `@RequestMapping` methods with matching URL patterns.

For a `@RequestMapping` without HTTP method declarations, the "Allow" header is set to `"GET,HEAD,POST,PUT,PATCH,DELETE,OPTIONS"`. Controller methods should always declare the supported HTTP methods for example by using the HTTP method specific variants — `@GetMapping`, `@PostMapping`, etc.

`@RequestMapping` method can be explicitly mapped to HTTP HEAD and HTTP OPTIONS, but that is not necessary in the common case.

#### Custom Annotations

Same in Spring MVC

Spring WebFlux supports the use of composed annotations for request mapping. Those are

annotations that are themselves meta-annotated with `@RequestMapping` and composed to redeclare a subset (or all) of the `@RequestMapping` attributes with a narrower, more specific purpose.

`@GetMapping`, `@PostMapping`, `@PutMapping`, `@DeleteMapping`, and `@PatchMapping` are examples of composed annotations. They're provided out of the box because arguably most controller methods should be mapped to a specific HTTP method vs using `@RequestMapping` which by default matches to all HTTP methods. If you need an example of composed annotations, look at how those are declared.

Spring WebFlux also supports custom request mapping attributes with custom request matching logic. This is a more advanced option that requires sub-classing `RequestMappingHandlerMapping` and overriding the `getCustomMethodCondition` method where you can check the custom attribute and return your own `RequestCondition`.

### 1.4.3. Handler methods

Same in Spring MVC

`@RequestMapping` handler methods have a flexible signature and can choose from a range of supported controller method arguments and return values.

#### Method arguments

Same in Spring MVC

The table below shows supported controller method arguments.

Reactive types (Reactor, RxJava, or other) are supported on arguments that require blocking I/O, e.g. reading the request body, to be resolved. This is marked in the description column. Reactive types are not expected on arguments that don't require blocking.

JDK 1.8's `java.util.Optional` is supported as a method argument in combination with annotations that have a `required` attribute — e.g. `@RequestParam`, `@RequestHeader`, etc, and is equivalent to `required=false`.

| Controller method argument | Description |
|---|---|
| `ServerWebExchange` | Access to the full `ServerWebExchange` — container for the HTTP request and response, request and session attributes, `checkNotModified` methods, and others. |
| `ServerHttpRequest`, `ServerHttpResponse` | Access to the HTTP request or response. |
| `WebSession` | Access to the session; this does not force the start of a new session unless attributes are added. Supports reactive types. |
| `java.security.Principal` | Currently authenticated user; possibly a specific `Principal` implementation class if known. Supports reactive types. |
| `org.springframework.http.HttpMethod` | The HTTP method of the request. |
| `java.util.Locale` | The current request locale, determined by the most specific `LocaleResolver` available, in effect, the configured `LocaleResolver`/`LocaleContextResolver`. |

| Controller method argument | Description |
| --- | --- |
| `java.util.TimeZone` + `java.time.ZoneId` | The time zone associated with the current request, as determined by a `LocaleContextResolver`. |
| `@PathVariable` | For access to URI template variables. See URI Patterns. |
| `@MatrixVariable` | For access to name-value pairs in URI path segments. See Matrix variables. |
| `@RequestParam` | For access to Servlet request parameters. Parameter values are converted to the declared method argument type. See @RequestParam.<br><br>Note that use of `@RequestParam` is optional, e.g. to set its attributes. See "Any other argument" further below in this table. |
| `@RequestHeader` | For access to request headers. Header values are converted to the declared method argument type. See @RequestHeader. |
| `@CookieValue` | For access to cookies. Cookies values are converted to the declared method argument type. See @CookieValue. |
| `@RequestBody` | For access to the HTTP request body. Body content is converted to the declared method argument type using `HttpMessageReader`'s. Supports reactive types. See @RequestBody. |
| `HttpEntity<B>` | For access to request headers and body. The body is converted with `HttpMessageReader`'s. Supports reactive types. See HttpEntity. |
| `@RequestPart` | For access to a part in a "multipart/form-data" request. Supports reactive types. See Multipart and Multipart data. |
| `java.util.Map`, `org.springframework.ui.Model`, `org.springframework.ui.ModelMap` | For access to the model that is used in HTML controllers and exposed to templates as part of view rendering. |
| `@ModelAttribute` | For access to an existing attribute in the model (instantiated if not present) with data binding and validation applied. See @ModelAttribute as well as Model and DataBinder.<br><br>Note that use of `@ModelAttribute` is optional, e.g. to set its attributes. See "Any other argument" further below in this table. |
| `Errors`, `BindingResult` | For access to errors from validation and data binding for a command object (i.e. `@ModelAttribute` argument), or errors from the validation of an `@RequestBody` or `@RequestPart` arguments; an `Errors`, or `BindingResult` argument must be declared immediately after the validated method argument. |
| `SessionStatus` + class-level `@SessionAttributes` | For marking form processing complete which triggers cleanup of session attributes declared through a class-level `@SessionAttributes` annotation. See @SessionAttributes for more details. |
| `UriComponentsBuilder` | For preparing a URL relative to the current request's host, port, scheme, context path, and the literal part of the servlet mapping also taking into account `Forwarded` and `X-Forwarded-*` headers. // TODO: See URI Links. |

| Controller method argument | Description |
|---|---|
| `@SessionAttribute` | For access to any session attribute; in contrast to model attributes stored in the session as a result of a class-level `@SessionAttributes` declaration. See @SessionAttribute for more details. |
| `@RequestAttribute` | For access to request attributes. See @RequestAttribute for more details. |
| Any other argument | If a method argument is not matched to any of the above, by default it is resolved as an `@RequestParam` if it is a simple type, as determined by BeanUtils#isSimpleProperty, or as an `@ModelAttribute` otherwise. |

#### Return values

Same in Spring MVC

The table below shows supported controller method return values. Note that reactive types from libraries such as Reactor, RxJava, or other are generally supported for all return values.

| Controller method return value | Description |
|---|---|
| `@ResponseBody` | The return value is encoded through `HttpMessageWriter`'s and written to the response. See @ResponseBody. |
| `HttpEntity<B>`, `ResponseEntity<B>` | The return value specifies the full response including HTTP headers and body be encoded through `HttpMessageWriter`'s and written to the response. See ResponseEntity. |
| `HttpHeaders` | For returning a response with headers and no body. |
| `String` | A view name to be resolved with `ViewResolver`'s and used together with the implicit model — determined through command objects and `@ModelAttribute` methods. The handler method may also programmatically enrich the model by declaring a `Model` argument (see above). |
| `View` | A `View` instance to use for rendering together with the implicit model — determined through command objects and `@ModelAttribute` methods. The handler method may also programmatically enrich the model by declaring a `Model` argument (see above). |
| `java.util.Map`, `org.springframework.ui.Model` | Attributes to be added to the implicit model with the view name implicitly determined based on the request path. |
| `@ModelAttribute` | An attribute to be added to the model with the view name implicitly determined based on the request path.<br><br>Note that `@ModelAttribute` is optional. See "Any other return value" further below in this table. |
| `Rendering` | An API for model and view rendering scenarios. |

| Controller method return value | Description |
| --- | --- |
| `void` | A method with a `void`, possibly async (e.g. `Mono<Void>`), return type (or a `null` return value) is considered to have fully handled the response if it also has a `ServerHttpResponse`, or a `ServerWebExchange` argument, or an `@ResponseStatus` annotation. The same is true also if the controller has made a positive ETag or lastModified timestamp check. // TODO: See Controllers for details.<br><br>If none of the above is true, a `void` return type may also indicate "no response body" for REST controllers, or default view name selection for HTML controllers. |
| `Flux<ServerSentEvent>`, `Observable<ServerSentEvent>`, or other reactive type | Emit server-sent events; the `SeverSentEvent` wrapper can be omitted when only data needs to be written (however `text/event-stream` must be requested or declared in the mapping through the produces attribute). |
| Any other return value | If a return value is not matched to any of the above, by default it is treated as a view name, if it is `String` or `void` (default view name selection applies); or as a model attribute to be added to the model, unless it is a simple type, as determined by BeanUtils#isSimpleProperty in which case it remains unresolved. |

#### Type Conversion

Same in Spring MVC

Some annotated controller method arguments that represent String-based request input — e.g. `@RequestParam`, `@RequestHeader`, `@PathVariable`, `@MatrixVariable`, and `@CookieValue`, may require type conversion if the argument is declared as something other than `String`.

For such cases type conversion is automatically applied based on the configured converters. By default simple types such as `int`, `long`, `Date`, etc. are supported. Type conversion can be customized through a `WebDataBinder`, see [mvc-ann-initbinder], or by registering `Formatters` with the `FormattingConversionService`, see Spring Field Formatting.

#### Matrix variables

Same in Spring MVC

RFC 3986 discusses name-value pairs in path segments. In Spring WebFlux we refer to those as "matrix variables" based on an "old post" by Tim Berners-Lee but they can be also be referred to as URI path parameters.

Matrix variables can appear in any path segment, each variable separated by semicolon and multiple values separated by comma, e.g. `"/cars;color=red,green;year=2012"`. Multiple values can also be specified through repeated variable names, e.g. `"color=red;color=green;color=blue"`.

Unlike Spring MVC, in WebFlux the presence or absence of matrix variables in a URL does not affect request mappings. In other words you're not required to use a URI variable to mask variable

content. That said if you want to access matrix variables from a controller method you need to add a URI variable to the path segment where matrix variables are expected. Below is an example:

```
// GET /pets/42;q=11;r=22

@GetMapping("/pets/{petId}")
public void findPet(@PathVariable String petId, @MatrixVariable int q) {

    // petId == 42
    // q == 11
}
```

Given that all path segments may contain matrix variables, sometimes you may need to disambiguate which path variable the matrix variable is expected to be in. For example:

```
// GET /owners/42;q=11/pets/21;q=22

@GetMapping("/owners/{ownerId}/pets/{petId}")
public void findPet(
        @MatrixVariable(name="q", pathVar="ownerId") int q1,
        @MatrixVariable(name="q", pathVar="petId") int q2) {

    // q1 == 11
    // q2 == 22
}
```

A matrix variable may be defined as optional and a default value specified:

```
// GET /pets/42

@GetMapping("/pets/{petId}")
public void findPet(@MatrixVariable(required=false, defaultValue="1") int q) {

    // q == 1
}
```

To get all matrix variables, use a `MultiValueMap`:

```
// GET /owners/42;q=11;r=12/pets/21;q=22;s=23

@GetMapping("/owners/{ownerId}/pets/{petId}")
public void findPet(
        @MatrixVariable MultiValueMap<String, String> matrixVars,
        @MatrixVariable(pathVar="petId"") MultiValueMap<String, String> petMatrixVars)
{

    // matrixVars: ["q" : [11,22], "r" : 12, "s" : 23]
    // petMatrixVars: ["q" : 22, "s" : 23]
}
```

**@RequestParam**

Same in Spring MVC

Use the `@RequestParam` annotation to bind query parameters to a method argument in a controller. The following code snippet shows the usage:

```
@Controller
@RequestMapping("/pets")
public class EditPetForm {

    // ...

    @GetMapping
    public String setupForm(<strong>@RequestParam("petId") int petId</strong>, Model
model) {
        Pet pet = this.clinic.loadPet(petId);
        model.addAttribute("pet", pet);
        return "petForm";
    }

    // ...

}
```

Unlike the Servlet API "request paramater" concept that conflate query parameters, form data, and multiparts into one, in WebFlux each is accessed individually through the `ServerWebExchange`. While `@RequestParam` binds to query parameters only, you can use data binding to apply query paramerters, form data, and multiparts to a command object.

Method parameters using using the `@RequestParam` annotation are required by default, but you can specify that a method parameter is optional by setting `@RequestParam`'s `required` flag to `false` or by declaring the argument with an `java.util.Optional` wrapper.

Type conversion is applied automatically if the target method parameter type is not `String`. See

[mvc-ann-typeconversion].

When an `@RequestParam` annotation is declared as `Map<String, String>` or `MultiValueMap<String, String>` argument, the map is populated with all query parameters.

Note that use of `@RequestParam` is optional, e.g. to set its attributes. By default any argument that is a simple value type, as determined by BeanUtils#isSimpleProperty, and is not resolved by any other argument resolver, is treated as if it was annotated with `@RequestParam`.

**@RequestHeader**

Same in Spring MVC

Use the `@RequestHeader` annotation to bind a request header to a method argument in a controller.

Given request with headers:

```
Host                    localhost:8080
Accept                  text/html,application/xhtml+xml,application/xml;q=0.9
Accept-Language         fr,en-gb;q=0.7,en;q=0.3
Accept-Encoding         gzip,deflate
Accept-Charset          ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive              300
```

The following gets the value of the `Accept-Encoding` and `Keep-Alive` headers:

```
@GetMapping("/demo")
public void handle(
        <strong>@RequestHeader("Accept-Encoding")</strong> String encoding,
        <strong>@RequestHeader("Keep-Alive")</strong> long keepAlive) {
    //...
}
```

Type conversion is applied automatically if the target method parameter type is not `String`. See [mvc-ann-typeconversion].

When an `@RequestHeader` annotation is used on a `Map<String, String>`, `MultiValueMap<String, String>`, or `HttpHeaders` argument, the map is populated with all header values.

Built-in support is available for converting a comma-separated string into an array/collection of strings or other types known to the type conversion system. For example a method parameter annotated with `@RequestHeader("Accept")` may be of type `String` but also `String[]` or `List<String>`.

**@CookieValue**

Same in Spring MVC

Use the `@CookieValue` annotation to bind the value of an HTTP cookie to a method argument in a controller.

Given request with the following cookie:

```
JSESSIONID=415A4AC178C59DACE0B2C9CA727CDD84
```

The following code sample demonstrates how to get the cookie value:

```
@GetMapping("/demo")
public void handle(<strong>@CookieValue("JSESSIONID")</strong> String cookie) {
    //...
}
```

Type conversion is applied automatically if the target method parameter type is not `String`. See [mvc-ann-typeconversion].

#### @ModelAttribute

Same in Spring MVC

Use the `@ModelAttribute` annotation on a method argument to access an attribute from the model, or have it instantiated if not present. The model attribute is also overlaid with values of query parameters and form fields whose names match to field names. This is referred to as data binding and it saves you from having to deal with parsing and converting individual query parameters and form fields. For example:

```
@PostMapping("/owners/{ownerId}/pets/{petId}/edit")
public String processSubmit(<strong>@ModelAttribute Pet pet</strong>) { }
```

The `Pet` instance above is resolved as follows:

- From the model if already added via Model.
- From the HTTP session via @SessionAttributes.
- From the invocation of a default constructor.
- From the invocation of a "primary constructor" with arguments matching to query parameters or form fields; argument names are determined via JavaBeans `@ConstructorProperties` or via runtime-retained parameter names in the bytecode.

After the model attribute instance is obtained, data binding is applied. The `WebExchangeDataBinder` class matches names of query parameters and form fields to field names on the target Object. Matching fields are populated after type conversion is applied where necessary. For more on data binding (and validation) see Validation. For more on customizing data binding see DataBinder.

Data binding may result in errors. By default a `WebExchangeBindException` is raised but to check for such errors in the controller method, add a `BindingResult` argument immediately next to the

`@ModelAttribute` as shown below:

```
@PostMapping("/owners/{ownerId}/pets/{petId}/edit")
public String processSubmit(<strong>@ModelAttribute("pet") Pet pet</strong>,
BindingResult result) {
    if (result.hasErrors()) {
        return "petForm";
    }
    // ...
}
```

Validation can be applied automatically after data binding by adding the `javax.validation.Valid` annotation or Spring's `@Validated` annotation (also see Bean validation and Spring validation). For example:

```
@PostMapping("/owners/{ownerId}/pets/{petId}/edit")
public String processSubmit(<strong>@Valid @ModelAttribute("pet") Pet pet</strong>,
BindingResult result) {
    if (result.hasErrors()) {
        return "petForm";
    }
    // ...
}
```

Spring WebFlux, unlike Spring MVC, supports reactive types in the model, e.g. `Mono<Account>` or `io.reactivex.Single<Account>`. An `@ModelAttribute` argument can be declared with or without a reactive type wrapper, and it will be resolved accordingly, to the actual value if necessary. Note however that in order to use a `BindingResult` argument, you must declare the `@ModelAttribute` argument before it without a reactive type wrapper, as shown earlier. Alternatively, you can handle any errors through the reactive type:

```
@PostMapping("/owners/{ownerId}/pets/{petId}/edit")
public Mono<String> processSubmit(@Valid @ModelAttribute("pet") Mono<Pet> petMono) {
    return petMono
        .flatMap(pet -> {
            // ...
        })
        .onErrorResume(ex -> {
            // ...
        });
}
```

Note that use of `@ModelAttribute` is optional, e.g. to set its attributes. By default any argument that is not a simple value type, as determined by BeanUtils#isSimpleProperty, and is not resolved by any other argument resolver, is treated as if it was annotated with `@ModelAttribute`.

#### @SessionAttributes

Same in Spring MVC

`@SessionAttributes` is used to store model attributes in the `WebSession` between requests. It is a type-level annotation that declares session attributes used by a specific controller. This will typically list the names of model attributes or types of model attributes which should be transparently stored in the session for subsequent requests to access.

For example:

```
@Controller
<strong>@SessionAttributes("pet")</strong>
public class EditPetForm {
    // ...
}
```

On the first request when a model attribute with the name "pet" is added to the model, it is automatically promoted to and saved in the `WebSession`. It remains there until another controller method uses a `SessionStatus` method argument to clear the storage:

```
@Controller
<strong>@SessionAttributes("pet")</strong>
public class EditPetForm {

    // ...

    @PostMapping("/pets/{id}")
    public String handle(Pet pet, BindingResult errors, SessionStatus status) {
        if (errors.hasErrors) {
            // ...
        }
            status.setComplete();
            // ...
        }
    }
}
```

#### @SessionAttribute

Same in Spring MVC

If you need access to pre-existing session attributes that are managed globally, i.e. outside the controller (e.g. by a filter), and may or may not be present use the `@SessionAttribute` annotation on a method parameter:

```
@GetMapping("/")
public String handle(<strong>@SessionAttribute</strong> User user) {
    // ...
}
```

For use cases that require adding or removing session attributes consider injecting `WebSession` into the controller method.

For temporary storage of model attributes in the session as part of a controller workflow consider using `SessionAttributes` as described in @SessionAttributes.

#### @RequestAttribute

Same in Spring MVC

Similar to `@SessionAttribute` the `@RequestAttribute` annotation can be used to access pre-existing request attributes created earlier, e.g. by a `WebFilter`:

```
@GetMapping("/")
public String handle(<strong>@RequestAttribute</strong> Client client) {
    // ...
}
```

#### Multipart

Same in Spring MVC

As explained in Multipart data, `ServerWebExchange` provides access to multipart content. The best way to handle a file upload form (e.g. from a browser) in a controller is through data binding to a command object:

```
class MyForm {

    private String name;

    private MultipartFile file;

    // ...

}

@Controller
public class FileUploadController {

    @PostMapping("/form")
    public String handleFormUpload(MyForm form, BindingResult errors) {
        // ...
    }

}
```

Multipart requests can also be submitted from non-browser clients in a RESTful service scenario. For example a file along with JSON:

```
POST /someUrl
Content-Type: multipart/mixed

--edt7Tfrdusa7r3lNQc79vXuhIIMlatb7PQg7Vp
Content-Disposition: form-data; name="meta-data"
Content-Type: application/json; charset=UTF-8
Content-Transfer-Encoding: 8bit

{
    "name": "value"
}
--edt7Tfrdusa7r3lNQc79vXuhIIMlatb7PQg7Vp
Content-Disposition: form-data; name="file-data"; filename="file.properties"
Content-Type: text/xml
Content-Transfer-Encoding: 8bit
... File Data ...
```

You can access individual parts with `@RequestPart`:

```
@PostMapping("/")
public String handle(<strong>@RequestPart("meta-data") Part metadata,
        @RequestPart("file-data") FilePart file</strong>) {
    // ...
}
```

To deserialize the raw part content, for example to JSON (similar to `@RequestBody`), simply declare a concrete target Object, instead of `Part`:

```
@PostMapping("/")
public String handle(<strong>@RequestPart("meta-data") MetaData metadata</strong>) {
    // ...
}
```

`@RequestPart` can be used in combination with `javax.validation.Valid`, or Spring's `@Validated` annotation, which causes Standard Bean Validation to be applied. By default validation errors cause a `WebExchangeBindException` which is turned into a 400 (BAD_REQUEST) response. Alternatively validation errors can be handled locally within the controller through an `Errors` or `BindingResult` argument:

```
@PostMapping("/")
public String handle(<strong>@Valid</strong> @RequestPart("meta-data") MetaData
metadata,
        <strong>BindingResult result</strong>) {
    // ...
}
```

To access all multipart data in as a `MultiValueMap` use `@RequestBody`:

```
@PostMapping("/")
public String handle(<strong>@RequestBody Mono<MultiValueMap<String, Part>> parts<
/strong>) {
    // ...
}
```

To access multipart data sequentially, in streaming fashion, use `@RequestBody` with `Flux<Part>` instead. For example:

```
@PostMapping("/")
public String handle(<strong>@RequestBody Flux<Part> parts</strong>) {
    // ...
}
```

**@RequestBody**

Same in Spring MVC

Use the `@RequestBody` annotation to have the request body read and deserialized into an Object through an HttpMessageReader. Below is an example with an `@RequestBody` argument:

```
@PostMapping("/accounts")
public void handle(@RequestBody Account account) {
    // ...
}
```

Unlike Spring MVC, in WebFlux the `@RequestBody` method argument supports reactive types and fully non-blocking reading and (client-to-server) streaming:

```
@PostMapping("/accounts")
public void handle(@RequestBody Mono<Account> account) {
    // ...
}
```

You can use the HTTP message codecs option of the WebFlux Config to configure or customize message readers.

`@RequestBody` can be used in combination with `javax.validation.Valid`, or Spring's `@Validated` annotation, which causes Standard Bean Validation to be applied. By default validation errors cause a `WebExchangeBindException` which is turned into a 400 (BAD_REQUEST) response. Alternatively validation errors can be handled locally within the controller through an `Errors` or `BindingResult` argument:

```
@PostMapping("/accounts")
public void handle(@Valid @RequestBody Account account, BindingResult result) {
    // ...
}
```

#### HttpEntity

Same in Spring MVC

`HttpEntity` is more or less identical to using @RequestBody but based on a container object that exposes request headers and body. Below is an example:

```
@PostMapping("/accounts")
public void handle(HttpEntity<Account> entity) {
    // ...
}
```

#### @ResponseBody

Same in Spring MVC

Use the `@ResponseBody` annotation on a method to have the return serialized to the response body through an HttpMessageWriter. For example:

```
@GetMapping("/accounts/{id}")
@ResponseBody
public Account handle() {
    // ...
}
```

`@ResponseBody` is also supported at the class level in which case it is inherited by all controller methods. This is the effect of `@RestController` which is nothing more than a meta-annotation marked with `@Controller` and `@ResponseBody`.

`@ResponseBody` supports reactive types which means you can return Reactor or RxJava types and have the asynchronous values they produce rendered to the response. For additional details, see HTTP Streaming and JSON rendering.

`@ResponseBody` methods can be combined with JSON serialization views. See Jackson JSON for details.

You can use the HTTP message codecs option of the WebFlux Config to configure or customize message writing.

#### ResponseEntity

Same in Spring MVC

`ResponseEntity` is more or less identical to using @ResponseBody but based on a container object that specifies request headers and body. Below is an example:

```
@PostMapping("/something")
public ResponseEntity<String> handle() {
    // ...
    URI location = ...
    return new ResponseEntity.created(location).build();
}
```

#### Jackson JSON

##### Jackson serialization views

Same in Spring MVC

Spring WebFlux provides built-in support for Jackson's Serialization Views which allows rendering only a subset of all fields in an Object. To use it with `@ResponseBody` or `ResponseEntity` controller methods, use Jackson's `@JsonView` annotation to activate a serialization view class:

```
@RestController
public class UserController {

    @GetMapping("/user")
    @JsonView(User.WithoutPasswordView.class)
    public User getUser() {
        return new User("eric", "7!jd#h23");
    }
}

public class User {

    public interface WithoutPasswordView {};
    public interface WithPasswordView extends WithoutPasswordView {};

    private String username;
    private String password;

    public User() {
    }

    public User(String username, String password) {
        this.username = username;
        this.password = password;
    }

    @JsonView(WithoutPasswordView.class)
    public String getUsername() {
        return this.username;
    }

    @JsonView(WithPasswordView.class)
    public String getPassword() {
        return this.password;
    }
}
```

`@JsonView` allows an array of view classes but you can only specify only one per controller method. Use a composite interface if you need to activate multiple views.

### 1.4.4. Model

Same in Spring MVC

The `@ModelAttribute` annotation can be used:

- On a method argument in `@RequestMapping` methods to create or access an Object from the model, and to bind it to the request through a `WebDataBinder`.

- As a method-level annotation in `@Controller` or `@ControllerAdvice` classes helping to initialize the model prior to any `@RequestMapping` method invocation.
- On a `@RequestMapping` method to mark its return value is a model attribute.

This section discusses `@ModelAttribute` methods, or the 2nd from the list above. A controller can have any number of `@ModelAttribute` methods. All such methods are invoked before `@RequestMapping` methods in the same controller. A `@ModelAttribute` method can also be shared across controllers via `@ControllerAdvice`. See the section on Controller Advice for more details.

`@ModelAttribute` methods have flexible method signatures. They support many of the same arguments as `@RequestMapping` methods except for `@ModelAttribute` itself nor anything related to the request body.

An example `@ModelAttribute` method:

```
@ModelAttribute
public void populateModel(@RequestParam String number, Model model) {
    model.addAttribute(accountRepository.findAccount(number));
    // add more ...
}
```

To add one attribute only:

```
@ModelAttribute
public Account addAccount(@RequestParam String number) {
    return accountRepository.findAccount(number);
}
```

When a name is not explicitly specified, a default name is chosen based on the Object type as explained in the Javadoc for Conventions. You can always assign an explicit name by using the overloaded `addAttribute` method or through the name attribute on `@ModelAttribute` (for a return value).

Spring WebFlux, unlike Spring MVC, explicitly supports reactive types in the model, e.g. `Mono<Account>` or `io.reactivex.Single<Account>`. Such asynchronous model attributes may be transparently resolved (and the model updated) to their actual values at the time of `@RequestMapping` invocation, providing a `@ModelAttribute` argument is declared without a wrapper, for example:

```
@ModelAttribute
public void addAccount(@RequestParam String number) {
    Mono<Account> accountMono = accountRepository.findAccount(number);
    model.addAttribute("account", accountMono);
}

@PostMapping("/accounts")
public String handle(@ModelAttribute Account account, BindingResult errors) {
    // ...
}
```

In addition any model attributes that have a reactive type wrapper are resolved to their actual values (and the model updated) just prior to view rendering.

`@ModelAttribute` can also be used as a method-level annotation on `@RequestMapping` methods in which case the return value of the `@RequestMapping` method is interpreted as a model attribute. This is typically not required, as it is the default behavior in HTML controllers, unless the return value is a `String` which would otherwise be interpreted as a view name. `@ModelAttribute` can also help to customize the model attribute name:

```
@GetMapping("/accounts/{id}")
@ModelAttribute("myAccount")
public Account handle() {
    // ...
    return account;
}
```

### 1.4.5. DataBinder

Same in Spring MVC

`@Controller` or `@ControllerAdvice` classes can have `@InitBinder` methods in order to initialize instances of `WebDataBinder`, and those in turn are used to:

- Bind request parameters (i.e. form data or query) to a model object.
- Convert String-based request values such as request parameters, path variables, headers, cookies, and others, to the target type of controller method arguments.
- Format model object values as String values when rendering HTML forms.

`@InitBinder` methods can register controller-specific `java.bean.PropertyEditor`, or Spring `Converter` and `Formatter` components. In addition, the WebFlux Java config can be used to register `Converter` and `Formatter` types in a globally shared `FormattingConversionService`.

`@InitBinder` methods support many of the same arguments that a `@RequestMapping` methods do, except for `@ModelAttribute` (command object) arguments. Typically they're are declared with a `WebDataBinder` argument, for registrations, and a `void` return value. Below is an example:

```
@Controller
public class FormController {

    <strong>@InitBinder</strong>
    public void initBinder(WebDataBinder binder) {
        SimpleDateFormat dateFormat = new SimpleDateFormat("yyyy-MM-dd");
        dateFormat.setLenient(false);
        binder.registerCustomEditor(Date.class, new CustomDateEditor(dateFormat,
false));
    }

    // ...
}
```

Alternatively when using a `Formatter`-based setup through a shared `FormattingConversionService`, you could re-use the same approach and register controller-specific `Formatter`'s:

```
@Controller
public class FormController {

    <strong>@InitBinder</strong>
    protected void initBinder(WebDataBinder binder) {
        binder.addCustomFormatter(new DateFormatter("yyyy-MM-dd"));
    }

    // ...
}
```

### 1.4.6. Exceptions

Same in Spring MVC

`@Controller` and `@ControllerAdvice` classes can have `@ExceptionHandler` methods to handle exceptions from controller methods. For example:

```
@Controller
public class SimpleController {

    // ...

    @ExceptionHandler
    public ResponseEntity<String> handle(IOException ex) {
        // ...
    }
}
```

The exception may match against a top-level exception being propagated (i.e. a direct `IOException`

thrown), or against the immediate cause within a top-level wrapper exception (e.g. an `IOException` wrapped inside an `IllegalStateException`).

For matching exception types, preferably declare the target exception as a method argument as shown above. Alternatively, the annotation declaration may narrow the exception types to match. We generally recommend to be as specific as possible in the argument signature and to declare your primary root exception mappings on a `@ControllerAdvice` prioritized with a corresponding order. See the MVC section for details.

An `@ExceptionHandler` method in WebFlux supports the same method arguments and return values as an `@RequestMapping` method, with the exception of request body and `@ModelAttribute` related method arguments.

Support for `@ExceptionHandler` methods in Spring WebFlux is provided by the `HandlerAdapter` for `@RequestMapping` methods. See Exceptions under the `DispatcherHandler` section for more details.

**REST API exceptions**

Same in Spring MVC

A common requirement for REST services is to include error details in the body of the response. The Spring Framework does not automatically do this because the representation of error details in the response body is application specific. However a `@RestController` may use `@ExceptionHandler` methods with a `ResponseEntity` return value to set the status and the body of the response. Such methods may also be declared in `@ControllerAdvice` classes to apply them globally.

Note that Spring WebFlux does not have an equivalent for the Spring MVC `ResponseEntityExceptionHandler` because WebFlux only raises `ResponseStatusException` (or subclasses thereof), which and those do not need to be translated translation to an HTTP status code.

### 1.4.7. Controller Advice

Same in Spring MVC

Typically `@ExceptionHandler`, `@InitBinder`, and `@ModelAttribute` methods apply within the `@Controller` class (or class hierarchy) they are declared in. If you want such methods to apply more globally, across controllers, you can declare them in a class marked with `@ControllerAdvice` or `@RestControllerAdvice`.

`@ControllerAdvice` is marked with `@Component` which means such classes can be registered as Spring beans via component scanning. `@RestControllerAdvice` is also a meta-annotation marked with both `@ControllerAdvice` and `@ResponseBody` which essentially means `@ExceptionHandler` methods are rendered to the response body via message conversion (vs view resolution/template rendering).

On startup, the infrastructure classes for `@RequestMapping` and `@ExceptionHandler` methods detect Spring beans of type `@ControllerAdvice`, and then apply their methods at runtime. Global `@ExceptionHandler` methods (from an `@ControllerAdvice`) are applied **after** local ones (from the `@Controller`). By contrast global `@ModelAttribute` and `@InitBinder` methods are applied **before** local

ones.

By default `@ControllerAdvice` methods apply to every request, i.e. all controllers, but you can narrow that down to a subset of controllers via attributes on the annotation:

```
// Target all Controllers annotated with @RestController
@ControllerAdvice(annotations = RestController.class)
public class ExampleAdvice1 {}

// Target all Controllers within specific packages
@ControllerAdvice("org.example.controllers")
public class ExampleAdvice2 {}

// Target all Controllers assignable to specific classes
@ControllerAdvice(assignableTypes = {ControllerInterface.class, AbstractController
.class})
public class ExampleAdvice3 {}
```

Keep in mind the above selectors are evaluated at runtime and may negatively impact performance if used extensively. See the @ControllerAdvice Javadoc for more details.

# 1.5. Functional Endpoints

Spring WebFlux includes a lightweight, functional programming model in which functions are used to route and handle requests and contracts are designed for immutability. It is an alternative to the annotated-based programming model but otherwise running on the same Reactive Core foundation

## 1.5.1. Overview

An HTTP request is handled with a **`HandlerFunction`** that takes `ServerRequest` and returns `Mono<ServerResponse>`, both of which are immutable contracts that offer JDK-8 friendly access to the HTTP request and response. `HandlerFunction` is the equivalent of an `@RequestMapping` method in the annotation-based programming model.

Requests are routed to a `HandlerFunction` with a **`RouterFunction`** that takes `ServerRequest` and returns `Mono<HandlerFunction>`. When a request is matched to a particular route, the `HandlerFunction` mapped to the route is used. `RouterFunction` is the equivalent of an `@RequestMapping` annotation.

`RouterFunctions.route(RequestPredicate, HandlerFunction)` provides a router function default implementation that can be used with a number of built-in request predicates. For example:

```
import static org.springframework.http.MediaType.APPLICATION_JSON;
import static org.springframework.web.reactive.function.server.RequestPredicates.*;
import static org.springframework.web.reactive.function.server.RouterFunctions.route;

PersonRepository repository = ...
PersonHandler handler = new PersonHandler(repository);

RouterFunction<ServerResponse> route =
    route(GET("/person/{id}").and(accept(APPLICATION_JSON)), handler::getPerson)
        .andRoute(GET("/person").and(accept(APPLICATION_JSON)), handler::listPeople)
        .andRoute(POST("/person"), handler::createPerson);


public class PersonHandler {

    // ...

    public Mono<ServerResponse> listPeople(ServerRequest request) {
        // ...
    }

    public Mono<ServerResponse> createPerson(ServerRequest request) {
        // ...
    }

    public Mono<ServerResponse> getPerson(ServerRequest request) {
        // ...
    }
}
```

One way to run a `RouterFunction` is to turn it into an `HttpHandler` and install it through one of the built-in server adapters:

- `RouterFunctions.toHttpHandler(RouterFunction)`
- `RouterFunctions.toHttpHandler(RouterFunction, HandlerStrategies)`

Most applications will run through the WebFlux Java config, see Running a server.

### 1.5.2. HandlerFunction

`ServerRequest` and `ServerResponse` are immutable interfaces that offer JDK-8 friendly access to the HTTP request and response with Reactive Streams back pressure against the request and response body stream. The request body is represented with a Reactor `Flux` or `Mono`. The response body is represented with any Reactive Streams `Publisher`, including `Flux` and `Mono`. For more on that see Reactive Libraries.

#### ServerRequest

`ServerRequest` provides access to the HTTP method, URI, headers, and query parameters while

access to the body is provided through the `body` methods.

To extract the request body to a `Mono<String>`:

```
Mono<String> string = request.bodyToMono(String.class);
```

To extract the body to a `Flux<Person>`, where `Person` objects are decoded from some serialized form, such as JSON or XML:

```
Flux<Person> people = request.bodyToFlux(Person.class);
```

The above are shortcuts that use the more general `ServerRequest.body(BodyExtractor)` which accepts the `BodyExtractor` functional, strategy interface. The utility class `BodyExtractors` provides access to a number of instances. For example, the above can also be written as follows:

```
Mono<String> string = request.body(BodyExtractors.toMono(String.class));
Flux<Person> people = request.body(BodyExtractors.toFlux(Person.class));
```

To access form data:

```
Mono<MultiValueMap<String, String> map = request.body(BodyExtractors.toFormData());
```

To access multipart data as a map:

```
Mono<MultiValueMap<String, Part> map = request.body(BodyExtractors.toMultipartData());
```

To access multiparts, one at a time, in streaming fashion:

```
Flux<Part> parts = request.body(BodyExtractos.toParts());
```

#### ServerResponse

`ServerResponse` provides access to the HTTP response and since it is immutable, you use a build to create it. The builder can be used to set the response status, to add response headers, or to provide a body. Below is an example with a 200 (OK) response with JSON content:

```
Mono<Person> person = ...
ServerResponse.ok().contentType(MediaType.APPLICATION_JSON).body(person,
Person.class);
```

This is how to build a 201 (CREATED) response with `"Location"` header, and no body:

```
URI location = ...
ServerResponse.created(location).build();
```

### Handler Classes

We can write a handler function as a lambda. For example:

```
HandlerFunction<ServerResponse> helloWorld =
  request -> ServerResponse.ok().body(fromObject("Hello World"));
```

That is convenient but in an application we need multiple functions and useful to group related handler functions together into a handler (like an `@Controller`). For example, here is a class that exposes a reactive `Person` repository:

```
import static org.springframework.http.MediaType.APPLICATION_JSON;
import static org.springframework.web.reactive.function.ServerResponse.ok;
import static org.springframework.web.reactive.function.BodyInserters.fromObject;

public class PersonHandler {

    private final PersonRepository repository;

    public PersonHandler(PersonRepository repository) {
        this.repository = repository;
    }

    public Mono<ServerResponse> listPeople(ServerRequest request) { ①
        Flux<Person> people = repository.allPeople();
        return ok().contentType(APPLICATION_JSON).body(people, Person.class);
    }

    public Mono<ServerResponse> createPerson(ServerRequest request) { ②
        Mono<Person> person = request.bodyToMono(Person.class);
        return ok().build(repository.savePerson(person));
    }

    public Mono<ServerResponse> getPerson(ServerRequest request) { ③
        int personId = Integer.valueOf(request.pathVariable("id"));
        return repository.getPerson(personId)
            .flatMap(person -> ok().contentType(APPLICATION_JSON).body(fromObject
(person)))
            .switchIfEmpty(ServerResponse.notFound().build());
    }
}
```

① `listPeople` is a handler function that returns all `Person` objects found in the repository as JSON.

② `createPerson` is a handler function that stores a new `Person` contained in the request body. Note

that `PersonRepository.savePerson(Person)` returns `Mono<Void>`: an empty Mono that emits a completion signal when the person has been read from the request and stored. So we use the `build(Publisher<Void>)` method to send a response when that completion signal is received, i.e. when the `Person` has been saved.

③ `getPerson` is a handler function that returns a single person, identified via the path variable `id`. We retrieve that `Person` via the repository, and create a JSON response if it is found. If it is not found, we use `switchIfEmpty(Mono<T>)` to return a 404 Not Found response.

### 1.5.3. RouterFunction

`RouterFunction` is used to route requests to a `HandlerFunction`. Typically, you do not write router functions yourself, but rather use `RouterFunctions.route(RequestPredicate, HandlerFunction)`. If the predicate applies, the request is routed to the given `HandlerFunction`, or otherwise no routing is performed, and that would translate to a 404 (Not Found) response.

#### Predicates

You can write your own `RequestPredicate`, but the `RequestPredicates` utility class offers commonly implementations, based on the request path, HTTP method, content-type, and so on. For example:

```
RouterFunction<ServerResponse> route =
    RouterFunctions.route(RequestPredicates.path("/hello-world"),
    request -> Response.ok().body(fromObject("Hello World")));
```

You can compose multiple request predicates together via:

- `RequestPredicate.and(RequestPredicate)` — both must match.
- `RequestPredicate.or(RequestPredicate)` — either may match.

Many of the predicates from `RequestPredicates` are composed. For example `RequestPredicates.GET(String)` is composed from `RequestPredicates.method(HttpMethod)` and `RequestPredicates.path(String)`.

You can compose multiple router functions into one, such that they're evaluated in order, and if the first route doesn't match, the second is evaluated. You can declare more specific routes before more general ones.

#### Routes

You can compose multiple router functions together via:

- `RouterFunction.and(RouterFunction)`
- `RouterFunction.andRoute(RequestPredicate, HandlerFunction)` — shortcut for `RouterFunction.and()` with nested `RouterFunctions.route()`.

Using composed routes and predicates, we can then declare the following routes, referring to methods in the `PersonHandler`, shown in [webflux-fn-handler-class], through method-references:

```
import static org.springframework.http.MediaType.APPLICATION_JSON;
import static org.springframework.web.reactive.function.server.RequestPredicates.*;

PersonRepository repository = ...
PersonHandler handler = new PersonHandler(repository);

RouterFunction<ServerResponse> personRoute =
    route(GET("/person/{id}").and(accept(APPLICATION_JSON)), handler::getPerson)
        .andRoute(GET("/person").and(accept(APPLICATION_JSON)), handler::listPeople)
        .andRoute(POST("/person"), handler::createPerson);
```

### 1.5.4. Running a server

How do you run a router function in an HTTP server? A simple option is to convert a router function to an `HttpHandler` using one of the following:

- `RouterFunctions.toHttpHandler(RouterFunction)`
- `RouterFunctions.toHttpHandler(RouterFunction, HandlerStrategies)`

The returned `HttpHandler` can then be used with a number of servers adapters by following HttpHandler for server-specific instructions.

A more advanced option is to run with a DispatcherHandler-based setup through the WebFlux Config which uses Spring configuration to declare the components quired to process requests. The WebFlux Java config declares the following infrastructure components to support functional endpoints:

- `RouterFunctionMapping` — detects one or more `RouterFunction<?>` beans in the Spring configuration, combines them via `RouterFunction.andOther`, and routes requests to the resulting composed `RouterFunction`.
- `HandlerFunctionAdapter` — simple adapter that allows the `DispatcherHandler` to invoke a `HandlerFunction` that was mapped to a request.
- `ServerResponseResultHandler` — handles the result from the invocation of a `HandlerFunction` by invoking the `writeTo` method of the `ServerResponse`.

The above components allow functional endpoints to fit within the `DispatcherHandler` request processing lifecycle, and also potentially run side by side with annotated controllers, if any are declared. It is also how functional endpoints are enabled the Spring Boot WebFlux starter.

Below is example WebFlux Java config (see DispatcherHandler for how to run):

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Bean
    public RouterFunction<?> routerFunctionA() {
        // ...
    }

    @Bean
    public RouterFunction<?> routerFunctionB() {
        // ...
    }

    // ...

    @Override
    public void configureHttpMessageCodecs(ServerCodecConfigurer configurer) {
        // configure message conversion...
    }

    @Override
    public void addCorsMappings(CorsRegistry registry) {
        // configure CORS...
    }

    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        // configure view resolution for HTML rendering...
    }
}
```

### 1.5.5. HandlerFilterFunction

Routes mapped by a router function can be filtered by calling `RouterFunction.filter(HandlerFilterFunction)`, where `HandlerFilterFunction` is essentially a function that takes a `ServerRequest` and `HandlerFunction`, and returns a `ServerResponse`. The handler function parameter represents the next element in the chain: this is typically the `HandlerFunction` that is routed to, but can also be another `FilterFunction` if multiple filters are applied. With annotations, similar functionality can be achieved using `@ControllerAdvice` and/or a `ServletFilter`. Let's add a simple security filter to our route, assuming that we have a `SecurityManager` that can determine whether a particular path is allowed:

```
import static org.springframework.http.HttpStatus.UNAUTHORIZED;

SecurityManager securityManager = ...
RouterFunction<ServerResponse> route = ...

RouterFunction<ServerResponse> filteredRoute =
    route.filter((request, next) -> {
        if (securityManager.allowAccessTo(request.path())) {
            return next.handle(request);
        }
        else {
            return ServerResponse.status(UNAUTHORIZED).build();
        }
  });
```

You can see in this example that invoking the `next.handle(ServerRequest)` is optional: we only allow the handler function to be executed when access is allowed.

CORS support for functional endpoints is provided via a dedicated `CorsWebFilter`.

# 1.6. URI Links

Same in Spring MVC

This section describes various options available in the Spring Framework to prepare URIs.

## 1.6.1. UriComponents

Spring MVC and Spring WebFlux

`UriComponentsBuilder` helps to build URI's from URI templates with variables:

```
UriComponents uriComponents = UriComponentsBuilder
        .fromUriString("http://example.com/hotels/{hotel}")  ①
        .queryParam("q", "{q}")  ②
        .encode() ③
        .build(); ④

URI uri = uriComponents.expand("Westin", "123").toUri();  ⑤
```

① Static factory method with a URI template.

② Add and/or replace URI components.

③ Request to have the URI template and URI variables encoded.

④ Build a `UriComponents`.

⑤ Expand variables, and obtain the `URI`.

The above can be consolidated into one chain and shortened with `buildAndExpand`:

```
URI uri = UriComponentsBuilder
        .fromUriString("http://example.com/hotels/{hotel}")
        .queryParam("q", "{q}")
        .encode()
        .buildAndExpand("Westin", "123")
        .toUri();
```

It can be shortened further by going directly to URI (which implies encoding):

```
URI uri = UriComponentsBuilder
        .fromUriString("http://example.com/hotels/{hotel}")
        .queryParam("q", "{q}")
        .build("Westin", "123");
```

Or shorter further yet, with a full URI template:

```
URI uri = UriComponentsBuilder
        .fromUriString("http://example.com/hotels/{hotel}?q={q}")
        .build("Westin", "123");
```

### 1.6.2. UriBuilder

Spring MVC and Spring WebFlux

`UriComponentsBuilder` implements `UriBuilder`. A `UriBuilder` in turn can be created with a `UriBuilderFactory`. Together `UriBuilderFactory` and `UriBuilder` provide a pluggable mechanism to build URIs from URI templates, based on shared configuration such as a base url, encoding preferences, and others.

The `RestTemplate` and the `WebClient` can be configured with a `UriBuilderFactory` to customize the preparation of URIs. `DefaultUriBuilderFactory` is a default implementation of `UriBuilderFactory` that uses `UriComponentsBuilder` internally and exposes shared configuration options.

`RestTemplate` example:

```
// import org.springframework.web.util.DefaultUriBuilderFactory.EncodingMode;

String baseUrl = "http://example.org";
DefaultUriBuilderFactory factory = new DefaultUriBuilderFactory(baseUrl);
factory.setEncodingMode(EncodingMode.TEMPLATE_AND_VARIABLES);

RestTemplate restTemplate = new RestTemplate();
restTemplate.setUriTemplateHandler(factory);
```

`WebClient` example:

```
// import org.springframework.web.util.DefaultUriBuilderFactory.EncodingMode;

String baseUrl = "http://example.org";
DefaultUriBuilderFactory factory = new DefaultUriBuilderFactory(baseUrl);
factory.setEncodingMode(EncodingMode.TEMPLATE_AND_VARIABLES);

WebClient client = WebClient.builder().uriBuilderFactory(factory).build();
```

In addition `DefaultUriBuilderFactory` can also be used directly. It is similar to using `UriComponentsBuilder` but instead of static factory methods, it is an actual instance that holds configuration and preferences:

```
String baseUrl = "http://example.com";
DefaultUriBuilderFactory uriBuilderFactory = new DefaultUriBuilderFactory(baseUrl);

URI uri = uriBuilderFactory.uriString("/hotels/{hotel}")
        .queryParam("q", "{q}")
        .build("Westin", "123");
```

### 1.6.3. URI Encoding

Spring MVC and Spring WebFlux

`UriComponentsBuilder` exposes encoding options at 2 levels:

1. UriComponentsBuilder#encode() - pre-encodes the URI template first, then strictly encodes URI variables when expanded.
2. UriComponents#encode() - encodes URI components *after* URI variables are expanded.

Both options replace non-ASCII and illegal characters with escaped octets, however option 1 also replaces characters with reserved meaning that appear in URI variables.

Consider ";" which is legal in a path but has reserved meaning. Option 1 replaces ";" with "%3B" in URI variables but not in the URI template. By contrast, option 2 never replaces ";" since it is a legal character in a path.

For most cases option 1 is likely to give the expected result because it treats URI variables as opaque data to be fully encoded, while option 2 is useful only if URI variables intentionally contain reserved characters.

Example usage using option 1:

```
URI uri = UriComponentsBuilder.fromPath("/hotel list/{city}")
            .queryParam("q", "{q}")
            .encode()
            .buildAndExpand("New York", "foo+bar")
            .toUri();

    // Result is "/hotel%20list/New%20York?q=foo%2Bbar"
```

The above can be shortened by going directly to URI (which implies encoding):

```
URI uri = UriComponentsBuilder.fromPath("/hotel list/{city}")
            .queryParam("q", "{q}")
            .build("New York", "foo+bar")
```

Or shorter further yet, with a full URI template:

```
URI uri = UriComponentsBuilder.fromPath("/hotel list/{city}?q={q}")
            .build("New York", "foo+bar")
```

The `WebClient` and the `RestTemplate` expand and encode URI templates internally through the `UriBuilderFactory` strategy. Both can be configured with a custom strategy:

```
String baseUrl = "http://example.com";
DefaultUriBuilderFactory factory = new DefaultUriBuilderFactory(baseUrl)
factory.setEncodingMode(EncodingMode.TEMPLATE_AND_VALUES);

// Customize the RestTemplate..
RestTemplate restTemplate = new RestTemplate();
restTemplate.setUriTemplateHandler(factory);

// Customize the WebClient..
WebClient client = WebClient.builder().uriBuilderFactory(factory).build();
```

The `DefaultUriBuilderFactory` implementation uses `UriComponentsBuilder` internally to expand and encode URI templates. As a factory it provides a single place to configure the approach to encoding based on one of the below encoding modes:

- `TEMPLATE_AND_VALUES` — uses `UriComponentsBuilder#encode()`, corresponding to option 1 above, to pre-encode the URI template and strictly encode URI variables when expanded.
- `VALUES_ONLY` — does not encode the URI template and instead applies strict encoding to URI variables via `UriUtils#encodeUriUriVariables` prior to expanding them into the template.
- `URI_COMPONENTS` — uses `UriComponents#encode()`, corresponding to option 2 above, to encode URI component value *after* URI variables are expanded.
- `NONE` — no encoding is applied.

Out of the box the `RestTemplate` is set to `EncodingMode.URI_COMPONENTS` for historic reasons and for backwards compatibility. The `WebClient` relies on the default value in `DefaultUriBuilderFactory` which was changed from `EncodingMode.URI_COMPONENTS` in 5.0.x to `EncodingMode.TEMPLATE_AND_VALUES` in 5.1.

# 1.7. CORS

Same in Spring MVC

## 1.7.1. Introduction

Same in Spring MVC

For security reasons browsers prohibit AJAX calls to resources outside the current origin. For example you could have your bank account in one tab and evil.com in another. Scripts from evil.com should not be able to make AJAX requests to your bank API with your credentials, e.g. withdrawing money from your account!

Cross-Origin Resource Sharing (CORS) is a W3C specification implemented by most browsers that allows you to specify what kind of cross domain requests are authorized rather than using less secure and less powerful workarounds based on IFRAME or JSONP.

## 1.7.2. Processing

Same in Spring MVC

The CORS specification distinguishes between preflight, simple, and actual requests. To learn how CORS works, you can read this article, among many others, or refer to the specification for more details.

Spring WebFlux `HandlerMapping`'s provide built-in support for CORS. After successfully mapping a request to a handler, `HandlerMapping`'s check the CORS configuration for the given request and handler and take further actions. Preflight requests are handled directly while simple and actual CORS requests are intercepted, validated, and have required CORS response headers set.

In order to enable cross-origin requests (i.e. the `Origin` header is present and differs from the host of the request) you need to have some explicitly declared CORS configuration. If no matching CORS configuration is found, preflight requests are rejected. No CORS headers are added to the responses of simple and actual CORS requests and consequently browsers reject them.

Each `HandlerMapping` can be configured individually with URL pattern based `CorsConfiguration` mappings. In most cases applications will use the WebFlux Java config to declare such mappings, which results in a single, global map passed to all `HadlerMappping`'s.

Global CORS configuration at the `HandlerMapping` level can be combined with more fine-grained, handler-level CORS configuration. For example annotated controllers can use class or method-level `@CrossOrigin` annotations (other handlers can implement `CorsConfigurationSource`).

The rules for combining global and local configuration are generally additive — e.g. all global and

all local origins. For those attributes where only a single value can be accepted such as `allowCredentials` and `maxAge`, the local overrides the global value. See `CorsConfiguration#combine(CorsConfiguration)` for more details.

To learn more from the source or make advanced customizations, check:

- `CorsConfiguration`
- `CorsProcessor`, `DefaultCorsProcessor`
- `AbstractHandlerMapping`

### 1.7.3. @CrossOrigin

Same in Spring MVC

The `@CrossOrigin` annotation enables cross-origin requests on annotated controller methods:

```
@RestController
@RequestMapping("/account")
public class AccountController {

    @CrossOrigin
    @GetMapping("/{id}")
    public Mono<Account> retrieve(@PathVariable Long id) {
        // ...
    }

    @DeleteMapping("/{id}")
    public Mono<Void> remove(@PathVariable Long id) {
        // ...
    }
}
```

By default `@CrossOrigin` allows:

- All origins.
- All headers.
- All HTTP methods to which the controller method is mapped.
- `allowedCredentials` is not enabled by default since that establishes a trust level that exposes sensitive user-specific information such as cookies and CSRF tokens, and should only be used where appropriate.
- `maxAge` is set to 30 minutes.

`@CrossOrigin` is supported at the class level too and inherited by all methods:

```
@CrossOrigin(origins = "http://domain2.com", maxAge = 3600)
@RestController
@RequestMapping("/account")
public class AccountController {

    @GetMapping("/{id}")
    public Mono<Account> retrieve(@PathVariable Long id) {
        // ...
    }

    @DeleteMapping("/{id}")
    public Mono<Void> remove(@PathVariable Long id) {
        // ...
    }
}
```

`CrossOrigin` can be used at both class and method-level:

```
@CrossOrigin(maxAge = 3600)
@RestController
@RequestMapping("/account")
public class AccountController {

    @CrossOrigin("http://domain2.com")
    @GetMapping("/{id}")
    public Mono<Account> retrieve(@PathVariable Long id) {
        // ...
    }

    @DeleteMapping("/{id}")
    public Mono<Void> remove(@PathVariable Long id) {
        // ...
    }
}
```

### 1.7.4. Global Config

Same in Spring MVC

In addition to fine-grained, controller method level configuration you'll probably want to define some global CORS configuration too. You can set URL-based `CorsConfiguration` mappings individually on any `HandlerMapping`. Most applications however will use the WebFlux Java config to do that.

By default global configuration enables the following:

- All origins.
- All headers.

- `GET`, `HEAD`, and `POST` methods.
- `allowedCredentials` is not enabled by default since that establishes a trust level that exposes sensitive user-specific information such as cookies and CSRF tokens, and should only be used where appropriate.
- `maxAge` is set to 30 minutes.

To enable CORS in the WebFlux Java config, use the `CorsRegistry` callback:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void addCorsMappings(CorsRegistry registry) {

        registry.addMapping("/api/**")
            .allowedOrigins("http://domain2.com")
            .allowedMethods("PUT", "DELETE")
            .allowedHeaders("header1", "header2", "header3")
            .exposedHeaders("header1", "header2")
            .allowCredentials(true).maxAge(3600);

        // Add more mappings...
    }
}
```

### 1.7.5. CORS WebFilter

Same in Spring MVC

You can apply CORS support through the built-in `CorsWebFilter`, which is a good fit with functional endpoints.

To configure the filter, you can declare a `CorsWebFilter` bean and pass a `CorsConfigurationSource` to its constructor:

```
@Bean
CorsWebFilter corsFilter() {

    CorsConfiguration config = new CorsConfiguration();

    // Possibly...
    // config.applyPermitDefaultValues()

    config.setAllowCredentials(true);
    config.addAllowedOrigin("http://domain1.com");
    config.addAllowedHeader("*");
    config.addAllowedMethod("*");

    UrlBasedCorsConfigurationSource source = new UrlBasedCorsConfigurationSource();
    source.registerCorsConfiguration("/**", config);

    return new CorsWebFilter(source);
}
```

## 1.8. Web Security

Same in Spring MVC

The Spring Security project provides support for protecting web applications from malicious exploits. Check out the Spring Security reference documentation including:

- WebFlux Security
- "WebFlux Testing Support"
- CSRF Protection
- Security Response Headers

## 1.9. View Technologies

Same in Spring MVC

The use of view technologies in Spring WebFlux is pluggable, whether you decide to use Thymeleaf, FreeMarker, or other, is primarily a matter of a configuration change. This chapter covers view technologies integrated with Spring WebFlux. We assume you are already familiar with View Resolution.

### 1.9.1. Thymeleaf

Same in Spring MVC

Thymeleaf is modern server-side Java template engine that emphasizes natural HTML templates that can be previewed in a browser by double-clicking, which is very helpful for independent work on UI templates, e.g. by designer, without the need for a running server. Thymeleaf offers an

extensive set of features and it is actively developed and maintained. For a more complete introduction see the Thymeleaf project home page.

The Thymeleaf integration with Spring WebFlux is managed by the Thymeleaf project. The configuration involves a few bean declarations such as `SpringResourceTemplateResolver`, `SpringWebFluxTemplateEngine`, and `ThymeleafReactiveViewResolver`. For more details see Thymeleaf+Spring and the WebFlux integration announcement.

### 1.9.2. FreeMarker

Same in Spring MVC

Apache FreeMarker is a template engine for generating any kind of text output from HTML to email, and others. The Spring Framework has a built-in integration for using Spring WebFlux with FreeMarker templates.

#### View config

Same in Spring MVC

To configure FreeMarker as a view technology:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        registry.freemarker();
    }

    // Configure FreeMarker...

    @Bean
    public FreeMarkerConfigurer freeMarkerConfigurer() {
        FreeMarkerConfigurer configurer = new FreeMarkerConfigurer();
        configurer.setTemplateLoaderPath("classpath:/templates");
        return configurer;
    }
}
```

Your templates need to be stored in the directory specified by the `FreeMarkerConfigurer` shown above. Given the above configuration if your controller returns the view name "welcome" then the resolver will look for the `classpath:/templates/freemarker/welcome.ftl` template.

#### FreeMarker config

Same in Spring MVC

FreeMarker 'Settings' and 'SharedVariables' can be passed directly to the FreeMarker `Configuration`

object managed by Spring by setting the appropriate bean properties on the `FreeMarkerConfigurer` bean. The `freemarkerSettings` property requires a `java.util.Properties` object and the `freemarkerVariables` property requires a `java.util.Map`.

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    // ...

    @Bean
    public FreeMarkerConfigurer freeMarkerConfigurer() {
        Map<String, Object> variables = new HashMap<>();
        variables.put("xml_escape", new XmlEscape());

        FreeMarkerConfigurer configurer = new FreeMarkerConfigurer();
        configurer.setTemplateLoaderPath("classpath:/templates");
        configurer.setFreemarkerVariables(variables);
        return configurer;
    }
}
```

See the FreeMarker documentation for details of settings and variables as they apply to the `Configuration` object.

### 1.9.3. Script Views

Same in Spring MVC

The Spring Framework has a built-in integration for using Spring WebFlux with any templating library that can run on top of the JSR-223 Java scripting engine. Below is a list of templating libraries we've tested on different script engines:

**Handlebars**
: Nashorn

**Mustache**
: Nashorn

**React**
: Nashorn

**EJS**
: Nashorn

**ERB**
: JRuby

**String templates**

Jython

**Kotlin Script templating**

Kotlin

The basic rule for integrating any other script engine is that it must implement the `ScriptEngine` and `Invocable` interfaces.

### Requirements

Same in Spring MVC

You need to have the script engine on your classpath:

- Nashorn JavaScript engine is provided with Java 8+. Using the latest update release available is highly recommended.
- JRuby should be added as a dependency for Ruby support.
- Jython should be added as a dependency for Python support.
- `org.jetbrains.kotlin:kotlin-script-util` dependency and a `META-INF/services/javax.script.ScriptEngineFactory` file containing a `org.jetbrains.kotlin.script.jsr223.KotlinJsr223JvmLocalScriptEngineFactory` line should be added for Kotlin script support, see this example for more details.

You need to have the script templating library. One way to do that for Javascript is through WebJars.

### Script templates

Same in Spring MVC

Declare a `ScriptTemplateConfigurer` bean in order to specify the script engine to use, the script files to load, what function to call to render templates, and so on. Below is an example with Mustache templates and the Nashorn JavaScript engine:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        registry.scriptTemplate();
    }

    @Bean
    public ScriptTemplateConfigurer configurer() {
        ScriptTemplateConfigurer configurer = new ScriptTemplateConfigurer();
        configurer.setEngineName("nashorn");
        configurer.setScripts("mustache.js");
        configurer.setRenderObject("Mustache");
        configurer.setRenderFunction("render");
        return configurer;
    }
}
```

The render function is called with the following parameters:

- `String template`: the template content
- `Map model`: the view model
- `RenderingContext renderingContext`: the RenderingContext that gives access to the application context, the locale, the template loader and the url (since 5.0)

`Mustache.render()` is natively compatible with this signature, so you can call it directly.

If your templating technology requires some customization, you may provide a script that implements a custom render function. For example, Handlerbars needs to compile templates before using them, and requires a polyfill in order to emulate some browser facilities not available in the server-side script engine.

```
@Configuration
@EnableWebMvc
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        registry.scriptTemplate();
    }

    @Bean
    public ScriptTemplateConfigurer configurer() {
        ScriptTemplateConfigurer configurer = new ScriptTemplateConfigurer();
        configurer.setEngineName("nashorn");
        configurer.setScripts("polyfill.js", "handlebars.js", "render.js");
        configurer.setRenderFunction("render");
        configurer.setSharedEngine(false);
        return configurer;
    }
}
```

Setting the `sharedEngine` property to `false` is required when using non thread-safe script engines with templating libraries not designed for concurrency, like Handlebars or React running on Nashorn for example. In that case, Java 8u60 or greater is required due to this bug.

`polyfill.js` only defines the `window` object needed by Handlebars to run properly:

```
var window = {};
```

This basic `render.js` implementation compiles the template before using it. A production ready implementation should also store and reused cached templates / pre-compiled templates. This can be done on the script side, as well as any customization you need (managing template engine configuration for example).

```
function render(template, model) {
    var compiledTemplate = Handlebars.compile(template);
    return compiledTemplate(model);
}
```

Check out the Spring Framework unit tests, java, and resources, for more configuration examples.

### 1.9.4. JSON, XML

Same in Spring MVC

For Content negotiation purposes it is useful to be able to alternate between rendering a model

with an HTML template or as other formats such as JSON or XML, depending on the content type requested by the client. To support this Spring WebFlux provides the `HttpMessageWriterView` that can be used to plug in any of the available Codecs from `spring-web` such as `Jackson2JsonEncoder`, `Jackson2SmileEncoder`, or `Jaxb2XmlEncoder`.

Unlike other view technologies, `HttpMessageWriterView` does not require a `ViewResolver`, but instead is configured as a default view. You can configure one more such default views, wrapping different `HttpMessageWriter`'s or `Encoder`'s. The one that matches the requested content type is used at runtime.

In most cases a model will contain multiple attributes. In order to determine which one to serialize, `HttpMessageWriterView` can be configured with the name of the model attribute to use render, of if the model contains only one attribute, it will be used.

# 1.10. HTTP Caching

Same in Spring MVC

HTTP caching can significantly improve the performance of a web application. HTTP caching revolves around the "Cache-Control" response header and subsequently conditional request headers such as "Last-Modified" and "ETag". "Cache-Control" advises private (e.g. browser) and public (e.g. proxy) caches how to cache and re-use responses. An "ETag" header is used to make a conditional request that may result in a 304 (NOT_MODIFIED) without a body, if the content has not changed. "ETag" can be seen as a more sophisticated successor to the `Last-Modified` header.

This section describes HTTP caching related options available in Spring Web MVC.

## 1.10.1. `CacheControl`

Same in Spring MVC

`CacheControl` provides support for configuring settings related to the "Cache-Control" header and is accepted as an argument in a number of places:

- Controllers
- Static resources

While RFC 7234 describes all possible directives for the "Cache-Control" response header, the `CacheControl` type takes a use case oriented approach focusing on the common scenarios:

```
// Cache for an hour - "Cache-Control: max-age=3600"
CacheControl ccCacheOneHour = CacheControl.maxAge(1, TimeUnit.HOURS);

// Prevent caching - "Cache-Control: no-store"
CacheControl ccNoStore = CacheControl.noStore();

// Cache for ten days in public and private caches,
// public caches should not transform the response
// "Cache-Control: max-age=864000, public, no-transform"
CacheControl ccCustom = CacheControl.maxAge(10, TimeUnit.DAYS).noTransform()
.cachePublic();
```

### 1.10.2. Controllers

Same in Spring MVC

Controllers can add explicit support for HTTP caching. This is recommended since the lastModified or ETag value for a resource needs to be calculated before it can be compared against conditional request headers. A controller can add an ETag and "Cache-Control" settings to a `ResponseEntity`:

```
@GetMapping("/book/{id}")
public ResponseEntity<Book> showBook(@PathVariable Long id) {

    Book book = findBook(id);
    String version = book.getVersion();

    return ResponseEntity
            .ok()
            .cacheControl(CacheControl.maxAge(30, TimeUnit.DAYS))
            .eTag(version) // lastModified is also available
            .body(book);
}
```

This will send an 304 (NOT_MODIFIED) response with an empty body, if the comparison to the conditional request headers indicates the content has not changed. Otherwise the "ETag" and "Cache-Control" headers will be added to the response.

The check against conditional request headers can also be made in the controller:

```
@RequestMapping
public String myHandleMethod(ServerWebExchange exchange, Model model) {

    long eTag = ... ①

    if (exchange.checkNotModified(eTag)) {
        return null; ②
    }

    model.addAttribute(...); ③
    return "myViewName";
}
```

① Application-specific calculation.

② Response has been set to 304 (NOT_MODIFIED), no further processing.

③ Continue with request processing.

There are 3 variants for checking conditional requests against eTag values, lastModified values, or both. For conditional "GET" and "HEAD" requests, the response may be set to 304 (NOT_MODIFIED). For conditional "POST", "PUT", and "DELETE", the response would be set to 409 (PRECONDITION_FAILED) instead to prevent concurrent modification.

### 1.10.3. Static resources

Same in Spring MVC

Static resources should be served with a "Cache-Control" and conditional response headers for optimal performance. See section on configuring Static resources.

## 1.11. WebFlux Config

Same in Spring MVC

The WebFlux Java config declares components required to process requests with annotated controllers or functional endpoints, and it offers an API to customize the configuration. That means you do not need to understand the underlying beans created by the Java config but, if you want to, it's very easy to see them in `WebFluxConfigurationSupport` or read more what they are in Special bean types.

For more advanced customizations, not available in the configuration API, it is also possible to gain full control over the configuration through the Advanced config mode.

### 1.11.1. Enable WebFlux config

Same in Spring MVC

Use the `@EnableWebFlux` annotation in your Java config:

```
@Configuration
@EnableWebFlux
public class WebConfig {
}
```

The above registers a number of Spring WebFlux infrastructure beans also adapting to dependencies available on the classpath — for JSON, XML, etc.

### 1.11.2. WebFlux config API

Same in Spring MVC

In your Java config implement the `WebFluxConfigurer` interface:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    // Implement configuration methods...

}
```

### 1.11.3. Conversion, formatting

Same in Spring MVC

By default formatters for `Number` and `Date` types are installed, including support for the `@NumberFormat` and `@DateTimeFormat` annotations. Full support for the Joda-Time formatting library is also installed if Joda-Time is present on the classpath.

To register custom formatters and converters:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void addFormatters(FormatterRegistry registry) {
        // ...
    }

}
```

See FormatterRegistrar SPI and the `FormattingConversionServiceFactoryBean` for more information on when to use FormatterRegistrars.

### 1.11.4. Validation

Same in Spring MVC

By default if Bean Validation is present on the classpath — e.g. Hibernate Validator, the `LocalValidatorFactoryBean` is registered as a global Validator for use with `@Valid` and `Validated` on `@Controller` method arguments.

In your Java config, you can customize the global `Validator` instance:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public Validator getValidator(); {
        // ...
    }

}
```

Note that you can also register `Validator`'s locally:

```
@Controller
public class MyController {

    @InitBinder
    protected void initBinder(WebDataBinder binder) {
        binder.addValidators(new FooValidator());
    }

}
```

If you need to have a `LocalValidatorFactoryBean` injected somewhere, create a bean and mark it with `@Primary` in order to avoid conflict with the one declared in the MVC config.

### 1.11.5. Content type resolvers

Same in Spring MVC

You can configure how Spring WebFlux determines the requested media types for `@Controller`'s from the request. By default only the "Accept" header is checked but you can also enable a query parameter based strategy.

To customize the requested content type resolution:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void configureContentTypeResolver(RequestedContentTypeResolverBuilder
builder) {
        // ...
    }
}
```

### 1.11.6. HTTP message codecs

Same in Spring MVC

To customize how the request and response body are read and written:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void configureHttpMessageCodecs(ServerCodecConfigurer configurer) {
        // ...
    }
}
```

`ServerCodecConfigurer` provides a set of default readers and writers. You can use it to add more readers and writers, customize the default ones, or replace the default ones completely.

For Jackson JSON and XML, consider using the Jackson2ObjectMapperBuilder which customizes Jackson's default properties with the following ones:

1. `DeserializationFeature.FAIL_ON_UNKNOWN_PROPERTIES` is disabled.
2. `MapperFeature.DEFAULT_VIEW_INCLUSION` is disabled.

It also automatically registers the following well-known modules if they are detected on the classpath:

1. jackson-datatype-jdk7: support for Java 7 types like `java.nio.file.Path`.
2. jackson-datatype-joda: support for Joda-Time types.
3. jackson-datatype-jsr310: support for Java 8 Date & Time API types.
4. jackson-datatype-jdk8: support for other Java 8 types like `Optional`.

### 1.11.7. View resolvers

Same in Spring MVC

To configure view resolution:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        // ...
    }
}
```

The `ViewResolverRegistry` has shortcuts for view technologies that the Spring Framework integrates with. Here is an example with FreeMarker which also requires configuring the underlying FreeMarker view technology:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {


    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        registry.freeMarker();
    }

    // Configure Freemarker...

    @Bean
    public FreeMarkerConfigurer freeMarkerConfigurer() {
        FreeMarkerConfigurer configurer = new FreeMarkerConfigurer();
        configurer.setTemplateLoaderPath("classpath:/templates");
        return configurer;
    }
}
```

You can also plug in any `ViewResolver` implementation:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {


    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        ViewResolver resolver = ... ;
        registry.viewResolver(resolver);
    }
}
```

To support Content negotiation and rendering other formats through view resolution, besides HTML, you can configure one or more default views based on the `HttpMessageWriterView` implementation which accepts any of the available Codecs from `spring-web`:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {


    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        registry.freeMarker();

        Jackson2JsonEncoder encoder = new Jackson2JsonEncoder();
        registry.defaultViews(new HttpMessageWriterView(encoder));
    }

    // ...
}
```

See View Technologies for more on the view technologies integrated with Spring WebFlux.

### 1.11.8. Static resources

Same in Spring MVC

This option provides a convenient way to serve static resources from a list of Resource-based locations.

In the example below, given a request that starts with `"/resources"`, the relative path is used to find and serve static resources relative to `"/static"` on the classpath. Resources will be served with a 1-year future expiration to ensure maximum use of the browser cache and a reduction in HTTP requests made by the browser. The `Last-Modified` header is also evaluated and if present a `304` status code is returned.

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void addResourceHandlers(ResourceHandlerRegistry registry) {
        registry.addResourceHandler("/resources/**")
            .addResourceLocations("/public", "classpath:/static/")
            .setCacheControl(CacheControl.maxAge(365, TimeUnit.DAYS));
    }

}
```

The resource handler also supports a chain of ResourceResolver's and ResourceTransformer's. which can be used to create a toolchain for working with optimized resources.

The `VersionResourceResolver` can be used for versioned resource URLs based on an MD5 hash computed from the content, a fixed application version, or other. A `ContentVersionStrategy` (MD5 hash) is a good choice with some notable exceptions such as JavaScript resources used with a module loader.

For example in your Java config;

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void addResourceHandlers(ResourceHandlerRegistry registry) {
        registry.addResourceHandler("/resources/**")
                .addResourceLocations("/public/")
                .resourceChain(true)
                .addResolver(new VersionResourceResolver().addContentVersionStrategy(
"/**"));
    }

}
```

You can use `ResourceUrlProvider` to rewrite URLs and apply the full chain of resolvers and transformers — e.g. to insert versions. The WebFlux config provides a `ResourceUrlProvider` so it can be injected into others.

Unlike Spring MVC at present in WebFlux there is no way to transparently rewrite static resource URLs since there are no view technologies that can make use of a non-blocking chain of resolvers and transformers. When serving only local resources the workaround is to use `ResourceUrlProvider` directly (e.g. through a custom tag) and block.

Note that when using both `GzipResourceResolver` and `VersionedResourceResolver`, they must be

registered in that order to ensure content based versions are always computed reliably based on the unencoded file.

WebJars is also supported via `WebJarsResourceResolver` and automatically registered when `"org.webjars:webjars-locator"` is present on the classpath. The resolver can re-write URLs to include the version of the jar and can also match to incoming URLs without versions — e.g. `"/jquery/jquery.min.js"` to `"/jquery/1.2.0/jquery.min.js"`.

### 1.11.9. Path Matching

Same in Spring MVC

Spring WebFlux uses parsed representation of path patterns — i.e. `PathPattern`, and also the incoming request path — i.e. `RequestPath`, which eliminates the need to indicate whether to decode the request path, or remove semicolon content, since `PathPattern` can now access decoded path segment values and match safely.

Spring WebFlux also does not support suffix pattern matching so effectively there are only two minor options to customize related to path matching — whether to match trailing slashes (`true` by default) and whether the match is case-sensitive (`false`).

To customize those options:

```
@Configuration
@EnableWebFlux
public class WebConfig implements WebFluxConfigurer {

    @Override
    public void configurePathMatch(PathMatchConfigurer configurer) {
        // ...
    }

}
```

### 1.11.10. Advanced config mode

Same in Spring MVC

`@EnableWebFlux` imports `DelegatingWebFluxConfiguration` that (1) provides default Spring configuration for WebFlux applications and (2) detects and delegates to `WebFluxConfigurer`'s to customize that configuration.

For advanced mode, remove `@EnableWebFlux` and extend directly from `DelegatingWebFluxConfiguration` instead of implementing `WebFluxConfigurer`:

```
@Configuration
public class WebConfig extends DelegatingWebFluxConfiguration {

    // ...

}
```

You can keep existing methods in `WebConfig` but you can now also override bean declarations from the base class and you can still have any number of other `WebMvcConfigurer`'s on the classpath.

## 1.12. HTTP/2

Same in Spring MVC

Servlet 4 containers are required to support HTTP/2 and Spring Framework 5 is compatible with Servlet API 4. From a programming model perspective there is nothing specific that applications need to do. However there are considerations related to server configuration. For more details please check out the HTTP/2 wiki page.

Currently Spring WebFlux does not support HTTP/2 with Netty. There is also no support for pushing resources programmatically to the client.

# Chapter 2. WebClient

The `spring-webflux` module includes a reactive, non-blocking client for HTTP requests with a functional-style API client and Reactive Streams support. `WebClient` depends on a lower level HTTP client library to execute requests and that support is pluggable.

`WebClient` uses the same codecs as WebFlux server applications do, and shares a common base package, some common APIs, and infrastructure with the server functional web framework. The API exposes Reactor `Flux` and `Mono` types, also see Reactive Libraries. By default it uses it uses Reactor Netty as the HTTP client library but others can be plugged in through a custom `ClientHttpConnector`.

By comparison to the RestTemplate, the `WebClient` is:

- non-blocking, reactive, and supports higher concurrency with less hardware resources.
- provides a functional API that takes advantage of Java 8 lambdas.
- supports both synchronous and asynchronous scenarios.
- supports streaming up or down from a server.

The `RestTemplate` is not a good fit for use in non-blocking applications, and therefore Spring WebFlux application should always use the `WebClient`. The `WebClient` should also be preferred in Spring MVC, in most high concurrency scenarios, and for composing a sequence of remote, inter-dependent calls.

## 2.1. Retrieve

The `retrieve()` method is the easiest way to get a response body and decode it:

```
WebClient client = WebClient.create("http://example.org");

Mono<Person> result = client.get()
        .uri("/persons/{id}", id).accept(MediaType.APPLICATION_JSON)
        .retrieve()
        .bodyToMono(Person.class);
```

You can also get a stream of objects decoded from the response:

```
Flux<Quote> result = client.get()
        .uri("/quotes").accept(MediaType.TEXT_EVENT_STREAM)
        .retrieve()
        .bodyToFlux(Quote.class);
```

By default, responses with 4xx or 5xx status codes result in an error of type `WebClientResponseException` but you can customize that:

```
Mono<Person> result = client.get()
        .uri("/persons/{id}", id).accept(MediaType.APPLICATION_JSON)
        .retrieve()
        .onStatus(HttpStatus::is4xxServerError, response -> ...)
        .onStatus(HttpStatus::is5xxServerError, response -> ...)
        .bodyToMono(Person.class);
```

## 2.2. Exchange

The `exchange()` method provides more control. The below example is equivalent to `retrieve()` but also provides access to the `ClientResponse`:

```
Mono<Person> result = client.get()
        .uri("/persons/{id}", id).accept(MediaType.APPLICATION_JSON)
        .exchange()
        .flatMap(response -> response.bodyToMono(Person.class));
```

At this level you can also create a full `ResponseEntity`:

```
Mono<ResponseEntity<Person>> result = client.get()
        .uri("/persons/{id}", id).accept(MediaType.APPLICATION_JSON)
        .exchange()
        .flatMap(response -> response.toEntity(Person.class));
```

Note that unlike `retrieve()`, with `exchange()` there are no automatic error signals for 4xx and 5xx responses. You have to check the status code and decide how to proceed.

When using `exchange()` you must always use any of the body or toEntity methods of `ClientResponse` to ensure resources are released and to avoid potential issues with HTTP connection pooling. You can use `bodyToMono(Void.class)` if no response content is expected. However keep in mind that if the response does have content, the connection will be closed and will not be placed back in the pool.

## 2.3. Request body

The request body can be encoded from an Object:

```
Mono<Person> personMono = ... ;

Mono<Void> result = client.post()
        .uri("/persons/{id}", id)
        .contentType(MediaType.APPLICATION_JSON)
        .body(personMono, Person.class)
        .retrieve()
        .bodyToMono(Void.class);
```

You can also have a stream of objects encoded:

```
Flux<Person> personFlux = ... ;

Mono<Void> result = client.post()
        .uri("/persons/{id}", id)
        .contentType(MediaType.APPLICATION_STREAM_JSON)
        .body(personFlux, Person.class)
        .retrieve()
        .bodyToMono(Void.class);
```

Or if you have the actual value, use the `syncBody` shortcut method:

```
Person person = ... ;

Mono<Void> result = client.post()
        .uri("/persons/{id}", id)
        .contentType(MediaType.APPLICATION_JSON)
        .syncBody(person)
        .retrieve()
        .bodyToMono(Void.class);
```

### 2.3.1. Form data

To send form data, provide a `MultiValueMap<String, String>` as the body. Note that the content is automatically set to `"application/x-www-form-urlencoded"` by the `FormHttpMessageWriter`:

```
MultiValueMap<String, String> formData = ... ;

Mono<Void> result = client.post()
        .uri("/path", id)
        .syncBody(formData)
        .retrieve()
        .bodyToMono(Void.class);
```

You can also supply form data in-line via `BodyInserters`:

```
import static org.springframework.web.reactive.function.BodyInserters.*;

Mono<Void> result = client.post()
        .uri("/path", id)
        .body(fromFormData("k1", "v1").with("k2", "v2"))
        .retrieve()
        .bodyToMono(Void.class);
```

### 2.3.2. Multipart data

To send multipart data, you need to provide a `MultiValueMap<String, ?>` whose values are either Objects representing part content, or `HttpEntity` representing the content and headers for a part. `MultipartBodyBuilder` provides a convenient API to prepare a multipart request:

```
MultipartBodyBuilder builder = new MultipartBodyBuilder();
builder.part("fieldPart", "fieldValue");
builder.part("filePart", new FileSystemResource("...logo.png"));
builder.part("jsonPart", new Person("Jason"));

MultiValueMap<String, HttpEntity<?>> parts = builder.build();
```

In most cases you do not have to specify the `Content-Type` for each part. The content type is determined automatically based on the `HttpMessageWriter` chosen to serialize it, or in the case of a `Resource` based on the file extension. If necessary you can explicitly provide the `MediaType` to use for each part through one fo the overloaded builder `part` methods.

Once a `MultiValueMap` is prepared, the easiest way to pass it to the the `WebClient` is through the `syncBody` method:

```
MultipartBodyBuilder builder = ...;

Mono<Void> result = client.post()
        .uri("/path", id)
        .syncBody(<strong>builder.build()</strong>)
        .retrieve()
        .bodyToMono(Void.class);
```

If the `MultiValueMap` contains at least one non-String value, which could also be represent regular form data (i.e. "application/x-www-form-urlencoded"), you don't have to set the `Content-Type` to "multipart/form-data". This is always the case when using `MultipartBodyBuilder` which ensures an `HttpEntity` wrapper.

As an alternative to `MultipartBodyBuilder`, you can also provide multipart content, inline-style, through the built-in `BodyInserters`. For example:

```
import static org.springframework.web.reactive.function.BodyInserters.*;

Mono<Void> result = client.post()
        .uri("/path", id)
        .body(fromMultipartData("fieldPart", "value").with("filePart", resource))
        .retrieve()
        .bodyToMono(Void.class);
```

## 2.4. Builder options

A simple way to create `WebClient` is through the static factory methods `create()` and `create(String)` with a base URL for all requests. You can also use `WebClient.builder()` for access to more options.

To customize the underlying HTTP client:

```
SslContext sslContext = ...

ClientHttpConnector connector = new ReactorClientHttpConnector(
        builder -> builder.sslContext(sslContext));

WebClient webClient = WebClient.builder()
        .clientConnector(connector)
        .build();
```

To customize the HTTP codecs used for encoding and decoding HTTP messages:

```
ExchangeStrategies strategies = ExchangeStrategies.builder()
        .codecs(configurer -> {
            // ...
        })
        .build();

WebClient webClient = WebClient.builder()
        .exchangeStrategies(strategies)
        .build();
```

The builder can be used to insert Client Filters.

Explore the `WebClient.Builder` in your IDE for other options related to URI building, default headers (and cookies), and more.

After the `WebClient` is built, you can always obtain a new builder from it, in order to build a new `WebClient`, based on, but without affecting the current instance:

```
    WebClient modifiedClient = client.mutate()
            // user builder methods...
            .build();
```

## 2.5. Client Filters

You can register an `ExchangeFilterFunction` in the `WebClient.Builder` to intercept and possibly modify requests performed through the client:

```
WebClient client = WebClient.builder()
        .filter((request, next) -> {

            ClientRequest filtered = ClientRequest.from(request)
                    .header("foo", "bar")
                    .build();

            return next.exchange(filtered);
        })
        .build();
```

This can be used for cross-cutting concerns such as authentication. The example below uses a filter for basic authentication through a static factory method:

```
// static import of ExchangeFilterFunctions.basicAuthentication

WebClient client = WebClient.builder()
        .filter(basicAuthentication("user", "password"))
        .build();
```

Filters apply globally to every request. To change how a filter's behavior for a specific request, you can add request attributes to the `ClientRequest` that can then be accessed by all filters in the chain:

```
WebClient client = WebClient.builder()
        .filter((request, next) -> {
            Optional<Object> usr = request.attribute("myAttribute");
            // ...
        })
        .build();

client.get().uri("http://example.org/")
        .attribute("myAttribute", "...")
        .retrieve()
        .bodyToMono(Void.class);

    }
```

You can also replicate an existing `WebClient`, and insert new filters or remove already registered filters. In the example below, a basic authentication filter is inserted at index 0:

```
// static import of ExchangeFilterFunctions.basicAuthentication

WebClient client = webClient.mutate()
        .filters(filterList -> {
            filterList.add(0, basicAuthentication("user", "password"));
        })
        .build();
```

## 2.6. Testing

To test code that uses the `WebClient`, you can use a mock web server such as the OkHttp MockWebServer. To see example use, check WebClientIntegrationTests in the Spring Framework tests, or the static-server sample in the OkHttp repository.

# Chapter 3. WebSockets

Same in Servlet stack

This part of the reference documentation covers support for Reactive stack, WebSocket messaging.

## 3.1. Introduction

The WebSocket protocol RFC 6455 provides a standardized way to establish a full-duplex, two-way communication channel between client and server over a single TCP connection. It is a different TCP protocol from HTTP but is designed to work over HTTP, using ports 80 and 443 and allowing re-use of existing firewall rules.

A WebSocket interaction begins with an HTTP request that uses the HTTP `"Upgrade"` header to upgrade, or in this case to switch, to the WebSocket protocol:

```
GET /spring-websocket-portfolio/portfolio HTTP/1.1
Host: localhost:8080
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Key: Uc9l9TMkWGbHFD2qnFHltg==
Sec-WebSocket-Protocol: v10.stomp, v11.stomp
Sec-WebSocket-Version: 13
Origin: http://localhost:8080
```

Instead of the usual 200 status code, a server with WebSocket support returns:

```
HTTP/1.1 101 Switching Protocols
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Accept: 1qVdfYHU9hPOl4JYYNXF623Gzn0=
Sec-WebSocket-Protocol: v10.stomp
```

After a successful handshake the TCP socket underlying the HTTP upgrade request remains open for both client and server to continue to send and receive messages.

A complete introduction of how WebSockets work is beyond the scope of this document. Please read RFC 6455, the WebSocket chapter of HTML5, or one of many introductions and tutorials on the Web.

Note that if a WebSocket server is running behind a web server (e.g. nginx) you will likely need to configure it to pass WebSocket upgrade requests on to the WebSocket server. Likewise if the application runs in a cloud environment, check the instructions of the cloud provider related to WebSocket support.

### 3.1.1. HTTP vs WebSocket

Even though WebSocket is designed to be HTTP compatible and starts with an HTTP request, it is important to understand that the two protocols lead to very different architectures and application programming models.

In HTTP and REST, an application is modeled as many URLs. To interact with the application clients access those URLs, request-response style. Servers route requests to the appropriate handler based on the HTTP URL, method, and headers.

By contrast in WebSockets there is usually just one URL for the initial connect and subsequently all application messages flow on that same TCP connection. This points to an entirely different asynchronous, event-driven, messaging architecture.

WebSocket is also a low-level transport protocol which unlike HTTP does not prescribe any semantics to the content of messages. That means there is no way to route or process a message unless client and server agree on message semantics.

WebSocket clients and servers can negotiate the use of a higher-level, messaging protocol (e.g. STOMP), via the `"Sec-WebSocket-Protocol"` header on the HTTP handshake request, or in the absence of that they need to come up with their own conventions.

### 3.1.2. When to use it?

WebSockets can make a web page dynamic and interactive. However in many cases a combination of Ajax and HTTP streaming and/or long polling could provide a simple and effective solution.

For example news, mail, and social feeds need to update dynamically but it may be perfectly okay to do so every few minutes. Collaboration, games, and financial apps on the other hand need to be much closer to real time.

Latency alone is not a deciding factor. If the volume of messages is relatively low (e.g. monitoring network failures) HTTP streaming or polling may provide an effective solution. It is the combination of low latency, high frequency and high volume that make the best case for the use WebSocket.

Keep in mind also that over the Internet, restrictive proxies outside your control, may preclude WebSocket interactions either because they are not configured to pass on the `Upgrade` header or because they close long lived connections that appear idle? This means that the use of WebSocket for internal applications within the firewall is a more straight-forward decision than it is for public facing applications.

## 3.2. WebSocket API

Same in Servlet stack

The Spring Framework provides a WebSocket API that can be used to write client and server side applications that handle WebSocket messages.

### 3.2.1. Server

Same in Servlet stack

To create a WebSocket server, first create a `WebSocketHandler`:

```
import org.springframework.web.reactive.socket.WebSocketHandler;
import org.springframework.web.reactive.socket.WebSocketSession;

public class MyWebSocketHandler implements WebSocketHandler {

    @Override
    public Mono<Void> handle(WebSocketSession session) {
        // ...
    }
}
```

Then map it to a URL and add a `WebSocketHandlerAdapter`:

```
@Configuration
static class WebConfig {

    @Bean
    public HandlerMapping handlerMapping() {
        Map<String, WebSocketHandler> map = new HashMap<>();
        map.put("/path", new MyWebSocketHandler());

        SimpleUrlHandlerMapping mapping = new SimpleUrlHandlerMapping();
        mapping.setUrlMap(map);
        mapping.setOrder(-1); // before annotated controllers
        return mapping;
    }

    @Bean
    public WebSocketHandlerAdapter handlerAdapter() {
        return new WebSocketHandlerAdapter();
    }
}
```

### 3.2.2. WebSocketHandler

The `handle` method of `WebSocketHandler` takes `WebSocketSession` and returns `Mono<Void>` to indicate when application handling of the session is complete. The session is handled through two streams, one for inbound and one for outbound messages:

| WebSocketSession method | Description |
|---|---|
| `Flux<WebSocketMessage> receive()` | Provides access to the inbound message stream, and completes when the connection is closed. |

| WebSocketSession method | Description |
| --- | --- |
| `Mono<Void> send(Publisher<WebSocketMessage>)` | Takes a source for outgoing messages, writes the messages, and returns a `Mono<Void>` that completes when the source completes and writing is done. |

A `WebSocketHandler` must compose the inbound and outbound streams into a unified flow, and return a `Mono<Void>` that reflects the completion of that flow. Depending on application requirements, the unified flow completes when:

- Either inbound or outbound message streams complete.
- Inbound stream completes (i.e. connection closed), while outbound is infinite.
- At a chosen point through the `close` method of `WebSocketSession`.

When inbound and outbound message streams are composed together, there is no need to check if the connection is open, since Reactive Streams signals will terminate activity. The inbound stream receives a completion/error signal, and the outbound stream receives receives a cancellation signal.

The most basic implementation of a handler is one that handles the inbound stream:

```
class ExampleHandler implements WebSocketHandler {

    @Override
    public Mono<Void> handle(WebSocketSession session) {
        return session.receive()            ①
                .doOnNext(message -> {
                    // ...                  ②
                })
                .concatMap(message -> {
                    // ...                  ③
                })
                .then();                    ④
    }
}
```

① Access stream of inbound messages.

② Do something with each message.

③ Perform nested async operation using message content.

④ Return `Mono<Void>` that completes when receiving completes.

For nested, asynchronous operations, you may need to call `message.retain()` on underlying servers that use pooled data buffers (e.g. Netty), or otherwise the data buffer may be released before you've had a chance to read the data. For more background see Data Buffers and Codecs.

The below implementation combines the inbound with the outbound streams:

```
class ExampleHandler implements WebSocketHandler {

    @Override
    public Mono<Void> handle(WebSocketSession session) {

        Flux<WebSocketMessage> output = session.receive()              ①
                .doOnNext(message -> {
                    // ...
                })
                .concatMap(message -> {
                    // ...
                })
                .map(value -> session.textMessage("Echo " + value));    ②

        return session.send(output);                                   ③
    }
}
```

① Handle inbound message stream.

② Create outbound message, producing a combined flow.

③ Return `Mono<Void>` that doesn't complete while we continue to receive.

Inbound and outbound streams can be independent, and joined only for completion:

```
class ExampleHandler implements WebSocketHandler {

    @Override
    public Mono<Void> handle(WebSocketSession session) {

        Mono<Void> input = session.receive()                           ①
                .doOnNext(message -> {
                    // ...
                })
                .concatMap(message -> {
                    // ...
                })
                .then();

        Flux<String> source = ... ;
        Mono<Void> output = session.send(source.map(session::textMessage)); ②

        return Mono.zip(input, output).then();                         ③
    }
}
```

① Handle inbound message stream.

② Send outgoing messages.

③ Join the streams and return `Mono<Void>` that completes when *either* stream ends.

### 3.2.3. Handshake

Same in Servlet stack

`WebSocketHandlerAdapter` delegates to a `WebSocketService`. By default that's an instance of `HandshakeWebSocketService`, which performs basic checks on the WebSocket request and then uses `RequestUpgradeStrategy` for the server in use. Currently there is built-in support for Reactor Netty, Tomcat, Jetty, and Undertow.

The above are just 3 examples to serve as a starting point.

### 3.2.4. Server config

Same in Servlet stack

The `RequestUpgradeStrategy` for each server exposes the WebSocket-related configuration options available for the underlying WebSocket engine. Below is an example of setting WebSocket options when running on Tomcat:

```
@Configuration
static class WebConfig {

    @Bean
    public WebSocketHandlerAdapter handlerAdapter() {
        return new WebSocketHandlerAdapter(webSocketService());
    }

    @Bean
    public WebSocketService webSocketService() {
        TomcatRequestUpgradeStrategy strategy = new TomcatRequestUpgradeStrategy();
        strategy.setMaxSessionIdleTimeout(0L);
        return new HandshakeWebSocketService(strategy);
    }
}
```

Check the upgrade strategy for your server to see what options are available. Currently only Tomcat and Jetty expose such options.

### 3.2.5. CORS

Same in Servlet stack

The easiest way to configure CORS and restrict access to a WebSocket endpoint is to have your `WebSocketHandler` implement `CorsConfigurationSource` and return a `CorsConfiguraiton` with allowed origins, headers, etc. If for any reason you can't do that, you can also set the `corsConfigurations` property on the `SimpleUrlHandler` to specify CORS settings by URL pattern. If both are specified they're combined via the `combine` method on `CorsConfiguration`.

### 3.2.6. Client

Spring WebFlux provides a `WebSocketClient` abstraction with implementations for Reactor Netty, Tomcat, Jetty, Undertow, and standard Java (i.e. JSR-356).

The Tomcat client is effectively an extension of the standard Java one with some extra functionality in the `WebSocketSession` handling taking advantage of Tomcat specific API to suspend receiving messages for back pressure.

To start a WebSocket session, create an instance of the client and use its `execute` methods:

```
WebSocketClient client = new ReactorNettyWebSocketClient();

URI url = new URI("ws://localhost:8080/path");
client.execute(url, session ->
        session.receive()
                .doOnNext(System.out::println)
                .then());
```

Some clients, e.g. Jetty, implement `Lifecycle` and need to be started in stopped before you can use them. All clients have constructor options related to configuration of the underlying WebSocket client.

# Chapter 4. Testing

Same in Spring MVC

The `spring-test` module provides mock implementations of `ServerHttpRequest`, `ServerHttpResponse`, and `ServerWebExchange`. See Spring Web Reactive mock objects.

The WebTestClient builds on these mock request and response objects to provide support for testing WebFlux applications without and HTTP server. The `WebTestClient` can be used for end-to-end integration tests too.

## 4.1. Threading model

# Chapter 5. Reactive Libraries

`spring-webflux` depends on `reactor-core` and uses it internally to compose asynchronous logic and to provide Reactive Streams support. Generally WebFlux APIs return `Flux` or `Mono` — since that's what's used internally, and leniently accept any Reactive Streams `Publisher` implementation as input. The use of `Flux` vs `Mono` is important because it helps to express cardinality — e.g. whether a single or multiple async values are expected, and that can be essential for making decisions, for example when encoding or decoding HTTP messages.

For annotated controllers, WebFlux transparently adapts to the reactive library chosen by the application. This is done with the help of the ReactiveAdapterRegistry which provides pluggable support for reactive library and other asynchronous types. The registry has built-in support for RxJava and `CompletableFuture`, but others can be registered too.

For functional APIs such as Functional Endpoints, the `WebClient`, and others, the general rules for WebFlux APIs apply — `Flux` and `Mono` as return values, and Reactive Streams `Publisher` as input. When a `Publisher`, whether custom or from another reactive library, is provided, it can only be treated as a stream with unknown semantics (0..N). If however the semantics are known, you can wrap it with `Flux` or `Mono.from(Publisher)` instead of passing the raw `Publisher`.

For example, given a `Publisher` that is not a `Mono`, the Jackson JSON message writer expects multiple values. If the media type implies an infinite stream — e.g. `"application/json+stream"`, values are written and flushed individually; otherwise values are buffered into a list and rendered as a JSON array.