



# Pro Spring 6

An In-Depth Guide to the Spring Framework

—

*Sixth Edition*

—

Iuliana Cosmina

Rob Harrop

Chris Schaefer

Clarence Ho

Apress®

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## *Pro Spring 6: An In-Depth Guide to the Spring Framework*

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*I dedicate this book to my Evelyn Walker. Thank you for being  
the friend I never knew I needed.*

*—Iuliana Cosmina*



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# About the Authors

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# About the Technical Reviewer



**Manuel Jordan Elera** is an autodidactic developer and researcher who enjoys learning new technologies for his own experiments and creating new integrations. Manuel won the Springy Award 2013 Community Champion and Spring Champion. In his little free time, he reads the Bible and composes music on his guitar. Manuel is known as `dr_pompeii`. He has tech-reviewed numerous books, including *Pro Spring MVC with WebFlux* (Apress, 2020), *Pro Spring Boot 2* (Apress, 2019), *Rapid Java Persistence and Microservices* (Apress, 2019), *Java Language Features* (Apress, 2018), *Spring Boot 2 Recipes* (Apress, 2018), and *Java APIs, Extensions and Libraries* (Apress, 2018). You can read his detailed tutorials on Spring technologies and contact him through his blog at [www.manueljordanelera.blogspot.com](http://www.manueljordanelera.blogspot.com). You can follow Manuel on his Twitter account, `@dr_pompeii`.

# Acknowledgments

Writing this book was difficult. Spring has grown exponentially since the first edition of this book was written, and a small framework providing dependency injection for Java applications became a collection of projects designed to be used to develop a myriad of modern applications, from websites to mobile applications to mini applications run on Arduinos and microservices.

This book has a long history; this is the sixth edition, after all. Rob Harrop and Jan Machacek wrote a comprehensive Spring book named *Pro Spring: From Professional to Expert*, which was published in 2005; that was the first edition. Spring has changed dramatically over the past 18 years, and the book has evolved accordingly, so much so that there is little left of the original text. What you are reading right now is its sixth edition. In previous editions, a rotating cast of authors have taken the mantle and responsibility of making this book better and upgrading it to keep up with Spring Framework's growth. I was brought on board for the fifth edition, to upgrade the material from Spring 4 to Spring 5, making this the second time I am involved in upgrading this book.

However, I did not produce the sixth edition alone, so in this section I want to thank all the people involved: Steve Anglin for taking a gamble on me in 2014 and giving me a chance to become a technical author; Mark Powers for guiding me through the process of producing a book that is worth publishing; to my technical reviewer, Manual Jordan Elera, for making sure making sure the code in the book is good; all the grammar reviewers for making sure the text in the book is readable, understandable, and meaningful.

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—Iuliana Cosmina

# Introduction

Covering version 6 of the Spring Framework, this book is the most comprehensive Spring reference and practical guide available for harnessing the power of this leading enterprise Java application development framework.

This edition covers core Spring and its integration with other leading Java technologies, such as Hibernate, JPA 3, Thymeleaf, Kafka, GraphQL, and WebFlux. The focus of the book is on using Java configuration classes, lambda expressions, Spring Boot, and reactive programming. We share our insights and real-world experiences with enterprise application development, including remoting, transactions, web and presentation tiers, and much more.

With Pro Spring 6, you'll learn how to do the following:

- Use inversion of control (IoC) and dependency injection (DI)
- Discover what is new in Spring Framework 6
- Build Spring-based web applications using Spring MVC
- Build Spring web reactive applications with Spring WebFlux
- Test Spring applications using Junit 5
- Utilize the new Java 8+ lambda syntax
- Use Spring Boot to an advanced level to get any kind of Spring application up and running in no time
- Package your Spring Native application into a Docker image with Cloud Native Buildpacks

There is a multimodule project associated with this book, configured using Gradle 8/Maven 3.9. The project is available on the Apress official repository: <https://github.com/Apress/pro-spring-6>. The project can be built immediately after cloning according to the instructions in its README.adoc file. If you do not have Gradle/Maven installed locally, you can rely on IntelliJ IDEA to download it and use it to build your project by using the Gradle/Maven Wrapper ([https://docs.gradle.org/current/userguide/gradle\\_wrapper.html](https://docs.gradle.org/current/userguide/gradle_wrapper.html)). There is a small appendix at the end of the book describing the project structure, configuration, and additional details related to development tools that can be used to develop and run the code samples of the book, which are available on GitHub.

As the book was being written, new versions of Spring 6 and Spring Boot 3 were released, a new version of IntelliJ IDEA was released, and new versions of Gradle/Maven and other technologies used in the book were updated. We upgraded to the new versions to provide the most recent information and keep this book synchronized with the official documentation. Several reviewers have checked the book for technical accuracy, but if you notice any inconsistencies, please send an email to [editorial@apress.com](mailto:editorial@apress.com) and errata will be created.

## ■ INTRODUCTION

You can access the example source code for this book at [github.com/apress/pro-spring-6](https://github.com/apress/pro-spring-6). It will be maintained, synchronized with new versions of the technologies, and enriched based on the recommendations of the developers using it to learn Spring.

We truly hope you will enjoy using this book to learn Spring as much as we enjoyed writing it.

## CHAPTER 1



# Introducing Spring

Every year there are tweets and blog posts announcing that Java is no longer relevant and there is a shiny new technology taking its place. And every year these turn out to be just industry rumors. Java is an ever-evolving technology that has been in the top 10 most used technologies by companies to build software solutions since its initial release in 1995. A lot of libraries and frameworks have been built on Java, many of them available to developers as open source projects, others safely locked away in a private cloud because of the sensitive information they manage (e.g., banking applications).

One of the most popular frameworks written in Java is the Spring Framework. The first version of Spring was released in October 2002 and consisted of a small core with an inversion of control container that was easy to configure and use. Over the years the Spring Framework has become the main replacement of Java Enterprise Edition (JEE) servers and has grown into a full-blown technology made up of many distinct projects, each with its own purpose. Whether you want to build microservices applications, or classical ERPs (Enterprise resource planning), or compile your app into a native image to run on GraalVM, Spring has a project for that.

Throughout this book, you will see many applications of different open source technologies, all of which are unified under the Spring Framework. When working with Spring, an application developer can use a large variety of open source tools, without needing to write reams of code and without coupling his application too closely to any particular tool.

This is an introductory chapter that covers important details about this book, introduces you to the Spring Framework, explains why understanding Spring in depth is so useful for developers, and describes how powerful Spring can be when used correctly. If you are already familiar with Spring, you might want to skip this chapter and proceed straight to **Chapter 2**.

## About This Book

Covering version 6 of the Spring Framework, this book is the most comprehensive Spring reference and practical guide available for harnessing the power of this leading enterprise Java application development framework.

This edition covers core Spring and its integration with other leading Java technologies, such as Hibernate, JPA 2, Thymeleaf, Apache Kafka, and others. The focus of the book is on using Java configuration classes, lambda expressions, Spring Boot, and reactive programming. We share our insights and real-world experiences with enterprise application development, including remoting, transactions, the web and presentation tiers, and much more.

With *Pro Spring 6*, you'll learn how to do the following:

- Use and understand inversion of control (IoC) and dependency injection (DI)
- Discover what's new in Spring Framework 6

- Build Spring-based web applications using Spring MVC
- Test Spring applications using JUnit 5 and other Java testing libraries
- Utilize the new capabilities of Java 19
- Use Spring Boot to an advanced level, but learn how to do without it as well
- Secure Spring applications
- Monitor Spring applications
- Write reactive applications using Spring
- Build your Spring application and run it on a compact native image with Spring Native

To make sure the focus of the book is on Spring, instructions on how to install additional technologies mentioned in the book are provided in documentation files for each project in the book repository. This, of course, will be pointed out to you in the book when necessary.

## What Is Spring?

Perhaps one of the hardest parts of explaining Spring is classifying exactly what it is. **Spring** was described in the beginning, shortly after being launched, as a *lightweight framework* for building Java applications, but that statement brings up two interesting points:

- You can use Spring to build any application in Java (for example, stand-alone, web, mobile, or JEE applications), unlike many other frameworks (such as Apache Struts, which is limited to web applications).
- The *lightweight* part of the description is not related to the number of classes or the size of the distribution but rather defines the principle of the Spring philosophy as a whole—that is, *minimal impact*. Spring is lightweight in the sense that you have to make few, if any, changes to your application code to gain the benefits of the Spring Core, and should you choose to stop using Spring at any point, you will find that doing so is quite simple.

Notice that we qualified that last statement to refer to the Spring Core only—many of the extra Spring components, such as data access, require a much closer coupling to the Spring Framework. However, the benefits of this coupling are quite clear, and throughout the book we present techniques for minimizing the impact this has on your application. Also, if coupling your code to a framework brings with it development speed and better dependency management, which reduces the number of build failures during upgrades, isn't the price worth it? Also, with Spring Native, Spring applications now can be run on native images (e.g., GraalVM) that provide various advantages, such as an instant startup and reduced memory consumption, so gone are the days when JavaScript or .NET developers could diss on Spring by saying it is *heavyweight*.

## Evolution of the Spring Framework

The Spring Framework originated from the book *Expert One-on-One: J2EE Design and Development* by Rod Johnson (Wrox, 2002). In his book, Johnson presented his own framework, called the Interface 21 Framework, which he developed to use in his own applications. Released into the open source world, this framework formed the foundation of the Spring Framework as we know it today. Over the last decade, the

Spring Framework has grown dramatically in core functionality, associated projects, and community support. Spring 0.9 started as a community project made of a few core modules and without an official documentation. VMware took it over and started its transition from XML to Java Config (using annotations) in version 2.5.

In 2012, Pivotal Software split from VMware and took over Spring and grew it from a framework to a collection of projects. There were two major releases under Pivotal: 4.x, which was the first version to fully support Java 8, and 5.x, which dropped support for XML configurations completely.

Together with Spring 4.x, Spring Boot was released and became one of the most used Spring projects. Spring Boot takes an opinionated view of building Spring applications. Developers at Pivotal have identified a few types of applications being built and have created templates for them using a set of default component dependencies and automatic configuration of components. These application templates are modeled by a set of Spring Boot starter projects. For example, if you would want to create a Spring web application, just add the `spring-boot-starter-web` dependency to your project and you have a minimal, Spring web application with default configurations. This is possible because Spring Boot has some cool features such as embedded application server (Jetty/Tomcat), a command-line interface based on Groovy, and health/metrics monitoring.

Spring Boot provides the ability to develop applications quickly, based on a stable, curated set of dependencies with all the required Spring Framework components configured correctly. This is good because it reduces the developer setup effort. However, this also reduces the need for a deeper understanding of the Spring Framework, which might trick developers into a false sense of confidence in their knowledge and understanding of the Spring Framework.



In the previous edition of this book, this chapter contained a long list of all the Spring versions ever released and their most important features. Since that information is available publicly on the Internet, we decided to skip that list both to reduce the size of the book and to dedicate that space to something more interesting such as Project Reactor<sup>1</sup> and Spring Native<sup>2</sup>.

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At the end of 2019, VMware bought Pivotal Software and took over Spring again, so at the end of 2021, Spring 6.x will be out, the first major Spring Release under VMware. At the time this chapter is being written, the first milestone has already been released and the most important thing about it is that the codebase has been upgraded to JDK 17. This version is considered the first JDK<sup>3</sup> produced by Oracle that provides enough performance and security improvements for a migration from JDK 1.8 to be worth it for companies that are (still) reluctant to do so.

A lot of deprecated classes and packages that provided support for deprecated third-party technologies have been removed and existing classes have been updated to work with newer versions of certain technologies (for example, Tomcat 10, Jetty 11, or Undertow 2.2.14).

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<sup>1</sup><https://projectreactor.io>

<sup>2</sup><https://docs.spring.io/spring-native/docs/current/reference/htmlsingle>

<sup>3</sup><https://blogs.oracle.com/javamagazine/post/its-time-to-move-your-applications-to-java-17-heres-why-and-heres-how>



## Spring Projects

The current Spring Projects are listed on the official Spring site<sup>4</sup>, but for your convenience here is a list of them with a short summary of each. The site might list a different set of projects because the Spring ecosystem is quite dynamic.

- **Spring Boot** consists of a set of libraries (called *starters*) that provide default application templates that can be customized easily to quickly develop multiple types of stand-alone, production-grade Spring-based applications.
- **Spring Framework** consists of a set of libraries that provide support for dependency injection, transaction management, data access, messaging, and other core functionalities for any type of application. The Spring Framework now includes the Spring WebFlux framework that represents the Spring reactive-stack designed to build fully non-blocking, with back-pressure support reactive applications on servers such as Netty, Undertow, and Servlet 3.1+ containers.
- **Spring Data** consists of a set of libraries that provide a consistent programming model for accessing various databases both relational (e.g., MySQL and Oracle) and nonrelational (e.g., MongoDB and Couchbase). Support for in-memory databases (e.g., H2 and MongoDB) is included, which is pretty useful for testing applications without the drag of a concrete database. Also, Spring Data R2DBC makes it easy to access reactive databases.
- **Spring Security** provides the ability to secure applications easily, with a simple model for authentication and authorization.
- **Spring Cloud** provides a set of common tools for writing microservices applications destined to run in distributed systems.
- **Spring Cloud Data Flow** provides a set of common tools for streaming and batch processing of data between microservices running in Cloud Foundry and Kubernetes.
- **Spring Integration** provides support for building Spring applications that make use of lightweight messaging and integrate with external systems via declarative adapters.
- **Spring Session** provides an API and implementations for managing a user's session information.
- **Spring HATEOAS** provides some APIs to ease creating REST representations that follow the HATEOAS principle when working with Spring and especially Spring MVC. Some developers/architects consider that the hypermedia<sup>5</sup> pollutes the REST data and a better solution is to use Swagger<sup>6</sup> to expose (and document) an application's API or Spring REST Docs.
- **Spring for GraphQL** provides the tools to build Spring applications on GraphQL Java. GraphQL<sup>7</sup> is a query language to retrieve data from a server.

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<sup>4</sup><https://spring.io/projects>

<sup>5</sup><https://en.wikipedia.org/wiki/HATEOAS>

<sup>6</sup><https://swagger.io>

<sup>7</sup><https://www.graphql-java.com>

- **Spring REST Docs** provides the tools to expose and document a Spring application's API.
- **Spring Batch** is a framework that provides the tools to build lightweight and robust Spring applications that handle immense volumes of data.
- **Spring AMQP** provides the tools to build AMQP-based messaging solutions using Spring.
- **Spring CredHub** is part of the Spring Cloud project family and provides client-side support for storing, retrieving, and deleting credentials from a CredHub server running in a CloudFoundry platform.
- **Spring Flo** is a JavaScript library that offers a basic embeddable HTML5 visual builder for pipelines and simple graphs. Spring Cloud Data Flow is an extension of this project.
- **Spring for Apache Kafka** provides tools for building Kafka-based messaging solutions using Spring.
- **Spring LDAP** is a library to simplify LDAP programming in Java, built on the same principles as Spring JDBC.
- **Spring Shell** provides the tools to build a full-featured shell (aka command line) application by depending on the Spring Shell jars and adding their own commands (which come as methods on Spring beans).
- **Spring Statemachine** is a framework for application developers to use state machine concepts with Spring applications.
- **Spring Vault** provides familiar Spring abstractions and client-side support for accessing, storing, and revoking secrets. It offers both low-level and high-level abstractions for interacting with HashiCorp's Vault<sup>8</sup>, freeing the user from infrastructural concerns.
- **Spring Web Flow** extends Spring MVC to provide the tools for implementing the "flows" of a web application. A flow encapsulates a sequence of steps that guide a user through the execution of some business task. It spans multiple HTTP requests, has state, deals with transactional data, is reusable, and may be dynamic and long-running in nature.
- **Spring Web Services** (Spring-WS) is a product of the Spring community focused on creating document-driven web services. Spring Web Services aims to facilitate contract-first SOAP service development, allowing for the creation of flexible web services using one of the many ways to manipulate XML payloads.
- **Spring Native** (currently still considered experimental, but quickly being adopted in the industry) provides support for compiling Spring applications to native executables using the GraalVM native-image compiler.

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<sup>8</sup><https://www.vaultproject.io>

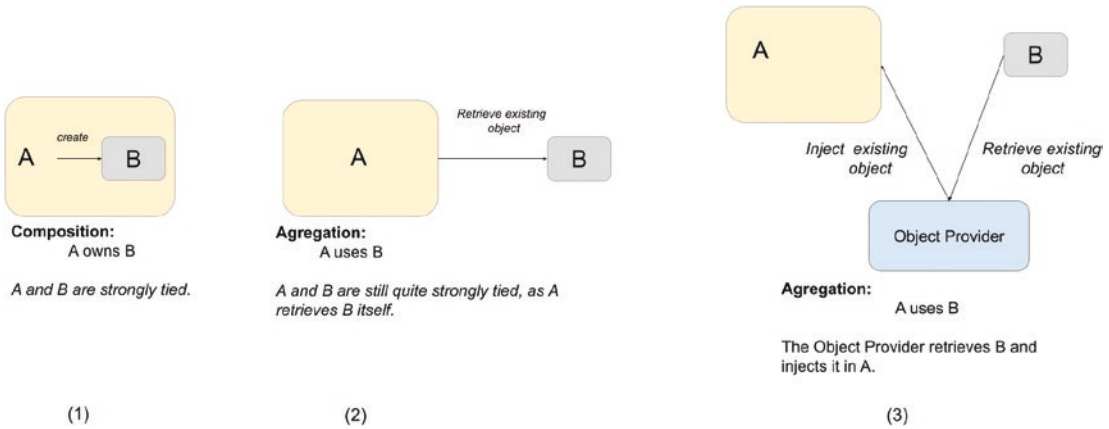
- **Spring Initializr** (not actually a project, but good to know), available at <https://start.spring.io>, provides a quick start for creating custom Spring Boot projects completely configurable according to the developer’s necessities: programming language, build tool, Spring Boot version, and project requirements (database access, web access, event messaging, security, etc.).

There are a few projects that over the years have lost the developer community’s interest (e.g., Spring Scala) and are now in a state called *in the attic*. If developers’ interest continues to drop, these projects are archived and others will surely take their place. If you want to keep up to date with the Spring projects ecosystem, check <https://spring.io/projects> from time to time.

That’s enough about Spring projects to pique your interest; let’s talk more in dept about Spring.

## Inverting Control or Injecting Dependencies?

The core of the Spring Framework is based on the principle of **inversion of control (IoC)**. IoC is a technique that externalizes the creation and management of component dependencies. The action performed by any program (not only Java) is the result of interaction between its interdependent components, usually named objects. Explaining inversion of control also requires an explanation of **dependency injection(DI)**, a concept that describes how dependent objects are connected at runtime by an external party. Take a look at Figure 1-1, which depicts two types of relationships between objects and how those objects “meet” each other.



**Figure 1-1.** Object relationships and how they “meet”

Object A needs an object of type B to perform its functions, thus *A depends on B*. The three ways these two objects get to interact shown in Figure 1-1 can be explained as follows:

- **Composition:** Object A directly creates object B. This ties them together, and basically object B exists as long as object A exists. This situation is depicted in section (1) in Figure 1-1.
- **Aggregation:** Object A itself retrieves object B that already exists. This ties them together as well, and object B must exist as long as object A needs it to. Also, object A must include the logic to be able to retrieve object B. This situation is depicted in section (2) in Figure 1-1.

- **Dependency injection** allows severing that tie, as depicted in section (3) in Figure 1-1, by using an external party to provide object B to object A, which is still aggregation, but with no direct ties and a twist.

**Inversion of control** is a design principle in which generic reusable components are used to control the execution of problem-specific code, as in retrieving dependencies. Thus, you can say that Spring is a **dependency handler** used to perform dependency injection, and it was designed following the IoC principle, also known as the Hollywood Principle: *Don't call us, we'll call you*.

Spring's DI implementation is based on two core Java concepts: JavaBeans (also known as POJOs, plain old Java objects) and interfaces. When you use Spring as the DI provider, you gain the flexibility of defining dependency configuration within your applications in different ways. Up to Spring 2.5, XML was the only way to do it. Spring 2.5 introduced a few annotations to support configuration within the code. Spring 3 introduced Java configuration classes, which became the norm, although XML is still supported in case you really need it. Starting with version 4, Spring provides support for Groovy-based configurations. This means that Groovy classes can be legitimate Spring beans.

JavaBeans (POJOs) provide a standard mechanism for creating Java resources that are configurable in a number of ways, such as constructors and setter methods. In **Chapter 3**, you will see how Spring uses the JavaBean specification to form the core of its DI configuration model; in fact, any Spring-managed resource is referred to as a *bean*. If you are unfamiliar with JavaBeans, we present a quick primer at the beginning of **Chapter 3**.

Interfaces and DI are technologies that are mutually beneficial. Clearly designing and coding an application to interfaces makes for a flexible application, but the complexity of wiring together an application designed using interfaces is quite high and places an additional coding burden on developers. By using DI, you reduce to almost zero the amount of code you need to use an interface-based design in your application. Likewise, by using interfaces, you can get the most out of DI because your beans can utilize any interface implementation to satisfy their dependency. The use of interfaces also allows Spring to utilize JDK dynamic proxies (the Proxy pattern) to provide powerful concepts such as aspect-oriented programming (AOP) for crosscutting concerns.

In the context of DI, Spring acts more like a container than a framework—providing instances of your application classes with all the dependencies they need—but it does so in a much less intrusive way. Using Spring for DI relies on nothing more than following the JavaBeans naming conventions within your classes—there are no special classes from which to inherit or proprietary naming schemes to follow. If anything, the only change you make in an application that uses DI is to expose more properties on your JavaBeans, thus allowing more dependencies to be injected at runtime.

## Evolution of Dependency Injection

In the past few years, thanks to the popularity gained by Spring and other DI frameworks, DI has gained wide acceptance among Java developer communities. At the same time, developers were convinced that using DI was a best practice in application development, and the benefits of using DI were also well understood. The popularity of DI was acknowledged when the Java Community Process (JCP) adopted JSR-330 (“Dependency Injection for Java”) in 2009. JSR-330 had become a formal Java specification request, and as you might expect, one of the specification leads was Rod Johnson—the founder of the Spring Framework.

In JEE 6, JSR-330 became one of the included specifications of the entire technology stack. In the meantime, the EJB architecture (starting from version 3.0) was also revamped dramatically; it adopted the DI model in order to ease the development of various Enterprise JavaBeans apps.

Although we leave the full discussion of DI until **Chapter 3**, it is worth taking a look at the benefits of using DI rather than a more traditional approach.

- *Reduced glue code:* DI dramatically reduces the amount of code you have to write to glue the components of your application together. Code required to glue components together is often trivial, but repetitive, and a lot of it can increase the

overall complexity of your solution. It gets even trickier when you need to look up dependencies in a Java Naming and Directory Interface (JNDI) repository or when the dependencies cannot be invoked directly, as is the case with remote resources. In these cases, DI can really simplify the glue code by providing automatic JNDI lookup and automatic proxying of remote resources.

- *Simplified application configuration:* A variety of ways can be used to configure classes that are injectable to other classes. You can use the same technique to express the dependency requirements to the “injector” for injecting the appropriate bean instance or property. In addition, DI makes it much simpler to swap one implementation of a dependency for another. For example, using DI, a DAO component that performs data operations against a PostgreSQL database can easily be switched to perform the same operations on an Oracle database via configuration (as you will see in **Chapter 6**).
- *Ability to manage common dependencies in a single repository:* Using a traditional approach to dependency management of common services—for example, data source connection, transaction, and remote services—you create instances (or lookup from some factory classes) of your dependencies where they are needed (within the dependent class). This causes the dependencies to spread across the classes in your application, and changing them can prove problematic. When you use DI, all the information about those common dependencies is contained in a single repository, making the management of dependencies much simpler and less error-prone.
- *Improved testability:* Classes designed for DI are easily testable because dependencies can be replaced easily. For example, if you want to test a DAO component, you can replace the concrete database with an in-memory database via configuration. This has the benefit of your tests being executed faster but within an appropriate context that mimics as much as possible a production environment. This mechanism can be extended for testing any tier of your application and is especially useful for testing web components where you can create mock implementations of `HttpServletRequest` and `HttpServletResponse`.
- *Fostering of good application design:* A typical injection-oriented application is designed so that all major components are defined as interfaces, and then concrete implementations of these interfaces are created and hooked together using the DI container. This kind of design was possible in Java before the advent of DI and DI-based containers such as Spring, but by using Spring, you get a whole host of DI features for free, and you are able to concentrate on building your application logic, not a framework to support it.

As you can see from this list, DI provides a lot of benefits for your application, but it is not without its drawbacks. In particular, DI can make it difficult for someone not intimately familiar with the code to see just what implementation of a particular dependency is being hooked into which objects. Typically, this is a problem only when developers are inexperienced with DI. We’ve heard a lot of colleagues in this situation mentioning that Spring *auto-magically* injects beans, or complaining that they don’t understand where a bean is coming from, or, worst of all, asking “Why is Spring not finding my bean?” After becoming more experienced and following good DI coding practice (for example, putting all injectable classes within each application layer into the same package), developers will be able to discover the whole picture easily. For the most part, the massive benefits of DI far outweigh this small drawback, but you should consider this when planning your application.

## Beyond Dependency Injection

Spring Core alone, with its advanced DI capabilities, is a worthy tool, but where Spring really excels is in its myriad of additional features, all elegantly designed and built using the principles of DI. Spring provides features for all layers of an application, from helper application programming interfaces (APIs) for data access right through to advanced MVC (Model View Controller) capabilities. What is great about these features in Spring is that, although Spring often provides its own approach, you can easily integrate them with other tools in Spring, making these tools first-class members of the Spring family.

The following list describes the most important Spring features and indicates the chapters in which they are covered in this book:

- *Aspect-oriented programming*: AOP provides the ability to implement crosscutting logic—that is, logic that applies to many parts of your application—in a single place and to have that logic applied across your application automatically. Spring’s approach to AOP, covered in **Chapter 5**, is to create dynamic proxies to the target objects and weave the objects with the configured advice to execute the crosscutting logic. By the nature of JDK dynamic proxies, target objects must implement an interface declaring the method in which the AOP advice will be applied.
- *Spring Expression Language*: Expression Language (EL) is a technology to allow an application to manipulate Java objects at runtime. However, the problem with EL is that different technologies provide their own EL implementations and syntax. For example, Java Server Pages (JSP) and Java Server Faces (JSF) both have their own EL, and their syntax are different. To solve the problem, the Unified Expression Language was created. *Spring Expression Language (SpEL)* was introduced in Spring 3.0. Its syntax is similar to Unified EL and provides powerful features for evaluating expressions and for accessing Java objects and Spring beans at runtime.
- *Validation*: Data managed by an application must abide by specific validation rules. The ideal scenario is that the validation rules of the attributes within JavaBeans containing business data can be applied in a consistent way, regardless of whether the data manipulation request is initiated from the front end, a batch job, or remotely (for example, via web services, RESTful web services, or remote procedure calls [RPCs]). To address these concerns, Spring provides a built-in validation API by way of the `Validator` interface. This interface provides a simple yet concise mechanism that allows you to encapsulate your validation logic into a class responsible for validating the target object. In addition to the target object, the `validate()` method takes an `Errors` object, which is used to collect any validation errors that may occur. The topic of validation and all aspects of it are covered in detail in **Chapter 11**.
- *Accessing data*: Data access and persistence seem to be the most discussed topics in the Java world. Spring provides excellent integration with a choice selection of data access tools. In addition, Spring makes plain-vanilla JDBC a viable option for many projects, with its simplified wrapper APIs around the standard API. Spring’s data access module provides out-of-the-box support for JDBC (**Chapter 6**), Hibernate (**Chapter 7**), JDO the JPA (**Chapter 8**), and various NoSQL databases(**Chapter 10**). When using the Spring APIs to access data via any tool, you are able to take advantage of Spring’s excellent transaction support. You’ll find a full discussion of this in **Chapter 9**.
- *Managing transactions*: Spring provides an excellent abstraction layer for transaction management, allowing for programmatic and declarative transaction control. By using the Spring abstraction layer for transactions, you can make it simple to change the underlying transaction protocol and resource managers. You can start with



simple, local, resource-specific transactions and move to global, multi-resource transactions without having to change your code. Transactions are covered in full detail in **Chapter 9**.

- *Object mapping*: Most applications need to integrate or provide services to other applications. One common requirement is to exchange data with other systems, either on a regular basis or in real time. In terms of data format, XML used to be the most commonly used, but nowadays JSON and YAML have taken over, mostly because the excellent support provided by the Jackson Project<sup>9</sup>. Starting with **Chapter 13**, in which we discuss remotely accessing a Spring application for business data in various formats, you will see how to use Spring's object mapping support in your application.
- *Job scheduling support*: Most nontrivial applications require some kind of scheduling capability. Whether this is for sending updates to customers or performing housekeeping tasks, the ability to schedule code to run at a predefined time is an invaluable tool for developers. Spring provides scheduling support that can fulfill most common scenarios. A task can be scheduled either for a fixed interval or by using a Unix cron expression. On the other hand, for task execution and scheduling, Spring integrates with other scheduling libraries as well. For example, in the application server environment, Spring can delegate execution to the CommonJ library that is used by many application servers. For job scheduling, Spring also supports libraries including the JDK Timer API and Quartz, a commonly used open source scheduling library. The scheduling support in Spring is covered in full in **Chapter 12**.
- *MVC in the web tier*: Although Spring can be used in almost any setting, from the desktop to the Web, it provides a rich array of classes to support the creation of web-based applications. Using Spring, you have maximum flexibility when you are choosing how to implement your web front end. For developing web applications, the MVC pattern is the most popular practice. In recent versions, Spring has gradually evolved from a simple web framework into a full-blown MVC implementation. First, view support in Spring MVC is extensive. In addition to standard support for JSP and Java Standard Tag Library (JSTL), which is greatly bolstered by the Spring tag libraries, you can take advantage of fully integrated support for Apache Velocity, FreeMarker, Thymeleaf, XSLT, React, and Mustache templates. In addition, you will find a set of base view classes that make it simple to add Microsoft Excel, PDF, and JasperReports output to your applications. Starting with **Chapter 15**, we discuss developing web applications by using Spring MVC.
- *Remoting support*: Accessing or exposing remote components in Java has never been the simplest of jobs. Using Spring, you can take advantage of extensive support for a wide range of remoting techniques to quickly expose and access remote services: JMS, Advanced Message Queuing Protocol (AMQP), and REST. Accessing remote services nowadays more often than not involves real-time streaming data, and applications must adapt to the data streams; this is where Apache Kafka comes in handy. How Spring integrates with these technologies is covered in **Chapter 13**, except REST, which is covered in **Chapter 16**.

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<sup>9</sup><https://github.com/FasterXML/jackson>



- *Simplified exception handling:* One area where Spring really helps reduce the amount of repetitive, boilerplate code you need to write is in exception handling. The core of the Spring philosophy in this respect is that checked exceptions are overused in Java and that a framework should not force you to catch any exception from which you are unlikely to be able to recover—a point of view that we agree with wholeheartedly. In reality, many frameworks are designed to reduce the impact of having to write code to handle checked exceptions. However, many of these frameworks take the approach of sticking with checked exceptions but artificially reducing the granularity of the exception class hierarchy. One thing you will notice with Spring is that because of the convenience afforded to the developer from using unchecked exceptions, the exception hierarchy is remarkably granular. Throughout the book, you will see examples in which the Spring exception-handling mechanisms can reduce the amount of code you have to write and, at the same time, improve your ability to identify, classify, and diagnose errors within your application.
- *WebSocket support:* Starting with Spring Framework 4.0, support for JSR-356 (“Java API for WebSocket”) is available. WebSocket defines an API for creating a persistent connection between a client and server, typically implemented in web browsers and servers. WebSocket-style development opens the door for efficient, full-duplex communication enabling real-time message exchanges for highly responsive applications. Use of WebSocket support is detailed further in **Chapter 19**. The Spring Framework provides a reactive WebSocket API that you can use to write client and server-side applications that handle WebSocket messages, which is covered briefly in **Chapter 20**.
- *Reactive programming:* Reactive programming describes a design paradigm that relies on asynchronous programming logic to handle real-time updates to otherwise static content. It provides an efficient means—the use of automated data streams—to handle data updates to content whenever a user makes an inquiry. The Spring team created its own reactive streams implementation, Project Reactor, when the JDK Reactive support was delayed, so Spring could have a jump-start into providing support for building reactive applications with Spring. How to develop reactive Spring applications is covered in **Chapter 20**.
- *Securing applications:* In a world where almost any business transaction is done over the Internet, securing data and ensuring access to it is no longer an option but a requirement. The Spring Security project<sup>10</sup>, formerly known as the *Acegi Security System for Spring*, is another important project within the Spring portfolio. Spring Security provides comprehensive support for both web application and method-level security. It tightly integrates with the Spring Framework and other commonly used authentication mechanisms, such as HTTP basic authentication, form-based login, X.509 certificate, OAuth2 and single sign-on (SSO) products (for example, CA SiteMinder). It provides role-based access control (RBAC) to application resources, and in applications with more-complicated security requirements (for example, data segregations), it supports use of an access control list (ACL). Spring Security is mostly used in securing web applications, which is covered in **Chapter 17**. Reactive security is briefly touched upon in **Chapter 20**.

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<sup>10</sup><https://projects.spring.io/spring-security>

- *Monitoring applications:* An application made of multiple components should have a setup that, after being put into production, ensures the smooth functioning of the many components that make up the application. You need to monitor its performance—its resource usage, user traffic, request rates, response times, bottlenecks, memory issues, and so forth—to be able to overcome these limitations and ensure a good end-user experience. Spring Actuator is used to expose operational information about the running application—health, metrics, info, dump, env, and so on. It uses HTTP endpoints or JMX beans to enable you to interact with it. Actuator uses Micrometer, a dimensional-first metrics collection facade whose aim is to allow you to time, count, and gauge your code with a vendor-neutral API. Despite its focus on dimensional metrics, Micrometer does map to hierarchical names to continue to serve older monitoring solutions like Ganglia or narrower scoped tools like JMX. The change to Micrometer arose out of a desire to better serve a wave of dimensional monitoring systems (think Prometheus, Datadog, Wavefront, SignalFx, Influx, etc.). This flexibility is an advantage of Spring being designed for DI, which allows easily swapping monitoring systems as well. Working with Actuator is covered in **Chapter 18**.
- *Run everywhere:* For a long time the technical evolution allow us to go big, we've found new ways of keeping CPUs cool while increasing their frequency, we've managed to provide more memory with smaller chips, but recently a new trend has arisen. Deploying applications on privately owned clouds has made people worry about the cloud costs, so an emerging trend is to build compact applications that require smaller CPUs and less memory to run. Better performance with less resource consumption means less cloud costs, and this is why the age of compact native images is coming. The experimental (for now) Spring Native project provides support for compiling Spring applications to native executables using the GraalVM native-image compiler. GraalVM is a high-performance runtime that provides significant improvements in application performance and efficiency, which is ideal for microservices. This means applications start faster and need less resources while running. This makes them suitable to be deployed in a private cloud (Amazon, GCP, Hetzner, etc.) with decent costs. How to build a Spring project to be runnable using a GraalVM native image using Spring Native and other goodies is covered in **Chapter 14**.

## The Spring Community

The Spring community is one of the best in any open source project we have encountered. The mailing lists and forums are always active, and progress on new features is usually rapid. The development team is truly dedicated to making Spring the most successful of all the Java application frameworks, and this shows in the quality of the code that is reproduced. As we mentioned already, Spring also benefits from excellent relationships with other open source projects, a fact that is extremely beneficial when you consider the large amount of dependency the full Spring distribution has. From a user's perspective, perhaps one of the best features of Spring is the excellent documentation and test suite that accompany the distribution.

Documentation is provided for almost all the features of Spring, making it easy for new users to pick up the framework. The test suite Spring provides is impressively comprehensive—the development team writes tests for everything. If they discover a bug, they fix that bug by first writing a test that highlights the bug and then getting the test to pass. Fixing bugs and creating new features is not limited just to the development

team! You can contribute code through pull requests against any portfolio of Spring projects through the official GitHub repositories<sup>11</sup>. Or you can help experimental projects grow their wings by contributing through the official experimental GitHub repositories<sup>12</sup>.

What does all this mean to you? Well, put simply, it means you can be confident in the quality of the Spring Framework and confident that, for the foreseeable future, the Spring development team will continue to improve what is already an excellent framework.

## Alternatives to Spring

Going back to our previous comments on the number of open source projects, you should not be surprised to learn that Spring is not the only framework offering dependency injection features or full end-to-end solutions for building applications.

A popular DI framework is **Google Guice**<sup>13</sup>. Led by the search engine giant Google, Guice is a lightweight framework that focuses on providing DI for application configuration management. It was also the reference implementation of JSR-330.

**Vaadin**<sup>14</sup> is an open source web application development platform for Java. Vaadin includes a set of web components, a Java web framework, and a set of tools that enable developers to implement modern web graphical user interfaces using the Java programming language only, TypeScript only, or a combination of both. Its scope is limited to web applications, but for more complex applications it easily integrates with Spring and can harness the power of the Spring IoC container.

The now defunct **JBoss Seam Framework**<sup>15</sup> used to be a good alternative to Spring. When I (Iuliana) took my first Spring training in 2012, I was pretty convinced the Spring annotation model for configuring its beans was inspired from it.

The now defunct **PicoContainer**<sup>16</sup> was an exceptionally small DI container that allowed you to use DI for your application without introducing any dependencies other than PicoContainer. Being nothing more than a DI container, writing a more complex application required adding of extra frameworks, such as Spring, in which case you would have been better off using Spring from the start. However, if all you needed was a tiny DI container, then PicoContainer was a good choice.

## Summary

In this chapter, you were provided a 10,000-foot view of the Spring Framework and its evolution onto a collection of projects that can be used to build any type of application you might need, complete with discussions of all the important features. A guide to the relevant sections of the book where these features are discussed in detail was provided, together with references to the additional technologies that will be used throughout the book.

After reading this chapter, you should understand what Spring can do for you; all that remains is to see how it can do it. In the next chapter, you will be provided all the information you need to know to prepare your development environment to get up and running with a basic Spring application. **Chapter 2** introduces some basic Spring code and configuration, including a time-honored *Hello World* example in all its DI-based glory.

---

<sup>11</sup> <https://github.com/spring-projects>

<sup>12</sup> <https://github.com/spring-projects-experimental>

<sup>13</sup> <https://code.google.com/p/google-guice>

<sup>14</sup> <https://vaadin.com>

<sup>15</sup> <https://www.seamframework.org>

<sup>16</sup> <http://picocontainer.com>

## CHAPTER 2



# Getting Started

The most difficult part when starting a new project is setting up a development environment, a process that involves selecting and optimizing the tooling so that then you can focus on writing the code. Fortunately, this book intends to make that easier. The project for this book is a Java project that uses Spring components, which means there are quite a few choices when it comes to editors, build tools, and even JDKs.

This chapter provides all the basic knowledge you need to get off to a flying start, but first let's look at a few conventions.

## Conventions

This book uses several formatting conventions that should make it easier to read. To that end, the following conventions are used within the book:

- Code or concept names in paragraphs appear as follows: `java.util.List`
- Code listings and configurations appear as follows:

```
public static void main(String... args) {
    System.out.println("Hello World!");
}
```







- Logs in console outputs appear as follows:

```
01:24:07.809 [main] INFO c.a.Application - Starting Application
01:24:07.814 [main] DEBUG c.a.p.c.Application - Running in debug mode
```

- `{xx}` is a placeholder, where the `xx` value is a pseudo-value giving a hint about the real value that should be used in the command or statement. For example, `{name_of_your_bean}` means that in a concrete example, the whole construct should be replaced by the name of your bean.
- *Italic* font is used for humorous metaphors, expressions, and bits of text that need some kind of separation from the text around them. For example, in **Chapter 1** the Hollywood Principle is introduced as *Don't call us, we'll call you*.
- **Bold** font is used for chapter references and important terms.

- (..) is used to replace sets of parameter declarations and arguments in methods and constructors, to avoid distracting you from the actual code.
- ... is used to replace code, configuration, and logs not relevant to the context.
- Packages import statements are kept to a minimum, and only the ones relevant to the component being discussed are shown. This is to reduce the space taken up by code in the book, which is better used for more in-depth explanations. You have the full code in the repository anyway!
- Each chapter has a few footnotes and links pointing you to documentation, tools, and blog articles. The book is readable without consulting them, so feel free to ignore them, but you might find them useful.
- Some paragraphs are shown in a rectangle and labeled with one of the icons in Table 2-1. The table also shows the meaning of each icon.

**Table 2-1.** *Special Paragraphs Icons and Meanings*

Icon	Meaning
	You might find this useful.
	You will definitely find this useful.
	This is really useful.
	Be careful when using this.
	Whatever this is about, it is recommended not to do it.
	Whatever this is about, just don't do it.

As for my style of writing, I (Iuliana) like to write my books in the same way I have technical conversations with colleagues and friends, sprinkling in jokes, giving production examples, and making analogies to non-programming situations. Because programming is nothing but just another way to model the real world.

## Who This Book Is For

This book assumes you are somewhat familiar with Java and tools involved in the development of Java applications. If you are not, that might not be too much of a problem, because the project is neatly set up such that you could build it without having any knowledge about what Gradle and Maven do. Also, if you stick to the recommended editor, which is IntelliJ IDEA, you should be able to just clone the repository, build the project, and get right to business.

## What You Need for This Book

You obviously need a **computer**, desktop or laptop, the choice of which doesn't really matter as long as it is up to date, running Windows, Linux, or macOS, and is connected to the **Internet**.

You need to have **JDK 17** installed locally. Instructions on how to do so on any operating system are available in the *JDK Installation Guide*, available on the Oracle official page<sup>1</sup>.



For any Unix-based system, **SDKMAN!**<sup>2</sup> is very useful. SDKMAN! is a tool for managing parallel versions of multiple software development kits on most Unix-based systems. It provides a convenient command-line interface (CLI) and API for installing, switching, removing, and listing software candidates. It works for JDK, Gradle, Maven, and many more.

---

As previously mentioned, the recommended **editor** is IntelliJ IDEA<sup>3</sup>; you can use the Enterprise version for free for 30 days, or you can help test Early Access versions. IntelliJ IDEA is a great editor for Spring applications because it comes with a great set of plug-ins that resolve beans by name in XML and Java configuration classes, thus helping you be very aware if your beans are properly configured. If you are more familiar with Eclipse IDE, you can try Spring Tools 4<sup>4</sup>.

You need the **sources** where all the code samples referenced in the book come from. Depending on how you are getting the project associated with this book, you might need **Git**<sup>5</sup> installed. You can use Git from the command line to clone the repository, or you can use the IDE, or you can download the sources as a zip from the repository page.



This is the project repository page: <https://github.com/Apress/pro-spring-6>

---

Any project dependencies that are more complex than a Java library and need to run services that the Spring applications interact with are provided via Docker containers; thus, you need to install Docker<sup>6</sup> on your computer. Instructions on how to download images and start them are provided in README.adoc files for the respective chapters.

To summarize the requirements for you to become a Spring Pro: this book, a computer, Internet, Java 17, Git, the sources, Docker, and a little bit of time and determination.

---

<sup>1</sup><https://docs.oracle.com/en/java/javase/17/install/overview-jdk-installation.html>

<sup>2</sup><https://sdkman.io>

<sup>3</sup><https://www.jetbrains.com/idea>

<sup>4</sup><https://spring.io/tools>

<sup>5</sup><https://git-scm.com/>

<sup>6</sup><https://www.docker.com/>

# Prepare Your Development Environment

Here is the list of steps you have to go through to start running the code associated with the book:

- Sit comfortably in front of your computer.
- Install JDK 17.

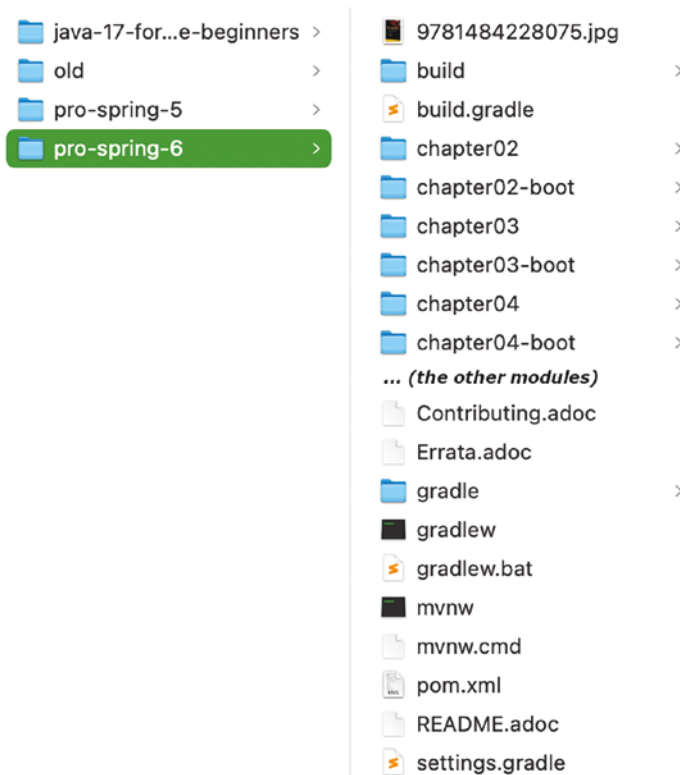


If you have older versions installed, make sure it is the default one used on your system by opening a terminal (Command Prompt or Power Shell on Windows systems) and running `java -version`. Expect the output to mention Java version 17, as depicted in code Listing 2-1.

**Listing 2-1.** Output of Command `java -version` Showing JDK 17 Set As Default

```
> java -version
java version "17.0.1" 2021-10-19 LTS
Java(TM) SE Runtime Environment (build 17.0.1+12-LTS-39)
Java HotSpot(TM) 64-Bit Server VM (build 17.0.1+12-LTS-39, mixed mode, sharing)
```

- 
- Clone the project repository or download the sources from the Apress official page and unzip them on your computer. You should have a directory named `pro-spring-6` containing the modules as shown in Figure 2-1.



**Figure 2-1.** The *pro-spring-6* project and its modules

- Open the IntelliJ IDEA editor, choose File ► Open in the main menu, and in the file selector window that opens, select the *pro-spring-6* directory. After a short while, on the left side (in a pane we'll call the *Project View* in the book), you should see the *pro-spring-6* project and its modules listed. On the right side of the window, you should see a section showing you the Gradle configuration (we'll call this the *Gradle View* in this book) and a section showing you the Maven configuration (we'll call this the *Maven View*). All three views are shown in Figure 2-2.



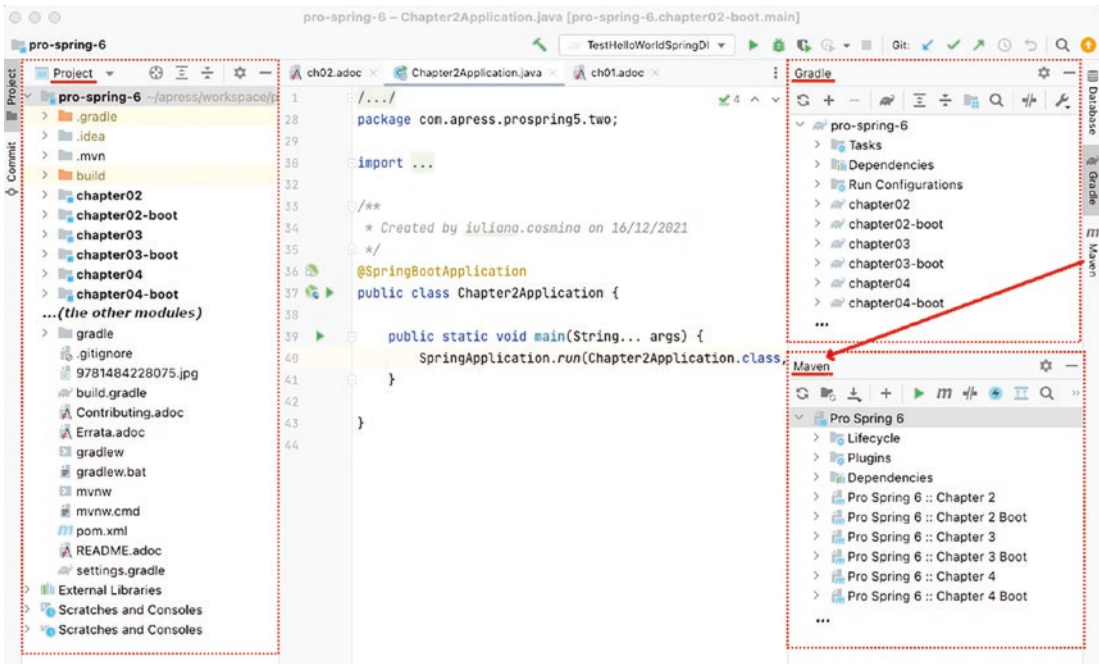



Figure 2-2. The pro-spring-6 project, Gradle and Maven Views

The project is made up of multiple modules, each representing a Java project. The name of each module corresponds to the chapter where its contents are referenced. Each chapter has two or more modules associated with it, depending on the context and topics covered. The ones with names that end in -boot are Spring Boot projects. The ones with names that don't end in -boot are just Java projects using Spring, because, yes, you can use Spring without using Spring Boot. We call these *classic Spring projects*, because this is how Spring applications were developed before Spring Boot was around. This project depends on a lot of libraries that will be automatically downloaded when your project is opened in an editor for the first time.

The project has a Gradle configuration and a Maven configuration; use whichever you feel most comfortable with. The project can be built right after cloning according to the instructions in its README.adoc file. The project does not need Gradle or Maven installed locally, since both are configured to use wrappers.

The Gradle version used to build the project at the time this chapter is being written is 7.4. The version likely will change by the time the book is released, but the version will be mentioned in the main README.adoc file and in the Gradle wrapper configuration file: gradle/wrapper/gradle-wrapper.properties.

Similarly, the Maven version used to build the project at the time of writing is 3.8.4. The version likely will change by the time the book is released, but the version will be mentioned in the main README.adoc file and in the Maven wrapper configuration file: .mvn/wrapper/maven-wrapper.properties.

IntelliJ IDEA identifies the wrapper configurations and builds your project using any of them. If you want to explicitly trigger any of the wrapper configurations from the interface, just click the  symbol that you see in the upper-left corner of Gradle View and Maven View.



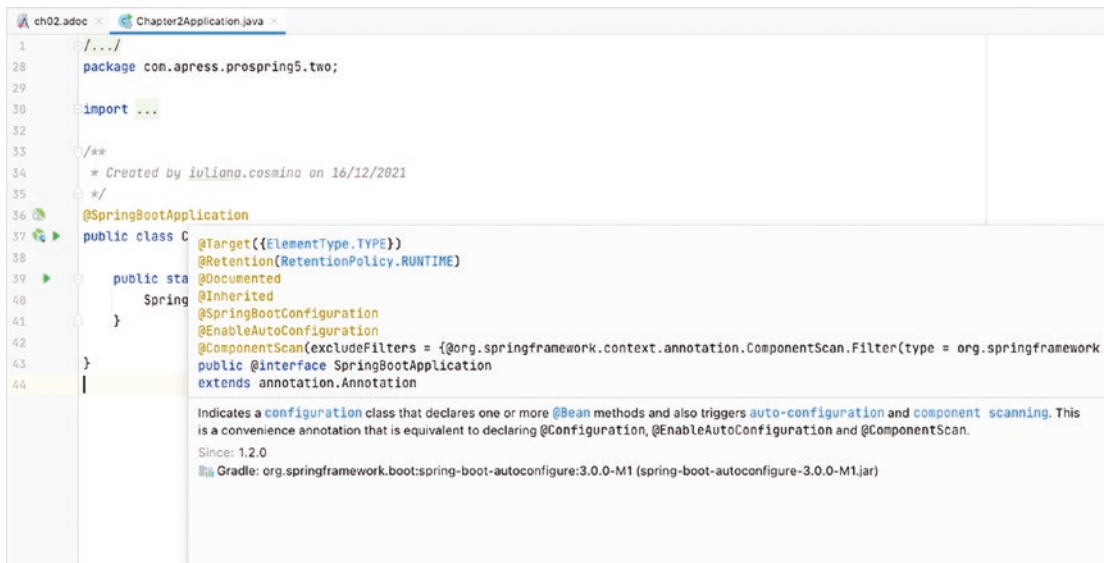
IntelliJ IDEA keeps the state of your project internally and sometimes gets... *ahem*... confused. If your project shows class names in red and complains about missing dependencies, try building it from the command line as explained in the README.adoc file. If that works, you might try one of these options under the File menu: **Invalidate Caches..., Reload All from Disk, Restart IDE, Repair IDE...**

Now that you have the project loaded and building successfully on your computer, we'll tell you more about Spring internals before explaining the pro-spring-6 project Maven and Gradle configurations.

## Understanding Spring Packaging

Spring packaging is modular; it allows you to pick and choose which components you want to use in your application and to include only those components when you are distributing your application. Spring has many modules, but you need only a subset of these modules depending on your application's needs. Each module has its compiled binary code in a JAR file along with corresponding Javadoc and source JARs. IntelliJ IDEA scans the dependencies of your project and, on request, it can download the sources and Javadoc. This means that you can see the code and read about Spring classes in your editor.

The Javadoc for a class is shown in a rectangle when hovering over its name, as depicted in Figure 2-3 for the `@SpringBootApplication` annotation.



**Figure 2-3.** IntelliJ IDEA displaying the Javadoc for the `@SpringBootApplication` annotation

You can also choose to press the Ctrl (Command for macOS) key and click a class name, and IntelliJ IDEA will download the sources for it and open them in a new tab. In Figure 2-4 you can see on the right the source for the `@SpringBootApplication` annotation.

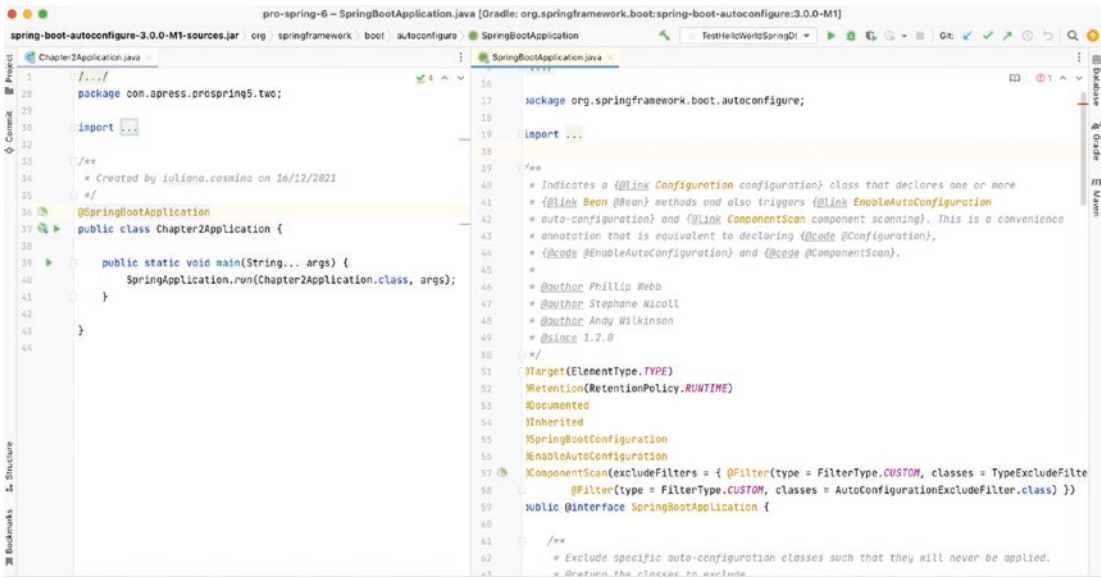


Figure 2-4. IntelliJ IDEA displaying the source for the @SpringBootApplication annotation

Back to the Spring modules. *Spring modules* are simply JAR files that package the required code for that module. The code base for the Spring Framework is publicly available on GitHub. If you are curious about what the code of the Spring Framework looks like and want to be on the cutting edge of Spring development, check out the latest version of the source code from Spring’s GitHub repository<sup>7</sup>.

After you understand the purpose of each module, you can select the modules required in your project and include them in your code. As shown by the most recent tag on GitHub, it seems that Spring Framework version 6.0 comes with 22 modules. Table 2-2 describes these JAR files and their corresponding modules. The actual JAR file name is, for example, `spring-aop-6.0.0.jar`, though we have included only the specific module portion for simplicity (as in `aop`, for example).

Table 2-2. Spring Modules

Module	Description
aop	This module contains all the classes you need to use Spring’s AOP features within your application. You also need to include this JAR in your application if you plan to use other features in Spring that use AOP, such as declarative transaction management. Moreover, classes that support integration with AspectJ are packed in this module.
aspects	This module contains all the classes for advanced integration with the AspectJ AOP library. For example, if you are using Java classes for your Spring configuration and need AspectJ-style annotation-driven transaction management, you need this module.
beans	This module contains all the classes for supporting Spring’s manipulation of Spring beans. Most of the classes here support Spring’s bean factory implementation. For example, the classes required for processing the Spring XML configuration file and Java annotations are packed into this module.

(continued)

<sup>7</sup><https://github.com/spring-projects/spring-framework>

**Table 2-2.** (continued)

Module	Description
context	This module contains classes that provide many extensions to Spring Core. You will find that all classes need to use Spring's <code>ApplicationContext</code> feature (covered in <b>Chapter 5</b> ), along with classes for Enterprise JavaBeans (EJB), Java Naming and Directory Interface (JNDI), and Java Management Extensions (JMX) integration. Also contained in this module are the Spring remoting classes, classes for integration with dynamic scripting languages (for example, JRuby, Groovy, and BeanShell), JSR-303 ("Bean Validation"), scheduling and task execution, and so on.
context-indexer	This module contains an indexer implementation that provides access to the candidates that are defined in <code>META-INF/spring.components</code> . The core class <code>CandidateComponentsIndex</code> is not meant to be used externally.
context-support	This module contains further extensions to the <code>spring-context</code> module. On the user-interface side, there are classes for mail support and integration with templating engines such as Velocity, FreeMarker, and JasperReports. Also, integration with various task execution and scheduling libraries, including CommonJ and Quartz, are packaged here.
core	This is the main module that you will need for every Spring application. In this JAR file, you will find all the classes that are shared among all other Spring modules (for example, classes for accessing configuration files). Also, in this JAR you will find selections of extremely useful utility classes that are used throughout the Spring codebase and that you can use in your own application.
expression	This module contains all support classes for Spring Expression Language (SpEL).
instrument	This module includes Spring's instrumentation agent for JVM bootstrapping. This JAR file is required for using load-time weaving with AspectJ in a Spring application.
jdbc	This module is only present for binary compatibility with existing Commons Logging usage, such as in Apache Commons Configuration.
jdbc	This module includes all classes for JDBC support. You will need this module for all applications that require database access. Classes for supporting data sources, JDBC data types, JDBC templates, native JDBC connections, and so on, are packed in this module.
jms	This module includes all classes for Java Message Service (JMS) support.
messaging	This module contains key abstractions taken from the Spring Integration project to serve as a foundation for message-based applications and adds support for Simple or Streaming Text Orientated Messaging Protocol (STOMP) messages.
orm	This module extends Spring's standard JDBC feature set with support for popular ORM tools including Hibernate, JDO, and JPA. Many of the classes in this JAR depend on classes contained in the <code>spring-jdbc</code> JAR file, so you definitely need to include that in your application as well.
oxm	This module provides support for Object/XML Mapping (OXM). Classes for the abstraction of XML marshalling and unmarshalling and support for popular tools such as Castor, JAXB, XMLBeans, and XStream are packed into this module.
r2dbc	This module makes R2DBC easier to use and reduces the likelihood of common errors. It provides simple error handling and a family of unchecked concise exceptions agnostic of the underlying Reactive Database Manager (RDBM).

(continued)

**Table 2-2.** (continued)

Module	Description
test	Spring provides a set of mock classes to aid in testing your applications, and many of these mock classes are used within the Spring test suite, so they are well tested and make testing your applications much simpler. Certainly we have found great use for the mock <code>HttpServletRequest</code> and <code>HttpServletResponse</code> classes in unit tests for our web applications. On the other hand, Spring provides a tight integration with the JUnit unit-testing framework, and many classes that support the development of JUnit test cases are provided in this module; for example <code>SpringExtension</code> integrates the <i>Spring TestContext Framework</i> into JUnit 5's <i>Jupiter</i> programming model.
tx	This module provides all classes for supporting Spring's transaction infrastructure. You will find classes from the transaction abstraction layer to support the Java Transaction API (JTA) and integration with application servers from major vendors.
web	This module contains the core classes for using Spring in your web applications, including classes for loading an <code>ApplicationContext</code> feature automatically, file upload support classes, and a bunch of useful classes for performing repetitive tasks such as parsing integer values from the query string.
webflux	This module contains core interfaces and classes for the Spring Web Reactive model.
webmvc	This module contains all the classes for Spring's own MVC framework. If you are using a separate MVC framework for your application, you won't need any of the classes from this JAR file. Spring MVC is covered in more detail in <b>Chapter 15</b> .
websocket	This module provides support for JSR-356 ("Java API for WebSocket").

If you use Spring Boot, you don't have to select Spring modules to add as dependencies explicitly, because the appropriate set of Spring dependencies are configured depending on the Spring Boot starter dependencies used. The codebase for Spring Boot is also publicly available on GitHub. If you are curious about how the Spring Boot code looks like and want to be on the cutting edge of Spring Boot development, check out the latest version of the source code from Spring's GitHub repository<sup>8</sup>. Under `spring-boot-project/spring-boot-starters` there is a list of Spring Boot starter modules that can be used as dependencies for a Spring project to build a certain type of Spring application, with a default configuration and curated set of dependencies. The modules are nothing but dependency descriptors that can be added under the `<dependencies>` section in `pom.xml`. They can be used with Gradle projects too. There are currently more than 30 of them, and Table 2-3 lists the ones most often used and the dependencies they configure for your application.

<sup>8</sup><https://github.com/spring-projects/spring-boot/>

**Table 2-3.** *Spring Boot Starter Modules*

Module	Description
spring-boot-starter	This is the simplest Spring Boot starter that adds the <code>spring-core</code> library as a dependency for your project. It can be used to create a very simple Spring application. It is used mostly for learning purposes and for creating base projects, and encapsulates common functionality shared among other modules in a project.
spring-boot-starter-aop	Adds the <code>spring-aop</code> library as a dependency for your project.
spring-boot-starter-data-*	This type of starter adds various Spring dependencies for working with data in your project. The <code>*</code> replaces the technology from which data is coming. For example, <code>spring-boot-starter-data-jdbc</code> adds classes for creating Spring Repository beans for handling data from databases supporting a JDBC driver: MySQL, PostgreSQL, Oracle, etc.
spring-boot-starter-web	Configures minimal dependencies for creating a web application.
spring-boot-starter-security	Configures minimal dependencies for securing a Spring web application.
spring-boot-starter-webflux	Configures minimal dependencies for creating a reactive web application.
spring-boot-starter-actuator	Configures the Spring Boot Actuator, which enables a set of endpoints for monitoring a Spring web application.
spring-boot-starter-test	Configures the following set of libraries: Spring Test, JUnit, Hamcrest, and Mockito.

## Choosing Modules for Your Application

Without a dependency management tool such as Maven or Gradle, choosing which modules to use in your application may be a bit tricky. For example, if you require Spring's bean factory and DI support only, you still need several modules, including `spring-core`, `spring-beans`, `spring-context`, and `spring-aop`. If you need Spring's web application support, you then need to further add `spring-web` and so on. Thanks to build tools features such as Maven's transitive dependencies support, all required third-party libraries would be included automatically.

## Accessing Spring Modules on the Maven Repository

Founded by Apache Software Foundation, Maven<sup>9</sup> has become one of the most popular tools in managing the dependencies for Java applications, from open source to enterprise environments. Maven is a powerful application building, packaging, and dependency management tool. It manages the entire build cycle of an application, from resource processing and compiling to testing and packaging. There also exists a large number of Maven plug-ins for various tasks, such as updating databases and deploying a packaged application to a specific server (for example: Tomcat, WildFly, or WebLogic). As of this writing, the current Maven version is 3.8.4.

<sup>9</sup><https://maven.apache.org>



Almost all open source projects support distribution of libraries via the Maven repository. The most popular one is the Maven Central repository hosted on Apache, and you can access and search for the existence and related information of an artifact on the Maven Central website<sup>10</sup>. If you download and install Maven into your development machine, you automatically gain access to the Maven Central repository. Some other open source communities (for example, JBoss and Spring) also provide their own Maven repository for their users. However, to be able to access those repositories, you need to add the repository into your Maven's setting file or in your project's POM file. (You can see an example of this in `pro-spring-6/pom.xml`; just look for the `<repositories>` element.)

A detailed discussion of Maven is not in the scope of this book, and you can always refer to the online documentation or books that give you a detailed reference to Maven. However, since Maven is widely adopted, it's worth mentioning the typical structure of the project packaging on the Maven repository.

A *group ID*, *artifact ID*, *packaging type*, and *version* identify each Maven artifact. For example, for `log4j-core`, the group ID is `org.apache.logging.log4j`, the artifact ID is `log4j-core`, and the packaging type is `jar`. Under that, different versions are defined. For example, for version `2.17.1`, the artifact's file name becomes `log4j-core-2.17.1.jar` under the group ID, artifact ID, and version folder. Maven configuration files are written in XML and must respect the Maven standard syntax defined by the [https://maven.apache.org/maven-v4\\_0\\_0.xsd](https://maven.apache.org/maven-v4_0_0.xsd) schema. The default name of a Maven configuration file for a project is `pom.xml`, and a sample file is shown in Listing 2-2.

**Listing 2-2.** `pom.xml` Snippet

```
<project xmlns="http://maven.apache.org/POM/4.0.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
  http://maven.apache.org/maven-v4_0_0.xsd">

  <modelVersion>4.0.0</modelVersion>

  <groupId>com.apress.prospring6.ch02</groupId>
  <artifactId>hello-world</artifactId>
  <packaging>jar</packaging>
  <version>5.0-SNAPSHOT</version>

  <name>hello-world</name>

  <dependencies>
    <dependency>
      <groupId>org.apache.logging.log4j</groupId>
      <artifactId>log4j-core</artifactId>
      <version>2.17.1</version>
    </dependency>
  </dependencies>

  <build>
    <plugins>
      <plugin>
        ...
```

---

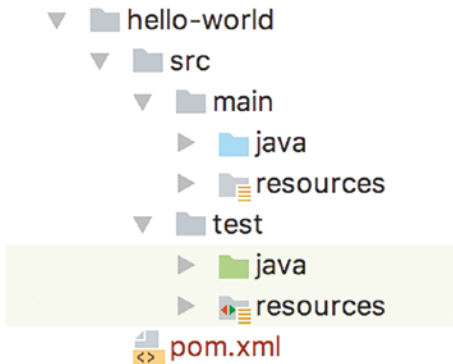
<sup>10</sup><https://mvnrepository.com/>

```

    </plugin>
  </plugins>
</build>
</project>

```

Maven also defines a typical standard project structure, as depicted in Figure 2-5.



**Figure 2-5.** Maven typical project structure

The main directory contains the application codebase in the `java` directory and application configuration files in the `resources` directory. The `test` directory contains the application test code in the `java` directory and the application test configuration files in the `resources` directory.

Accessing Spring modules and adding them as dependencies to a project is pretty similar to what was shown so far in this section, but Spring Boot's dependency management can be used even for Spring projects that don't use Spring Boot, and this ensures that transitive dependencies added to your projects will always be stable and compatible with each other. But first, let us introduce you to Gradle.

## Accessing Spring Modules Using Gradle

The Maven project standard structure and artifact categorization and organization is important because Gradle<sup>11</sup> respects the same rules and even uses the Maven central repository to retrieve artifacts. Various other repositories can be configured as well. Gradle is a powerful build tool that has given up the bloated XML for configuration and switched to the simplicity and flexibility of Groovy. Which is very good and provides a lot of flexibility, up until a developer gets too creative with their configuration, that is. At the time of writing, the current version of Gradle is 7.3.3. Starting with version 4.x, the Spring team has switched to using Gradle for the configuration of every Spring product. That is why the source code for this book can be built and executed using Gradle too. The default name of a Gradle configuration file for a project is `build.gradle`. The equivalent of the `pom.xml` file depicted earlier (well, one version of it) is shown in Listing 2-3.

<sup>11</sup> <https://gradle.org/>



**Listing 2-3.** build.gradle Snippet

```

group 'com.apress.prospring6.ch02'
version '6.0-SNAPSHOT'
apply plugin: 'java'
repositories {
    mavenCentral()
}

tasks.withType(JavaCompile) {
    options.encoding = "UTF-8"
}
dependencies {
    compile group: 'org.apache.logging.log4j', name: 'log4j-core', version: '2.17.1'
    ...
}

```

That's way more readable, right? As you can observe, the artifacts are identified using the *group*, *artifact*, and *version* as previously introduced with Maven, but the property names differ. Gradle is not in the scope of this book either, but it will be mentioned here and there in the book.

## Using Spring Boot Dependency Management

As previously mentioned, you can use a Spring Boot starter project as a parent project to provide your project with a minimal set of dependencies and default configurations. By declaring `spring-boot-starter-parent` as a parent project, Spring Boot dependency management is enabled, which means default configurations for your application and a complete dependency tree are set up for the project. Listing 2-4 depicts a Maven configuration file using `spring-boot-starter-parent` as a dependency. Since we are using a Spring Boot SNAPSHOT version, the <https://repo.spring.io/snapshot> repository is configured as well (line marked with 2).

**Listing 2-4.** pom.xml for a Project Using `spring-boot-starter-parent` As a Parent

```

<project xmlns="http://maven.apache.org/POM/4.0.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
  http://maven.apache.org/maven-v4_0_0.xsd">

  <modelVersion>4.0.0</modelVersion>

  <parent>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-parent</artifactId>
    <version>3.0.0-SNAPSHOT</version> <!-- 1 -->
    <relativePath/> <!-- lookup parent from repository -->
  </parent>

  <groupId>com.apress.prospring6.ch02</groupId>
  <artifactId>hello-world</artifactId>
  <version>6.0-SNAPSHOT</version>

```

```

<name>hello-world</name>
<properties>
  <java.version>17</java.version>
</properties>

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

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

<build>
  <plugins>
    <plugin>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-maven-plugin</artifactId>
    </plugin>
  </plugins>
</build>

<repositories>
  <repository>
    <id>spring-milestones</id>
    <url>https://repo.spring.io/milestone</url>
  </repository>
  <repository>
    <id>spring-snapshot</id>
    <url>https://repo.spring.io/snapshot</url> <!-- 2 -->
  </repository>
</repositories>
</project>

```

Notice how the only version declared in the file, beside the project version, is the one for `spring-boot-starter-parent`. There is no need to specify any version for Spring boot, or Spring dependencies, because they are already part of the configuration introduced by `spring-boot-starter-parent`. If you find it hard to believe, just open the IntelliJ IDEA Maven View and expand the `Dependencies` node. You should see the dependencies declared in the `pom.xml` file, and notice that they do have a version attached, even if you did not specify one. Also, notice their dependencies—the transitive dependencies of your project—have versions, and the best part is that you can declare any of these dependencies in your project and override the version.

So, sure, Spring Boot imposes a lot of defaults, but it is also easily customizable, and this affirmation is valid for dependencies and Java configurations as well. Figure 2-6 shows the Maven dependencies configured by the configuration file in Listing 2-4; only the `jakarta.annotation-api` dependency version has been overwritten with `2.1.0-B1`.

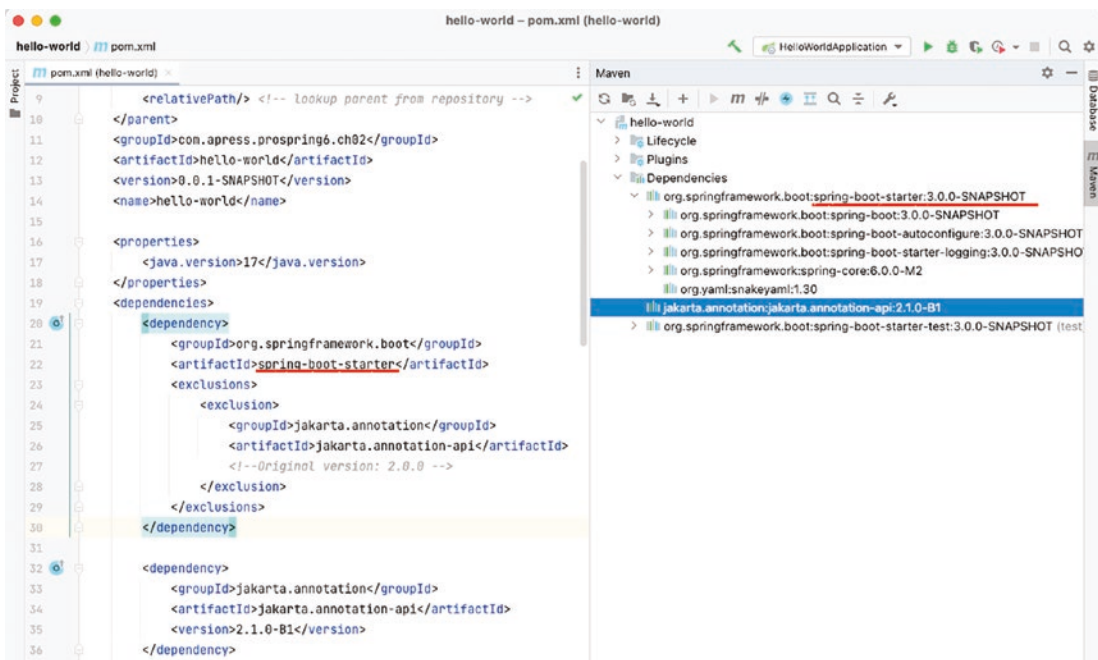


Figure 2-6. Maven Spring Boot project with customized version for jakarta.annotation-api

Having spring-boot-starter-parent as a parent for a project is not always convenient. Real-life projects have their own hierarchies and dependencies that are shared and not managed by Spring Boot. What is convenient is having proper dependency management where possible, and this can be achieved by removing the <parent> configuration and replacing it with the <dependencyManagement> configuration shown in Listing 2-5.

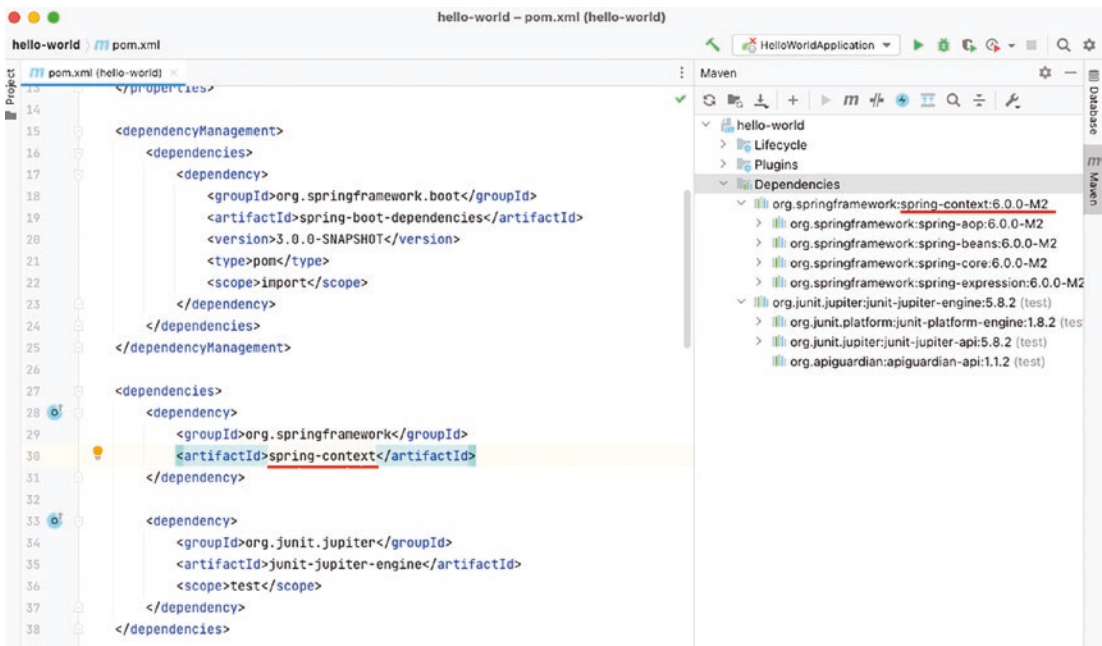
Listing 2-5. Spring Boot Project Maven Configuration Without spring-boot-starter-parent

```

<dependencyManagement>
  <dependencies>
    <dependency>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-dependencies</artifactId>
      <version>3.0.0-SNAPSHOT</version>
      <type>pom</type>
      <scope>import</scope>
    </dependency>
  </dependencies>
</dependencyManagement>

```

And the best part, Spring Boot dependency management can be used even in a Spring classic project—that does not use any Spring Boot starter dependencies. Figure 2-7 depicts a very simple Spring Project Maven configuration that only declares spring-context and junit-jupiter-engine as dependencies. Notice how there are no versions specified for the two dependencies, but in the Maven View we can clearly see the dependencies versions. This is done by importing the versions from the spring-boot-dependencies pom artifact.



**Figure 2-7.** Maven Spring (classic) project with dependency management provided by Spring Boot

What is the equivalent of this in Gradle? Since Gradle does not have a parent concept similar to Maven, dependency management is done using the `io.spring.dependency-management` plug-in. Listing 2-6 depicts a Gradle configuration analogous to the Maven configuration shown in Listing 2-4.

**Listing 2-6.** Simple Spring Boot Project Gradle Configuration

```

plugins {
    id 'org.springframework.boot' version '3.0.0-SNAPSHOT'
    id 'io.spring.dependency-management' version '1.0.11.RELEASE'
    id 'java'
}

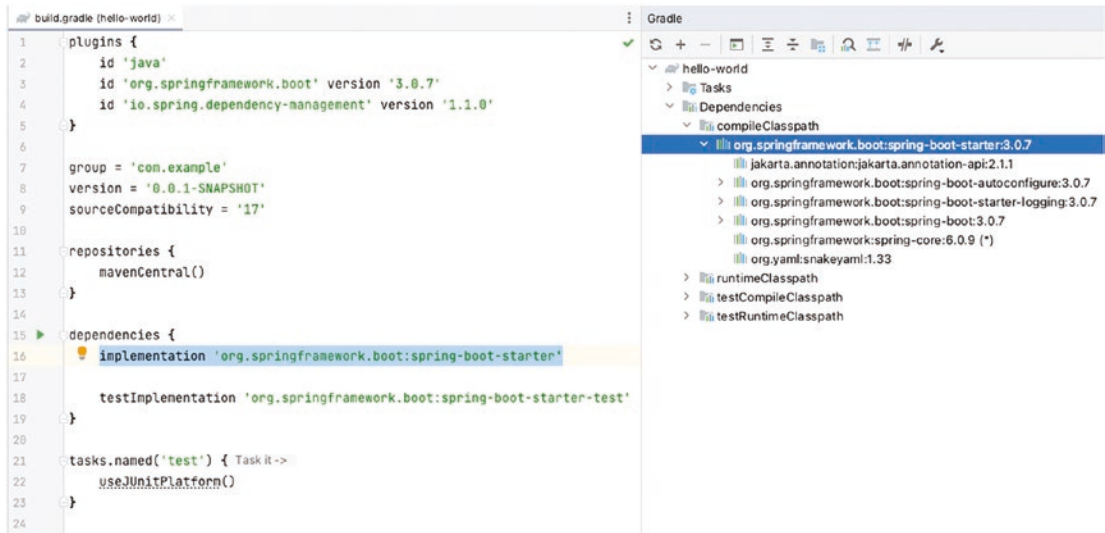
group = 'com.apress.prospring6.ch02'
version = '6.0-SNAPSHOT'
sourceCompatibility = '17'

repositories {
    mavenCentral()
    maven { url 'https://repo.spring.io/milestone' }
    maven { url 'https://repo.spring.io/snapshot' }
}

dependencies {
    implementation 'org.springframework.boot:spring-boot-starter'
    testImplementation 'org.springframework.boot:spring-boot-starter-test'
}
...

```

Overriding Spring Boot managed dependency versions is possible using Gradle as well. Figure 2-8 shows the IntelliJ IDEA’s Gradle View showing the dependencies introduced by Spring Boot dependency management and the Gradle configuration syntax for overriding versions.



**Figure 2-8.** Gradle Spring Boot project with customized version for `jakarta.annotation-api`

Since Spring Boot dependency management in Gradle is made using a plug-in, configuring Spring classic projects that make use of dependency management is possible without any additional change to the configurations, except removing starter dependencies and replacing them with the desired Spring dependencies.

In bigger projects, organized in multiple modules, configuration might get more complex, and simplifying it implies creating configuration templates that can be reused in modules. The `pro-spring-6` project is organized this way; the root `build.gradle` and `pom.xml` files contain configuration that is shared between all modules. Where necessary the module configuration files are used to override dependency versions and declare their own dependencies.

Gradle configuration is more readable and more concise, but in a big project, the lack of standards might lead to convoluted tasks implementations, because the only limit to declaring tasks is the developers’ understanding of Groovy. Maven, however, with its XML standard schema that is the same for all dependencies and plug-ins, is very consistent and easy to learn by beginners.

## Using Spring Documentation

One of the aspects of Spring that makes it such a useful framework for developers who are building real applications is its wealth of well-written, accurate documentation. In every release, the Spring Framework’s documentation team works hard to ensure that all the documentation is finished and polished by the development team. This means that every feature of Spring is not only fully documented in the Javadoc but is also covered in the Spring reference manual included in every distribution. If you haven’t yet familiarized yourself with the Spring Javadoc and the reference manual, do so now. This book is not a replacement for either of these resources; rather, it is a complementary reference, demonstrating how to build a Spring-based application from the ground up.

You can access the Spring Javadoc through the IntelliJ IDEA editor as mentioned previously, but if you prefer doing so in the browser, you can bookmark this URL: <https://docs.spring.io/spring-framework/docs/current/javadoc-api>.

For a more in-depth introduction to the Spring Framework, you can also bookmark the URL to the official reference documentation: <https://docs.spring.io/spring-framework/docs/current/reference/html>.

## Putting a Spring into Hello World

At this point in the book, we are optimistic that you are convinced that Spring is a solid, well-supported project that has all the makings of a great tool for application development and that understanding it in depth will not only make you a better developer but also boost your career. However, one thing is missing—we haven't shown you any code yet. We are sure you are dying to see Spring in action, and because we cannot go any longer without getting into the code, let's do just that. Do not worry if you do not fully understand all the code in this section; we go into much more detail on all the topics as we proceed through the book.

## Building the Sample Hello World Application

Now, we are sure you are familiar with the traditional Hello World example, but just in case you have been living on the moon for the past 30 years, the code snippet in Listing 2-7 shows the Java version in all its glory.

*Listing 2-7.* Classic Hello World Java Project

```
package com.apress.prospring6.two;

public class HelloWorld {

    public static void main(String... args) {
        System.out.println("Hello World!");
    }
}
```

As examples go, this one is pretty simple—it does the job, but it is not very extensible. What if we want to change the message? What if we want to output the message differently, maybe to standard error instead of standard output or enclosed in HTML tags rather than as plain text? We are going to redefine the requirements for the sample application and say that it must support a simple, flexible mechanism for changing the message, and it must be easy to change the rendering behavior. In the basic Hello World example, you can make both of these changes quickly and easily by just changing the code as appropriate. However, in a bigger application, recompiling takes time, and it requires the application to be fully tested again. A better solution is to externalize the message content and read it in at runtime, perhaps from the command-line arguments, as shown in Listing 2-8.

*Listing 2-8.* Classic Hello World Java Project with Arguments

```
package com.apress.prospring6.two;

public class HelloWorldWithCommandLine {

    public static void main(String... args) {
```

```

    if (args.length > 0) {
        System.out.println(args[0]);
    } else {
        System.out.println("Hello World!");
    }
}
}

```

This example accomplishes what we wanted—we can now change the message without changing the code. However, there is still a problem with this application: the component responsible for rendering the message is also responsible for obtaining the message. Changing how the message is obtained means changing the code in the renderer. Add to this the fact that we still cannot change the renderer easily; doing so means changing the class that launches the application.

If we take this application a step further (away from the basics of Hello World), a better solution is to refactor the rendering and message retrieval logic into separate components. Plus, if we really want to make our application flexible, we should have these components implement interfaces and define the interdependencies between the components and the launcher using these interfaces. By refactoring the message retrieval logic, we can define a simple `MessageProvider` interface with a single method, `getMessage()`, as shown in Listing 2-9.

*Listing 2-9.* MessageProvider Interface

```

package com.apress.prospring6.two.decoupled;

public interface MessageProvider {
    String getMessage();
}

```

The `MessageRenderer` interface is implemented by all components that can render messages, and such a component is depicted in Listing 2-10.

*Listing 2-10.* MessageRenderer Interface

```

package com.apress.prospring6.two.decoupled;

public interface MessageRenderer {
    void render();
    void setMessageProvider(MessageProvider provider);
    MessageProvider getMessageProvider();
}

```

As you can see, the `MessageRenderer` interface declares a method, `render()`, and also a JavaBean-style method, `setMessageProvider()`. Any `MessageRenderer` implementations are decoupled from message retrieval and delegate that responsibility to the `MessageProvider` instance with which they are supplied.

Here, `MessageProvider` is a dependency of `MessageRenderer`. Creating simple implementations of these interfaces is easy, as shown in Listing 2-11.

*Listing 2-11.* MessageProvider Implementation

```

package com.apress.prospring6.two.decoupled;

public class HelloWorldMessageProvider implements MessageProvider {
    @Override
    public String getMessage() {
        return "Hello World!";
    }
}

```

You can see that we have created a simple MessageProvider that always returns “Hello World!” as the message. The StandardOutMessageRenderer class shown in Listing 2-12 is just as simple.

*Listing 2-12.* MessageRenderer Implementation

```

package com.apress.prospring6.two.decoupled;

import static java.lang.System.*;

public class StandardOutMessageRenderer implements MessageRenderer {

    private MessageProvider messageProvider;

    public StandardOutMessageRenderer(){
        out.println(" --> StandardOutMessageRenderer: constructor called");
    }

    @Override
    public void render() {
        if (messageProvider == null) {
            throw new RuntimeException(
                "You must set the property messageProvider of class:"
                + StandardOutMessageRenderer.class.getName());
        }
        out.println(messageProvider.getMessage());
    }

    @Override
    public void setMessageProvider(MessageProvider provider) {
        out.println(" --> StandardOutMessageRenderer: setting the provider");
        this.messageProvider = provider;
    }

    @Override
    public MessageProvider getMessageProvider() {
        return this.messageProvider;
    }
}

```

Now all that remains is to rewrite the main(..) method of the entry class, as depicted in Listing 2-13.



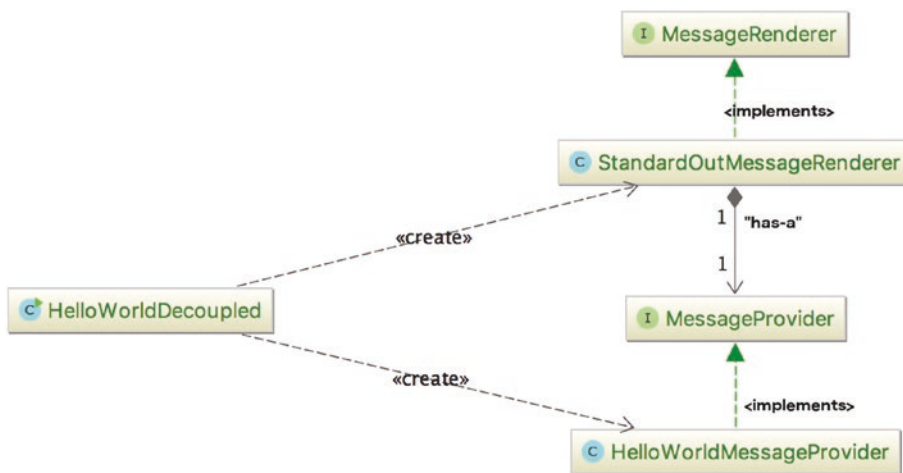
**Listing 2-13.** New main(..) Method

```

package com.apress.prospring6.two.decoupled;

public class HelloWorldDecoupled {
    public static void main(String... args) {
        MessageRenderer mr = new StandardOutMessageRenderer();
        MessageProvider mp = new HelloWorldMessageProvider();
        mr.setMessageProvider(mp);
        mr.render();
    }
}
    
```

Figure 2-9 depicts the abstract schema of the application built so far.



**Figure 2-9.** A little more decoupled Hello World application

The code here is fairly simple:

- We instantiate instances of HelloWorldMessageProvider and StandardOutMessageRenderer, although the declared types are MessageProvider and MessageRenderer, respectively. This is because we need to interact only with the methods provided by the interface in the programming logic, and HelloWorldMessageProvider and StandardOutMessageRenderer already implemented those interfaces, respectively.
- Then, we pass MessageProvider to MessageRenderer and invoke MessageRenderer#render().

If we compile and run this program, we get the expected “Hello World!” output. Now, this example is more like what we are looking for, but there is one small problem. Changing the implementation of either the MessageRenderer or MessageProvider interface means a change to the code.

To get around this we need to delegate the responsibility of retrieving the two implementation types and instantiating them to somebody else. The most *manual* one is to create a simple factory class that reads the implementation class names from a properties file and instantiates them on behalf of the application, as shown Listing 2-14.

**Listing 2-14.** Instance Factory Class Tasked with Retrieving the Two Implementation Types and Instantiating Them

```

package com.apress.prospring6.two.decoupled;

import java.util.Optional;
import java.util.Properties;

public class MessageSupportFactory {

    private static MessageSupportFactory instance;
    private Properties props;
    private MessageRenderer renderer;
    private MessageProvider provider;

    private MessageSupportFactory() {
        props = new Properties();
        try {
            props.load(this.getClass().getResourceAsStream("/msf.properties"));
            String rendererClass = props.getProperty("renderer.class");
            String providerClass = props.getProperty("provider.class");
            renderer = (MessageRenderer) Class.forName(rendererClass).
                getDeclaredConstructor().newInstance();
            provider = (MessageProvider) Class.forName(providerClass).
                getDeclaredConstructor().newInstance();
        } catch (Exception ex) {
            ex.printStackTrace();
        }
    }

    static {
        instance = new MessageSupportFactory();
    }

    public static MessageSupportFactory getInstance() {
        return instance;
    }

    public Optional<MessageRenderer> getMessageRenderer() {
        return renderer != null? Optional.of(renderer) : Optional.empty();
    }

    public Optional<MessageProvider> getMessageProvider() {
        return provider != null? Optional.of(provider) : Optional.empty();
    }
}

```

The implementation here is trivial and naive, the error handling is simplistic, and the name of the configuration file is hard-coded, but we already have a substantial amount of code. The configuration file for this class is quite simple and is depicted in Listing 2-15.

**Listing 2-15.** Configuration File Contents for the MessageSupportFactory Class, Ergo the Contents of the msf.properties File

```
renderer.class=com.apress.prospring6.ch2.decoupled.StandardOutMessageRenderer
provider.class=com.apress.prospring6.ch2.decoupled.HelloWorldMessageProvider
```

The configuration file must be on the project classpath. When running from IntelliJ IDEA, the file is located in the chapter02/src/main/resources directory and is added to the classpath when running the code.

To delegate the responsibilities of retrieving a MessageProvider and MessageRenderer instance to MessageSupportFactory, the main(..) method must be changed as shown in Listing 2-16.

**Listing 2-16.** HelloWorld Version Using MessageSupportFactory

```
package com.apress.prospring6.two.decoupled;

public class HelloWorldDecoupledWithFactory {

    public static void main(String... args) {
        MessageRenderer mr = MessageSupportFactory.getInstance().getMessageRenderer()
            .orElseThrow(() -> new IllegalArgumentException("Service of type
                'MessageRenderer' was not found!"));
        MessageProvider mp = MessageSupportFactory.getInstance().getMessageProvider()
            .orElseThrow(() -> new IllegalArgumentException("Service of type
                'MessageProvider' was not found!"));
        mr.setMessageProvider(mp);
        mr.render();
    }
}
```

However, there is another way to do this with pure Java, without creating the MessageSupportFactory class, because there is already a class named ServiceLoader in package java.util that does the exact thing. This class was introduced in Java 6 to facilitate discovering and loading implementations matching a given interface. The interfaces that this class retrieves implementations for are called *Service Provider Interface (SPI)*.

The approach is similar to the MessageSupportFactory, only the configuration file names have to respect three rules:

- Must be on the project classpath in a directory named META-INF/services.
- The file name is the fully qualified name of the SPI.
- Its content is the fully qualified name of the SPI implementation.

This means that in src/main/resources the directory and files structure shown in Listing 2-17 needs to be created.

**Listing 2-17.** Configuration Files Location for ServiceLoader

```
├── resources
│   └── META-INF
│       └── services
│           ├── com.apress.prospring6.two.decoupled.MessageProvider
│           └── com.apress.prospring6.two.decoupled.MessageRenderer
```

The `com.apress.prospring6.two.decoupled.MessageProvider` file contains the fully qualified name of the SPI implementation, which in this case is `com.apress.prospring6.two.decoupled.HelloWorldMessageProvider`.

The `com.apress.prospring6.two.decoupled.MessageRenderer` file contains the fully qualified name of the SPI implementation, which in this case is `com.apress.prospring6.two.decoupled.StandardOutMessageRenderer`.

Listing 2-18 depicts the `main(..)` method that uses `ServiceLoader`.

**Listing 2-18.** HelloWorld Version Using `ServiceLoader`

```
package com.apress.prospring6.two.decoupled;

import java.util.ServiceLoader;

public class HelloWorldWithServiceLoader {
    public static void main(String... args) {
        ServiceLoader<MessageRenderer> slr =          ServiceLoader.
            load(MessageRenderer.class);
        ServiceLoader<MessageProvider> slp = ServiceLoader.load(MessageProvider.class);

        MessageRenderer mr = slr.findFirst()
            .orElseThrow(() -> new IllegalArgumentException("Service of type
                'MessageRenderer' was not found!"));
        MessageProvider mp = slp.findFirst()
            .orElseThrow(() -> new IllegalArgumentException("Service of type
                'MessageProvider' was not found!"));

        mr.setMessageProvider(mp);
        mr.render();
    }
}
```



`ServiceLoader` is overkill for this example, and it shows its true power in multi-module projects, where Java modules are configured. The module providing the implementation declares the following in its `module.java` file: `provides {SPI} with {SPI-Implementation}`. The module using the service has no idea where the implementation is coming from, or its fully qualified name; it just declares in its `main.java` file uses `{SPI}` and the `ServiceLoader` picks whatever it finds on the classpath. You can find more details about this in *Java 17 for Absolute Beginners*, published by Apress in 2022.

---

Before we move on to see how we can introduce Spring into this application, let's quickly recap what we have done:

- We started with the simple Hello World application.
- We defined two additional requirements that the application must fulfill:
  - Changing the message should be simple.
  - Changing the rendering mechanism should also be simple.

- To meet these requirements, we used two interfaces: `MessageProvider` and `MessageRenderer`.
- The `MessageRenderer` interface depends on an implementation of the `MessageProvider` interface to be able to retrieve a message to render.
- Finally, we added a simple factory class to retrieve the names of the implementation classes and instantiate them as applicable. And this was just showing off, since `ServiceLoader` exists.

## Refactoring with Spring

The `MessageSupportFactory` example shown earlier met the goals laid out for the sample application, but its main problem is the quantity of glue code needed to piece the application together, while at the same time keeping the components loosely coupled. Using `SpringLoader` is the Java way of using dependency injection in your application and removes the necessity of writing all that glue code. However, one problem remains: we still had to provide the implementation of `MessageRenderer` with an instance of `MessageProvider` manually and explicitly in the code of the `main(..)` method. This last problem can be solved by Spring.

## Using Spring XML Configuration

Since we are using Spring for the full solution, `SpringLoader` is no longer necessary and its place is taken by a Spring interface named `ApplicationContext`. Don't worry too much about this interface; for now, it is enough to know that this interface is used by Spring for storing all the environmental information with regard to an application being managed by Spring. This interface extends another interface, `ListableBeanFactory`, which acts as the provider for any Spring-managed bean instance. Take a look at the code snippet in Listing 2-19.

**Listing 2-19.** HelloWorld Version Using Spring

```
package com.apress.prospring6.two;

import com.apress.prospring6.two.decoupled.MessageRenderer;
import org.springframework.context.ApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;

public class HelloWorldSpringDI {
    public static void main(String... args) {
        ApplicationContext ctx = new ClassPathXmlApplicationContext("spring/app-
            context.xml");

        MessageRenderer mr = ctx.getBean("renderer", MessageRenderer.class);
        mr.render();
    }
}
```

In the previous code snippet, you can see that the `main(..)` method obtains an instance of `ClassPathXmlApplicationContext` (the application configuration information is loaded from the file `spring/app-context.xml` in the project's classpath), typed as `ApplicationContext`, and from this, it obtains the `MessageRenderer` instances by using the `ApplicationContext#getBean()` method. Don't worry too much about the `getBean()` method for now; just know that this method reads the application

configuration (in this case, an XML file), initializes Spring's `ApplicationContext` environment, and then returns the configured bean instance. This `app-context.xml` XML file serves the same purpose as the one used for `MessageSupportFactory` or the ones used for `ServiceLoader`. The contents of this file are shown in Listing 2-20.

**Listing 2-20.** Spring XML Configuration File

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:p="http://www.springframework.org/schema/p"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
                           http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="provider"
          class="com.apress.prospring6.two.decoupled.HelloWorldMessageProvider"/>

    <bean id="renderer"
          class="com.apress.prospring6.two.decoupled.StandardOutMessageRenderer"
          p:messageProvider-ref="provider"/>
</beans>
```

Listing 2-20 shows a typical Spring `ApplicationContext` configuration. First, Spring's namespaces are declared, and the default namespace is `beans`. The `beans` namespace is used to declare the beans that need to be managed by Spring and to declare their dependency requirements (for the preceding example, the `renderer` bean's `messageProvider` property is referencing the `provider` bean). Spring will resolve and inject those dependencies.

Afterward, we declare the bean with the ID `provider` and the corresponding implementation class. When Spring sees this bean definition during the `ApplicationContext` initialization, it will instantiate the class and store it with the specified ID.

Then the `renderer` bean is declared, with the corresponding implementation class. Remember that this bean depends on the `MessageProvider` interface for getting the message to render. To inform Spring about the DI requirement, we use the `p` namespace attribute. The tag attribute `p:messageProvider-ref="provider"` tells Spring that the bean's property, `messageProvider`, should be injected with another bean. The bean to be injected into the property should reference a bean with the ID `provider`. When Spring sees this definition, it will instantiate the class, look up the bean's property named `messageProvider`, and inject it with the bean instance with the ID `provider`.

As you can see, upon the initialization of Spring's `ApplicationContext`, the `main(..)` method now just obtains the `MessageRenderer` bean by using its type-safe `getBean()` method (passing in the ID and the expected return type, which is the `MessageRenderer` interface) and calls `render()`. Spring has created the `MessageProvider` instance and injected it into the `MessageRenderer` instance. Notice that we didn't have to make any changes to the classes that are being wired together using Spring. In fact, these classes have no reference to Spring and are completely oblivious to its existence. However, this isn't always the case. Your classes can implement Spring-specified interfaces to interact in a variety of ways with the DI container.

With your new Spring configuration and modified `main(..)` method, let's see it in action. Using Gradle or Maven, build the full project by executing any of the commands in the `pro-spring-6/README.adoc`.

The only required Spring module to be declared in your configuration file is `spring-context`. Gradle/Maven will automatically bring in any dependencies required for this module. In Figure 2-10 you can see the transitive dependencies of `spring-context.jar` in Gradle View.

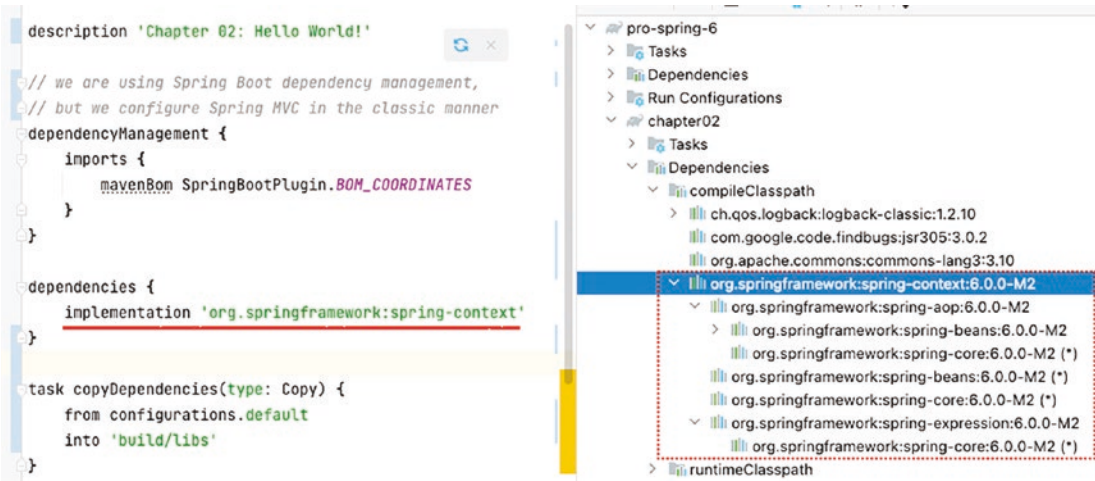


Figure 2-10. Gradle View showing spring-context and its dependencies

For module chapter02 the build will result in an executable JAR file.



Gradle stores artifacts produced by the build under {module\_name}/build/libs. Maven stores artifacts produced by the build under {module\_name}/target.

You can run any of the executable jars (produced by Gradle or Maven—they are identical) using the commands in Listing 2-21, in a terminal.

Listing 2-21. Commands to Run Executable Jars Produced by Gradle and Maven for Module chapter02

```

# Gradle
cd pro-spring-6/chapter02/build/libs
java -jar chapter02-6.0-SNAPSHOT.jar

# Maven
cd pro-spring-6/chapter02/target
java -jar chapter02-6.0-SNAPSHOT.jar
    
```

Running any of the jars yields the output in Listing 2-22.

Listing 2-22. Output Produced by Running the Executable jars Produced by Gradle and Maven for Module chapter02

```

--> HelloWorldMessageProvider: constructor called
--> StandardOutMessageRenderer: constructor called
--> StandardOutMessageRenderer: setting the provider
Hello World!
    
```



This section was kept in the book to show you how Spring configuration has evolved. Spring 5 has dropped support for XML configurations. This way of configuring Spring applications might still be used in legacy projects, so if you end up working on one, feel free to look for previous editions of this book.

## Spring Configuration Using Annotations

Starting with Spring 3.0, XML configuration files are no longer necessary when developing a Spring application. They can be replaced with **annotations** and **Java configuration classes**. Configuration classes are Java classes annotated with `@Configuration` that contain bean definitions (methods annotated with `@Bean`) or are configured themselves to identify bean definitions in the application by annotating them with `@ComponentScanning`. The equivalent of the `app-context.xml` file presented earlier is shown in Listing 2-23.

**Listing 2-23.** Spring Java Configuration Class

```

package com.apress.prospring6.two.annotated;
// some imports omitted
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;

@Configuration
public class HelloWorldConfiguration {

    @Bean // // equivalent to <bean id="provider" class=".."/>
    public MessageProvider provider() {
        return new HelloWorldMessageProvider();
    }

    @Bean // // equivalent to <bean id="renderer" class=".."/>
    public MessageRenderer renderer() {
        MessageRenderer renderer = new StandardOutMessageRenderer();
        renderer.setMessageProvider(provider());
        return renderer;
    }
}

```

The `main(..)` method has to be modified as follows: `ClassPathXmlApplicationContext` must be replaced with another `ApplicationContext` implementation that knows how to read bean definitions from configuration classes. This class is `AnnotationConfigApplicationContext`. This version of the method is depicted in Listing 2-24.

**Listing 2-24.** `main(..)` Method to Start a Spring Application Configured Using Java Configuration

```

package com.apress.prospring6.two.annotated;
// some imports omitted
import org.springframework.context.ApplicationContext;
import org.springframework.context.annotation.AnnotationConfigApplicationContext;

```



```

public class HelloWorldSpringAnnotated {

    public static void main(String... args) {
        ApplicationContext ctx = new AnnotationConfigApplicationContext(HelloWorldConfigura
            tion.class);
        MessageRenderer mr = ctx.getBean("renderer", MessageRenderer.class);
        mr.render();
    }
}

```

This is just one version of configuration using annotations and configuration classes. Without XML, things get pretty flexible when it comes to Spring configuration. You'll learn more about that later in this book, but the focus when it comes to configuration is on Java configuration and annotations.



Some interfaces and classes defined in the Hello World example may be used in later chapters. Although we showed the full source code in this example, future chapters may show condensed versions of code to avoid being verbose, especially in the case of incremental code modifications. The code has been organized to allow code reusability between modules. All classes that can be used in Spring future examples were placed under the `com.apress.prospring6.two.decoupled` and `com.apress.prospring6.two.annotated` packages.

---

## Summary

This chapter presented all the background information you need to get up and running with Spring. We showed you how to get started with Spring through dependency management systems and the current development version directly from GitHub. We described how Spring is packaged and the dependencies you need for each of Spring's features. Using this information, you can make informed decisions about which of the Spring JAR files your application needs and which dependencies you need to distribute with your application. Spring's documentation, guides, and test suite provide Spring users with an ideal base from which to start their Spring development, so we took some time to investigate what is made available by Spring.

Finally, we presented an example of how, using Spring DI, it is possible to make the traditional Hello World example a loosely coupled, extendable message-rendering application. The important thing to realize is that we only scratched the surface of Spring DI in this chapter, and we barely made a dent in Spring as a whole. In the next chapter, we take an in-depth look at IoC and DI in Spring.

## CHAPTER 3



# Introducing IoC and DI in Spring

**Chapters 1 and 2** have introduced you to the Spring world, explaining why this framework is necessary and why dependency injection is so cool and useful. In essence, Spring was built to make dependency injection easy. This software design pattern implies that dependent components delegate the dependency resolution to an external service that will take care of injecting the dependencies. The dependent component is not allowed to call the injector service and has very little to say when it comes to the dependencies that will be injected. This is why the behavior is also known as the “*Don’t call us, we’ll call you!*” principle, and it is technically known as *inversion of control (IoC)*. If you do a quick Google search, you will find a lot of conflicting opinions about dependency injection and inversion of control. You will find programming articles calling them *programming techniques*, *programming principles*, and *design patterns*. However, the best explanation comes from an article by Martin Fowler<sup>1</sup>, which is recognized in the Java world as the highest authority when it comes to design patterns. If you do not have the time to read it, here is a summary: *Inversion of control is a common characteristic of frameworks that facilitate injection of dependencies. And the basic idea of the dependency injection pattern is to have a separate object that injects dependencies with the required behavior, based on an interface contract.*

In this chapter the following DI features are covered:

- *Inversion of control concepts*: we discuss the various kinds of IoC, including dependency injection and dependency lookup. This section presents the differences between the various IoC approaches as well as the pros and cons of each.
- *Inversion of control in Spring*: we look at IoC capabilities available in Spring and how they are implemented. In particular, you’ll see the dependency injection services that Spring offers, including setter, constructor, and method injection.
- *Dependency injection in Spring*: we cover Spring’s implementation of the IoC container. For bean definition and DI requirements, `BeanFactory` is the main interface an application interacts with. However, other than the first few listings, the remainder of the sample code provided in this chapter focuses on using Spring’s `ApplicationContext` interface, which is an extension of `BeanFactory` and provides much more powerful features. We cover the difference between `BeanFactory` and `ApplicationContext` in later sections.

---

<sup>1</sup><https://martinfowler.com/articles/injection.html#InversionOfControl>

- *Configuring the Spring application context:* The final part of this chapter focuses on the annotation approach for `ApplicationContext` configuration. Groovy and Java configuration are further discussed in **Chapter 4**. This section starts with a discussion of DI configuration and moves on to present additional services provided by `BeanFactory`, such as bean inheritance, life-cycle management, and autowiring.

## Inversion of Control and Dependency Injection

At its core, IoC aims to offer a simpler mechanism for provisioning component dependencies (often referred to as an object's *collaborators*) and managing these dependencies throughout their life cycles. A component that requires certain dependencies is often referred to as the *dependent object* or, in the case of IoC, the *target*. In general, IoC can be decomposed into two subtypes: *dependency injection* and *dependency lookup*. These subtypes are further decomposed into concrete implementations of the IoC services. From this definition, you can clearly see that when we are talking about DI, we are always talking about IoC, but when we are talking about IoC, we are not always talking about DI (for example, dependency lookup is also a form of IoC).

### Types of Inversion of Control

You may be wondering why there are two types of IoC and why these types are split further into different implementations. There seems to be no clear answer to this question; certainly, the different types provide a level of flexibility, but to us, it seems that IoC is more of a mixture of old and new ideas. The two types of IoC represent this. Dependency lookup is a much more traditional approach, and at first glance, it seems more familiar to Java programmers. Dependency injection, although it appears counterintuitive at first, is actually much more flexible and usable than dependency lookup. With dependency lookup-style IoC, a component must acquire a reference to a dependency, whereas with dependency injection, the dependencies are injected into the component by the IoC container. Dependency lookup comes in two types:

- Dependency pull
- Contextualized dependency lookup (CDL)

Dependency injection also has two common flavors:

- Constructor dependency injection
- Setter dependency injection

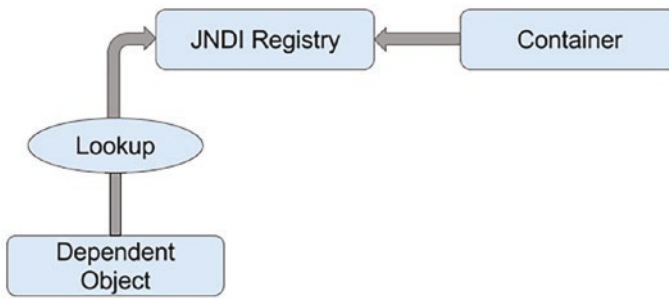


For the discussions in this section, we are not concerned with how the fictional IoC container comes to know about all the different dependencies, just that at some point, it performs the actions described for each mechanism.

---

### Dependency Pull

To a Java developer, dependency pull is the most familiar type of IoC. In dependency pull, dependencies are pulled from a registry as required. Anyone who has ever written code to access an EJB (2.1 or prior versions) has used dependency pull (that is, via the JNDI API to look up an EJB component). Figure 3-1 shows the scenario of dependency pull via the lookup mechanism.



**Figure 3-1.** Dependency pull via JNDI lookup

Spring also offers dependency pull as a mechanism for retrieving the components that the framework manages; you saw this in action in **Chapter 2**. Listing 3-1 shows an example of a typical dependency pull lookup in a Spring-based application.

**Listing 3-1.** Spring Dependency Pull Example

```

package com.apress.prospring6.two.annotated;
// some imports omitted
import org.springframework.context.ApplicationContext;
import org.springframework.context.annotation.AnnotationConfigApplicationContext;

public class HelloWorldSpringAnnotated {

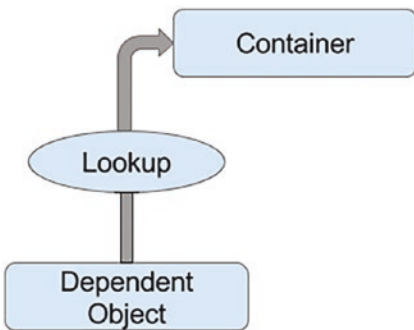
    public static void main(String... args) {
        ApplicationContext ctx = new AnnotationConfigApplicationContext(HelloWorldConfigura
            tion.class);
        MessageRenderer mr = ctx.getBean("renderer", MessageRenderer.class);
        mr.render();
    }
}
  
```

This code snippet, and all classes referenced in it, was introduced at the end of **Chapter 2** to show you how a Spring `ApplicationContext` is built. Notice that in the `main(...)` method the `MessageRenderer` bean is retrieved from the `ApplicationContext` that functions as a register of all beans in the application; this instance is therefore *pulled*, so its `render()` method can be invoked.

This kind of IoC is not only prevalent in JEE-based applications (using EJB 2.1 or prior versions), which make extensive use of JNDI lookups to obtain dependencies from a registry, but also pivotal to working with Spring in many environments.

## Contextualized Dependency Lookup

*Contextualized dependency lookup (CDL)* is similar, in some respects, to dependency pull, but in CDL, lookup is performed against the container that is managing the resource, not from some central registry, and it is usually performed at some set point. Figure 3-2 shows the CDL mechanism.



**Figure 3-2.** Contextualized dependency lookup

CDL works by having the component that requires a dependency implement an interface similar to the one in Listing 3-2.

**Listing 3-2.** Contextualized Dependency Lookup Interface

```

package com.apress.prospring6.three;
// some imports omitted

public interface ManagedComponent {
    void performLookup(Container container);
}
  
```

By implementing this interface, a component is signaling to the container that it wants to obtain a dependency. The container is usually provided by the underlying application server or framework (for example, Tomcat or JBoss) or framework (for example, Spring). The code in Listing 3-3 shows a simple Container interface that provides a dependency lookup service.

**Listing 3-3.** Container Interface That Provides a Dependency Lookup Service

```

package com.apress.prospring6.three;

public interface Container {
    Object getDependency(String key);
}
  
```

When the container is ready to pass dependencies to a component, it calls `performLookup()` on each component in turn. The component can then look up its dependencies by using the Container interface. To work with the already familiar example, the `MessageRenderer` interface is declared to extend the `ManagedComponent` interface, so that the `StandardOutMessageRenderer` can look up its own dependency using the provided Container implementation. The code for the `MessageRenderer` interface and `StandardOutMessageRenderer` class is displayed in Listing 3-4.

**Listing 3-4.** ManagedComponent Implementation Using the StandardOutMessageRenderer Class

```

package com.apress.prospring6.three;

interface MessageRenderer extends ManagedComponent {
    void render();
}

class StandardOutMessageRenderer implements MessageRenderer {

    private MessageProvider messageProvider;

    @Override
    public void performLookup(Container container) {
        this.messageProvider = (MessageProvider) container.getDependency("provider");
    }

    // other code omitted, already listed in Chapter 2
}

```



You might notice that the interface and class in this example have no type accessor. They are not public because they are not declared in separate file. Actually, all Java types related to the CDL example are part of the CDLDemo.java file. We decided to put all types related to this example in the same file because it makes navigating the project sources easier. Also, since all the types in the example are in the same file, there is no doubt where the bean definitions are coming from. We kept this approach wherever necessary in the project for this book.

---

## Constructor Dependency Injection

In *constructor dependency injection* the IoC container injects a component's dependencies via its constructor (or constructors). The component declares a constructor or a set of constructors, taking as arguments its dependencies, and the IoC container passes the dependencies to the component when instantiation occurs. This means this version of the StandardOutMessageRenderer looks like the one depicted in Listing 3-5.

**Listing 3-5.** StandardOutMessageRenderer Modified for Constructor Injection

```

package com.apress.prospring6.three.ci;

class StandardOutMessageRenderer implements MessageRenderer {
    private final MessageProvider messageProvider;

    public StandardOutMessageRenderer(MessageProvider messageProvider) {
        this.messageProvider = messageProvider;
    }

    // other code omitted, already listed in Chapter 2
}

```

An obvious consequence of using constructor injection is that an object cannot be created without its dependencies; thus, they are mandatory.

## Setter Dependency Injection

In *setter dependency injection*, the IoC container injects a component's dependencies via JavaBean-style setter methods. A component's setters expose the dependencies that the IoC container can manage. Listing 3-6 shows a typical setter dependency injection-based version of the `StandardOutMessageRenderer`.

**Listing 3-6.** `StandardOutMessageRenderer` Modified for Setter Injection

```
package com.apress.prospring6.three.di;

class StandardOutMessageRenderer implements MessageRenderer {
    private MessageProvider messageProvider;

    public void setMessageProvider(MessageProvider messageProvider) {
        this.messageProvider = messageProvider;
    }

    // other code omitted, already listed in Chapter 2
}
```

An obvious consequence of using setter injection is that an object can be created without its dependencies, and they can be provided later by calling the setter.

Within the container, the dependency requirement exposed by the `setMessageProvider()` method is referred to by the JavaBeans-style name, *dependency*. In practice, setter injection is the most widely used injection mechanism, and it is one of the simplest IoC mechanisms to implement.



There is another type of injection supported in Spring called *field injection*, but this will be covered later in the chapter, when you learn about autowiring using the `@Autowired` annotation.

---

## Injection vs. Lookup

Choosing which style of IoC to use—*injection* or *lookup*—usually is not a difficult decision. In many cases, the type of IoC you choose is mandated by the container you are using. For instance, if you are using EJB 2.1 or prior versions, you must use lookup-style IoC (via JNDI) to obtain an EJB from the JEE container. In Spring, aside from initial bean lookups, your components and their dependencies are always wired together using injection-style IoC.



When you are using Spring, you can access EJB resources without performing an explicit lookup. Spring can act as an adapter between lookup- and injection-style IoC systems, thus allowing you to manage all resources by using injection.

---

After reading thus far, what do you think? Would you use dependency injection or dependency lookup?

Using injection, you are free to use your classes completely decoupled from the IoC container that is supplying dependent objects with their collaborators manually, whereas with lookup your classes are always dependent on the classes and interfaces defined by the container. Another drawback with lookup is that testing your classes in isolation from the container becomes difficult. Using injection, testing your components is trivial because you can simply provide the dependencies yourself by using the appropriate constructor or setter, as you will see throughout this book.

The biggest reason to choose injection over lookup is that it makes your life easier. You write substantially less code when you are using injection, and the code that you do write is simple and can, in general, be automated by a good IDE. You will notice that all the code in the injection examples is passive, in that it doesn't actively try to accomplish a task. The most exciting thing you see in injection code is that objects get stored in a field only; no other code is involved in pulling the dependency from any registry or container. Therefore, the code is much simpler and less error prone. Passive code is much simpler to maintain than active code because there is very little that can go wrong. There are a lot of things that could go wrong with the `StandardOutMessageRenderer` from Listing 3-4: the dependency key could change, the container instance could be `null`, or the returned dependency might be the incorrect type. Using dependency lookup might decouple the components of your application, but it adds complexity in the additional code required to couple these components back together in order to perform any useful tasks.

## Setter Injection vs. Constructor Injection

At this point in the book, it is clear that dependency injection is the way to go. *Constructor injection* is useful when dependency must be enforced, and the component requiring a dependency won't work without it. Many containers, Spring included, provide a mechanism for ensuring that all dependencies are defined when you use setter injection, but by using constructor injection, you assert the requirement for the dependency in a container-agnostic manner. Constructor injection also helps achieve the use of immutable objects—this is why in Listing 3-5 the `MessageProvider` field is declared `final`.

*Setter injection* is useful in a variety of cases. If the component is exposing its dependencies to the container but is happy to provide its own defaults, setter injection is usually the best way to accomplish this. Another benefit of setter injection is that it allows dependencies to be declared on an interface, although this is not as useful as you might first think. Think about it, an interface can be implemented by multiple classes, that need to expose the same API, but need different dependencies. So, unless you are absolutely sure that all implementations of a particular business interface require a particular dependency, you should let each implementation class define its own dependencies and keep the business interface for business methods. Listing 3-7 depicts an interface for a newsletter sender service and it looks like a contraction to what was said so far.

### Listing 3-7. NewsletterSender Interface

```
package com.apress.prospring6.three;

public interface NewsletterSender {
    void setSmtpServer(String smtpServer);
    String getSmtpServer();

    void setFromAddress(String fromAddress);
    String getFromAddress();
    void send();
}
```



But here's the catch: the dependencies declared via this interface are configurations. Configuration parameters are a special case for dependencies. Certainly, your components depend on the configuration data, but configuration data is significantly different from the types of dependency you have seen so far. Thus, placing setters and getters for configuration parameters in the business interface is a good idea and makes setter injection a valuable tool.

Classes that send a set of newsletters via e-mail implement the `NewsletterSender` interface. The `send()` method is the only business method, but notice that we have defined two JavaBean properties on the interface. Why are we doing this when we just said that you shouldn't define dependencies in the business interface? The reason is that these values, the SMTP server address and the address the e-mails are sent from, are not dependencies in the practical sense; rather, they are configuration details that affect how all implementations of the `NewsletterSender` interface function. The question then is this: what is the difference between a configuration parameter and any other kind of dependency? In most cases, you can clearly see whether a dependency should be classified as a configuration parameter, but if you are not sure, look for the following three characteristics that point to a configuration parameter:

- *Configuration parameters are passive:* In the `NewsletterSender` example depicted in Listing 3-7, the `smtpServer` parameter is an example of a passive dependency. Passive dependencies are not used directly to perform an action; instead, they are used internally or by another dependency to perform their actions. In the `MessageRenderer` example from **Chapter 2**, the `MessageProvider` dependency was not passive; it performed a function that was necessary for the `MessageRenderer` to complete its task.
- *Configuration parameters are usually information, not other components:* By this we mean that a configuration parameter is usually some piece of information that a component needs to complete its work. Clearly, the SMTP server is a piece of information required by the `NewsletterSender`, but the `MessageProvider` is really another component that the `MessageRenderer` needs to function correctly.
- *Configuration parameters are usually simple values or collections of simple values:* This is really a byproduct of the previous two points, but configuration parameters are usually simple values. In Java this means they are a primitive (or the corresponding wrapper class) or a `String` or collections of these values. Simple values are generally passive. This means you can't do much with a `String` other than manipulate the data it represents; and you almost always use these values for information purposes—for example, an `int` value that represents the port number that a network socket should listen on or a `String` that represents the SMTP server through which an e-mail program should send messages.

When considering whether to define configuration options in the business interface, also consider whether the configuration parameter is applicable to all implementations of the business interface or just one. For instance, in the case of implementations of `NewsletterSender`, it is obvious that all implementations need to know which SMTP server to use when sending e-mails. However, we would probably choose to leave the configuration option that flags whether to send secure e-mail off the business interface because not all e-mail APIs are capable of this, and it is correct to assume that many implementations will not take security into consideration at all.



Recall that in **Chapter 2** we chose to define the dependencies in the business purposes. This was for illustration purposes only and should not be treated in any way as a best practice.

---

Setter injection also allows you to swap dependencies for a different implementation on-the-fly without creating a new instance of the parent component. Spring's JMX support makes this possible. Perhaps the biggest benefit of setter injection is that it is the least intrusive of the injection mechanisms.

In general, you should choose an injection type based on your use case. Setter-based injection allows dependencies to be swapped out without creating new objects and also lets your class choose appropriate defaults without the need to explicitly inject an object. Constructor injection is a good choice when you want to ensure that dependencies are being passed to a component and when designing for immutable objects. Do keep in mind that while constructor injection ensures that all dependencies are provided to a component, most containers provide a mechanism to ensure this as well but may incur a cost of coupling your code to the framework.

## Inversion of Control in Spring

As mentioned earlier, inversion of control is a big part of what Spring does. The core of Spring's implementation is based on dependency injection, although dependency lookup features are provided as well. When Spring provides collaborators to a dependent object automatically, it does so using dependency injection. In a Spring-based application, it is always preferable to use dependency injection to pass collaborators to dependent objects rather than have the dependent objects obtain the collaborators via lookup. Figure 3-3 shows Spring's dependency injection mechanism.



**Figure 3-3.** Spring's dependency injection mechanism

Although dependency injection is the preferred mechanism for wiring together collaborators and dependent objects, you need dependency lookup to access the dependent objects. In many environments, Spring cannot automatically wire up all of your application components by using dependency injection, and you must use dependency lookup to access the initial set of components. For example, in stand-alone Java applications, you need to bootstrap Spring's container in the `main(...)` method and obtain the dependencies (via the `ApplicationContext` interface) for processing programmatically. However, when you are building web applications by using Spring's MVC support, Spring can avoid this by gluing your entire application together automatically. Wherever it is possible to use dependency injection with Spring, you should do so; otherwise, you can fall back on the dependency lookup capabilities. You will see examples of both in action during the course of this chapter, and we will point them out when they first arise.

An interesting feature of Spring's IoC container is that it has the ability to act as an adapter between its own dependency injection container and external dependency lookup containers. We discuss this feature later in this chapter.

Spring supports both constructor and setter injection and bolsters the standard IoC feature set with a whole host of useful additions to make your life easier.

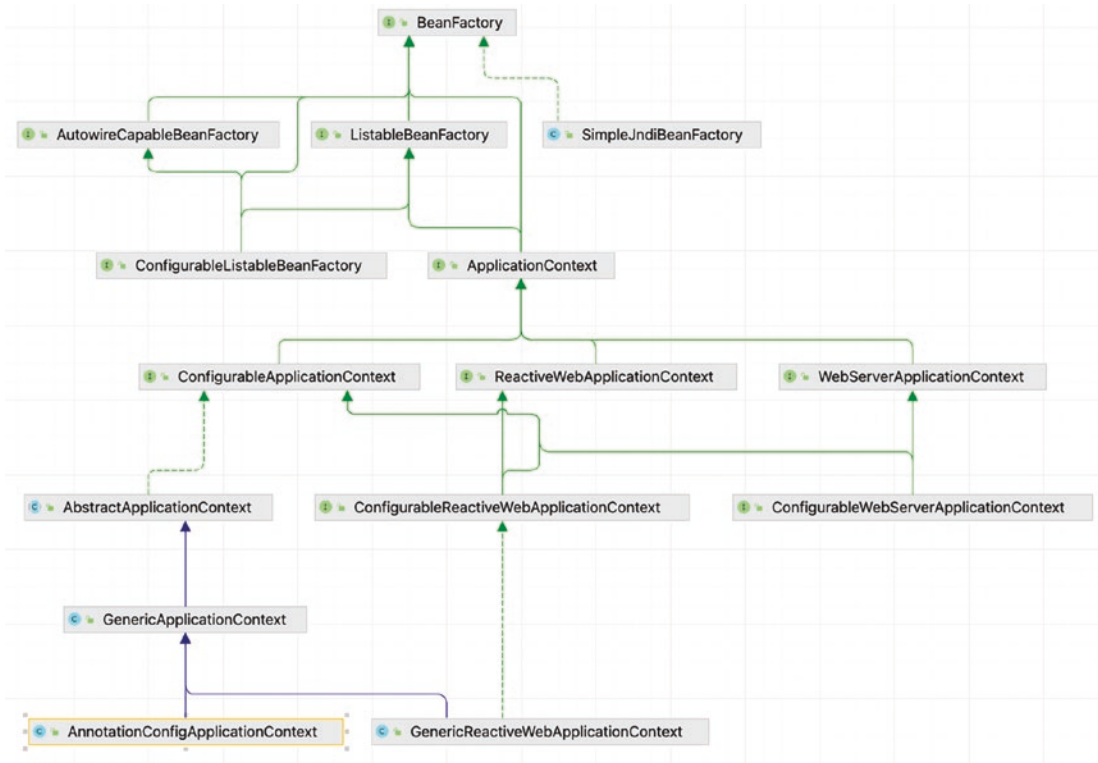
The rest of this chapter introduces the basics of Spring's DI container, complete with plenty of examples.

## Dependency Injection in Spring

Spring's support for dependency injection is comprehensive and, as you will see in **Chapter 4**, goes beyond the standard IoC feature set we have discussed so far. The rest of this chapter addresses the basics of Spring's dependency injection container, looking at setter, constructor, and Method Injection, along with a detailed look at how dependency injection is configured in Spring.

## Beans and BeanFactory

The `org.springframework.beans` and `org.springframework.context` packages are the basis for Spring Framework’s IoC container. The central point of Spring’s IoC container is the `org.springframework.beans.factory.BeanFactory` interface. Spring implementations of this interface are responsible for managing components, including their dependencies as well as their life cycles. Figure 3-4 shows the most commonly used `BeanFactory` implementations.



**Figure 3-4.** *BeanFactory* most common implementations

In Spring, the term *bean* is used to refer to any object managed by the Spring IoC container. The Spring IoC container creates, configures (assembles), and manages beans throughout their life cycle. Typically, your beans adhere, at some level, to the JavaBeans specification, but this is not required, especially if you plan to use constructor injection to wire your beans together.

If your application needs only DI support, you can interact with the Spring DI container via the `BeanFactory` interface. In this case, your application must create an instance of a class that implements the `BeanFactory` interface and configures it with bean and dependency information. This interface is implemented by objects that hold a number of bean definitions, each uniquely identified by a `String` name. After an instance of this type is created, your application can access the beans via `BeanFactory` and get on with its processing.

In some cases, all of this setup is handled automatically (for example, in a web application, Spring’s `ApplicationContext` will be bootstrapped by the web container during application startup via a Spring-provided `ContextLoaderListener` class declared in the `web.xml` descriptor file). But in many cases, you need to code the setup yourself. Most examples in this chapter require manual setup of the `BeanFactory` implementation.

The `ApplicationContext` interface is an extension to `BeanFactory`. In addition to DI services, `ApplicationContext` provides other services:

- Integration with Spring’s AOP features
- Message resource handling for internationalization (i18n)
- Application event handling
- Application layer-specific contexts (e.g., web, security, etc.)

In developing Spring-based applications, it’s recommended that you interact with Spring via the `ApplicationContext` interface. Spring supports the bootstrapping of `ApplicationContext` by manual coding (instantiate it manually and load the appropriate configuration) or in a web container environment via `ContextLoaderListener`. From this point onward, all the sample code in this book uses `ApplicationContext` and its implementations.

## Configuring ApplicationContext

In the first example in **Chapter 2**, the `org.springframework.context.ApplicationContext` was configured using an XML file. Although still possible, configuration using XML is limited to capabilities of Spring 4, since no technical investment in this area has been done from that version onward. During Spring’s there’s been a long discussion about which way of configuring an application is better, XML or annotations. It really depends on developer preferences. Annotations are intertwined with the types of the configured beans and they provide a lot of context, which makes configurations more concise. XML configures a Spring application while being decoupled from the actual code (the Spring XML configuration files are resource files), although this is valid for `JavaConfig` as well, which means the configuration can be externalized and modified without recompiling the code. One of the best things about Spring is that you can mix configuration styles easily.

To keep things simple in this edition of the book, Spring applications are configured only through Java annotations (`JavaConfig`) and Java code, that provide enough flexibility to describe any type of Spring application.

## Basic Configuration Overview

To configure a stand-alone Spring application, all that is needed is a class annotated with `@Configuration`. This annotation indicates that the class contains methods annotated with `@Bean`, which are bean declarations. This approach works for any type of object, especially types provided by third-party libraries—code that is not part of your project, and you cannot edit it to declare your beans. The same class can also be configured to enable looking for existing bean declarations by annotating it with `@ComponentScan`. The discoverable bean declarations are classes annotated with `@Component` and other stereotype annotations. The Spring container processes these classes to generate bean definitions and service requests for those beans at runtime. All these annotations are basically used to describe what objects should be created, the order they should be created in, initialization operations, and even operations to be executed before being discarded by the Garbage Collector, most simply referred to as **configuration metadata**.

This is the most compact way in which Spring applications can be configured. However, slowly expanding the topic is more appropriate. Let’s start with a Spring configuration class, shown in **Listing 3-8**, that declares two beans. You’ve already seen this class in **Chapter 2**, but now we are getting into details.

### *Listing 3-8.* Simple Spring Configuration Class

```
package com.apress.prospring6.two.annotated;
// other imports omitted
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
```

```

@Configuration
public class HelloWorldConfiguration {

    @Bean
    public MessageProvider provider() {
        return new HelloWorldMessageProvider();
    }

    @Bean
    public MessageRenderer renderer(){
        MessageRenderer renderer = new StandardOutMessageRenderer();
        renderer.setMessageProvider(provider());
        return renderer;
    }
}

```

Listing 3-8 declares two beans, one named `provider` and one named `renderer`; yes, the beans have the same name as the methods creating them. Naming beans is covered later in the chapter.

Spring configuration classes are typically bootstrapped using either `AnnotationConfigApplicationContext` or its web-capable variant, `AnnotationConfigWebApplicationContext`. Both classes implement `ApplicationContext`, and the code to bootstrap the application configured in Listing 3-8 can be written as shown in Listing 3-9.

**Listing 3-9.** Bootstrapping a Spring Application

```

package com.apress.prospring6.two.annotated;

import org.springframework.context.ApplicationContext;
import org.springframework.context.annotation.AnnotationConfigApplicationContext;

public class HelloWorldSpringAnnotated {

    public static void main(String... args) {
        ApplicationContext ctx =
            new AnnotationConfigApplicationContext(HelloWorldConfiguration.class);
        MessageRenderer mr = ctx.getBean("renderer", MessageRenderer.class);
        mr.render();
    }
}

```

When running the `HelloWorldSpringAnnotated` class, a Spring application context is created that contains the beans configured by the `HelloWorldConfiguration` class. A reference to the `renderer` bean is obtained by calling the `getBean("{name}", {type}.class)` method and its `render()` method is called. Since Spring injects the `MessageProvider` dependency according to the configuration, the “Hello World!” message is printed in the console, as expected.

The bootstrapping process consists of instantiating the `AnnotationConfigApplicationContext` class and providing the configuration simple class name as a parameter. By instantiating this class, we are creating an instance of a Spring IoC container that will read the bean declarations, create the beans, add them to its registry, and manage them. Using a reference to the container, beans can be retrieved and used, exactly as shown in Listing 3-9.

## Declaring Spring Components

Another way to declare beans is to annotate the classes directly with *stereotype* annotations. These annotations are called *stereotype* because they define the roles of types or methods in the overall architecture. They are part of a package named `org.springframework.stereotype`. This package groups together annotations used to define beans. These annotations are relevant to the role of a bean. For example, `@Service` is used to define a service bean, which is a more complex functional bean that provides services that other beans may require, and `@Repository` is used to define a bean that is used to retrieve/save data from/to a database. And `@Component` is the annotation that marks a class as a bean declaration.

`@Component` is a meta-annotation, and annotations used to configure beans are annotated with it. This makes them candidates for auto-detection when using annotation-based configuration and classpath scanning.

To create bean definitions using annotations, the bean classes must be annotated with the appropriate stereotype annotation, and the setters or constructors used to inject dependencies must be annotated with `@Autowired` to tell the Spring IoC container to look for a bean of that type and use it as an argument when calling that method.

In Listing 3-10, the annotations used to create the bean definition are highlighted. The stereotype annotations can have as a parameter the name of the resulting bean.

**Listing 3-10.** Declaring Spring Beans Using `@Component`

```
// HelloWorldMessageProvider.java
package com.apress.prospring6.three.constructor;

import com.apress.prospring6.two.decoupled.MessageProvider;
import org.springframework.stereotype.Component;

// simple bean without dependencies
@Component("provider")
public class HelloWorldMessageProvider implements MessageProvider {
    // some code omitted
}

// StandardOutMessageRenderer.java
package com.apress.prospring6.three.setter;

import com.apress.prospring6.two.decoupled.MessageRenderer;
import org.springframework.beans.factory.annotation.Autowired;

// simple bean requiring a dependency
@Component("renderer")
public class StandardOutMessageRenderer implements MessageRenderer {
    private MessageProvider messageProvider;

    @Autowired
    public void setMessageProvider(MessageProvider provider) {
        this.messageProvider = provider;
    }
    // some code omitted
}
```

By annotating a configuration class with `@ComponentScan`, when bootstrapping the `ApplicationContext`, Spring will seek out these classes, also called components, and instantiate the beans with the specified names. In Listing 3-11 you can see the simple `HelloWorldConfiguration` configuration class annotated with `@ComponentScan`.

**Listing 3-11.** Simple Spring Configuration Class with Component Scanning

```
package com.apress.prospring6.three.constructor;

import org.springframework.context.annotation.ComponentScan;

@Configuration
@ComponentScan
public class HelloWorldConfiguration {
}
```

The code to bootstrap a Spring environment using `AnnotationConfigApplicationContext` (see Listing 3-9) works with this class, too, with no additional changes.

The `@ComponentScan` annotation declares the scanning directive and may configure specific packages to scan. When no package is configured, scanning occurs from the package of the class that declares this annotation, regardless of whether the class is public or package-private.

The class in Listing 3-11 tells Spring to look for bean definitions in package `constructor` and its subpackages. If we want to widen or restrict the scanning context, we can do so by declaring the `@ComponentScan` annotation with the `basePackages` attribute that allows the declaration of a package or a collection of packages where Spring will look for components.

For example:

- `@ComponentScan(basePackages = "com.apress.prospring6")` tells Spring to look for component classes in package `com.apress.prospring6` and all its subpackages.
- `@ComponentScan(basePackages = { "com.apress.prospring6.two", "com.apress.prospring6.three" })` tells Spring to look for component classes in package `com.apress.prospring6.two` and package `com.apress.prospring6.three` and all their subpackages.



Bean definitions on package-private classes are picked up by the `@ComponentScan` configuration that includes the package they are part of.

---

Component scanning is a time-consuming operation, and it is good programming practice to try to limit the places where Spring will look for bean definitions in the codebase. The `@ComponentScan` annotation provides other attributes beside `basePackages` to help build concise definitions of the scanning locations:

- `basePackageClasses`: A class or more can be configured; the package of each class specified will be scanned.
- `includeFilters`: Specifies which types are eligible for component scanning.
- `excludeFilters`: Specifies which types are not eligible for component scanning.

In real-life production applications, there might be legacy code, developed with older versions of Spring, or requirements might be of such a nature that require XML and configuration classes. Fortunately, XML and Java configuration can be mixed in more than one way. For example, a configuration class can



import bean definitions from an XML file (or more) using `@ImportResource`, and the same bootstrapping using `AnnotationConfigApplicationContext` will work in this case as well. Other bean definitions from Java configuration classes can be imported using `@Import`.

So, Spring allows you to be really creative when defining your beans; you'll learn more about this in **Chapter 4**, which is focused solely on Spring application configuration.

## Using Setter Injection

In the previous section, setter injection was used to configure the renderer bean, but since the focus was on the Spring configuration classes, some extra details are needed.

To configure setter injection, the `@Autowired` annotation must be put on every setter that is called by Spring to inject a dependency. Listing 3-12 shows the version of `StandardOutMessageRenderer` that is designed to support setter injection.

**Listing 3-12.** Declaring `StandardOutMessageRenderer` Beans Using `@Component` and Setter Injection

```
package com.apress.prospring6.three.setter;

import org.springframework.beans.factory.annotation.Autowired;
// other import statements omitted

@Component("renderer")
public class StandardOutMessageRenderer implements MessageRenderer {
    private MessageProvider messageProvider;

    @Autowired
    public void setMessageProvider(MessageProvider provider) {
        out.println(" ~~ Injecting dependency using setter ~~");
        this.messageProvider = provider;
    }
// other code omitted
}
```

To make sure that when executing the code the dependency is injected using the setter method, we added the `out.println(" ~~ Injecting dependency using setter ~~")` statement to the setter method. The Java configuration class requires no changes; if `@ComponentScan` is configured correctly, the bean definitions are discovered regardless of the injection style used.



Instead of `@Autowired`, you can use `@Resource(name="provider")` to achieve the same result. `@Resource` is one of the annotations in the JSR-250 (“Common Annotations for the Java Platform”) standard that defines a common set of Java annotations for use on both JSE and JEE platforms. This annotation is currently part of the `jakarta.annotation-api` library. Different from `@Autowired`, the `@Resource` annotation supports the name parameter for more fine-grained DI requirements. Additionally, Spring supports use of the `@Inject` annotation introduced as part of JSR-299 (“Contexts and Dependency Injection for the Java EE Platform”), later moved to JSR-330 (“Dependency Injection for Java”). `@Inject` is equivalent in behavior to Spring’s `@Autowired` annotation and currently is part of the `jakarta.inject-api` library.

---



The code to bootstrap a Spring application context to test that configuring a Spring bean using setter injection works as intended is the same as the code for the `HelloWorldSpringAnnotated` class.



In the project attached to this book, most class names containing a `main(..)` method to bootstrap a Spring application context are suffixed with `Demo`. The demo class for this section is named `SetterInjectionDemo` and all bean definitions and configuration are part of the `SetterInjectionDemo.java` file. This decision was made to keep all implementations in a single file to make it easy to find their locations within the project.

---

## Using Constructor Injection

In the previous section, we injected a provider instance into the `renderer` bean, via a setter method. This works fine, because the `@Autowired` annotation by default enforces the injection of a dependency, and thus the Spring application cannot be started if there is a missing dependency. As you will see later in the book, there are cases when injecting a dependency via setter is not an option, because of the way Spring creates the beans: it first instantiates the constructor, then it invokes the setters to inject dependencies. If you want to make sure that a bean is not even created without its dependencies, you can do so by enforcing this earlier in the life cycle, right at the instantiation step, by declaring your dependency as an argument for the constructor, ergo designing your bean for *constructor injection*.

In our examples so far, creating a `renderer` if there is no provider makes no sense, so a better design for our `StandardOutMessageRenderer` class should involve a constructor with a `MessageProvider`, as shown in Listing 3-13.

**Listing 3-13.** `StandardOutMessageRenderer` Designed for Constructor Injection

```
package com.apress.prospring6.three.constructor;
// import statements omitted

@Component("renderer")
class StandardOutMessageRenderer implements MessageRenderer {
    private MessageProvider messageProvider;

    @Autowired
    public StandardOutMessageRenderer(MessageProvider messageProvider) {
        out.println(" ~~ Injecting dependency using constructor ~~");
        this.messageProvider = messageProvider;
    }
    // other code omitted
}
```

By implementing `MessageRenderer` like this, we've made it impossible to create an instance of `StandardOutMessageRenderer` without providing a value for the `messageProvider`. The `@Autowired` annotation is not used to decorate the constructor, which tells Spring which constructor to use when instantiating this bean, in case there is more than one.



In Spring 4.x, it was decided that if a bean declares a single constructor that initializes all dependencies, the `@Autowired` annotation was redundant, so in the spirit of **convention over configuration**, the Spring IoC was modified to call the only constructor present to create the bean regardless of the presence/absence of the annotation. So, the `renderer` bean declared in Listing 3-13 is valid even if the `@Autowired` annotation is removed.

Since we mentioned that a class representing a bean definition can have more than one constructor, we present to you the `ConstructorConfusion` class in Listing 3-14.

**Listing 3-14.** `ConstructorConfusion` Class with Multiple Constructors

```
package com.apress.prospring6.three.constructor;
// import statements omitted

@Component
public class ConstructorConfusion {
    private String someValue;

    public ConstructorConfusion(String someValue) {
        System.out.println("ConstructorConfusion(String) called");
        this.someValue = someValue;
    }

    @Autowired
    public ConstructorConfusion(@Value("90") int someValue) {
        System.out.println("ConstructorConfusion(int) called");
        this.someValue = "Number: " + Integer.toString(someValue);
    }

    public String toString() {
        return someValue;
    }

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(ConstructorConfusion.class);
        ctx.refresh();

        var cc = ctx.getBean(ConstructorConfusion.class);
        out.println("Does this work? " + cc);
    }
}
```

The `ConstructorConfusion` bean definition in Listing 3-14 is correct, because the second constructor is annotated with `@Autowired`. This tells Spring to use this constructor to instantiate this bean. Without that annotation, Spring cannot decide on its own which constructor to use, and running this class results in the following exception being thrown.

```
Caused by: org.springframework.beans.BeanInstantiationException:
  Failed to instantiate [com.apress.prospring6.three.constructor.ConstructorConfusion]:
  No default constructor found;
    nested exception is java.lang.NoSuchMethodException: com.apress.prospring6.three.
    constructor.ConstructorConfusion.<init>()
```



Notice the `@Value` annotation in the constructor annotated with `@Autowired`. This annotation is explained later in this chapter, but for now, in this simple example, know that it is necessary to inject a value for the constructor parameter, and that the constructor won't work without it.

---



The `ConstructorConfusion` class declares a bean but also has its own `main(..)` method used to do the following:

- Instantiate a simple, empty Spring application context of type `AnnotationConfigApplicationContext`
- that is then populated with the bean definition represented by the `ConstructorConfusion` class by calling `ctx.register(ConstructorConfusion.class)`
- and then the context is refreshed by calling `refresh()`, which re-creates all the beans according to the registered bean definitions.

Or you have already read all this and find it incredibly interesting that you can register bean definitions programmatically, without the need for a configuration class.

---



The example in Listing 3-14 also highlights that the `@Autowired` annotation can be applied to only one of the constructors within a class. If we apply the annotation to more than one constructor method, Spring will complain while bootstrapping `ApplicationContext`.

---

Another scenario that is interesting to introduce here is what happens if the dependency is not a bean. What if it is a simple object, such as a `String`? Let's tackle that by creating a configurable message provider. A configurable `MessageProvider` implementation that allows the message to be defined externally is shown in Listing 3-15.

**Listing 3-15.** Configurable `MessageProvider` Implementation

```
package com.apress.prospring6.three.configurable;

import org.springframework.beans.factory.annotation.Value;
// import statements omitted
```

```

@Component("provider")
class ConfigurableMessageProvider implements MessageProvider {

    private String message;

    public ConfigurableMessageProvider(@Value("Configurable message"), String message) {
        this.message = message;
    }

    @Override
    public String getMessage() {
        return message;
    }
}

```

By implementing `MessageProvider` like this, we've made it impossible to create an instance of `ConfigurableMessageProvider` without providing a value for the message. Notice the `@Value` annotation used to define the value to be injected into the constructor. This is how we inject values that are not beans into a Spring bean. Sadly, in this example the value is specified within the annotation declaration, so there is a necessary hard-coding, but using SpEL dynamic value injection is possible from other sources such as property files (more on this later in this chapter).

## Using Field Injection

There is a third type of dependency injection supported in Spring called *field injection*. As the name indicates, the dependency is injected directly into the field, with no constructor or setter needed. This is done by annotating the class member with the `@Autowired` annotation. This might seem practical, because when the dependency is not needed outside the object it is part of, it relieves the developer of writing some code that is no longer used after the initial creation of the bean. In the code snippet in Listing 3-16, the bean of type `NonSingletonDemo` has a field of type `Inspiration`.

**Listing 3-16.** `NonSingletonDemo` Class Used to Show Field Injection

```

package com.apress.prospring6.three.field;

import org.springframework.stereotype.Component;
// import statements omitted

@Component("singer")
class Singer {

    @Autowired
    private Inspiration inspirationBean;

    public void sing() {
        System.out.println("... " + inspirationBean.getLyric());
    }
}

```

The field is private, but the Spring IoC container does not really care about that; it uses reflection to populate the required dependency.

The `Inspiration` class code is shown in Listing 3-17 together with the class used to bootstrap a Spring application context; it is a simple bean with a `String` field.

**Listing 3-17.** Inspiration Class and Demo Class Used to Show How Field Injection Works

```

package com.apress.prospring6.three.field;
// import statements omitted

@Component
class Inspiration {
    private String lyric = "I can keep the door cracked open, to let light through";

    public Inspiration(@Value("For all my running, I can understand") String lyric) {
        this.lyric = lyric;
    }

    public String getLyric() {
        return lyric;
    }

    public void setLyric(String lyric) {
        this.lyric = lyric;
    }
}

// demo class
public class SingerFieldInjectionDemo {

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(Singer.class, Inspiration.class);
        ctx.refresh();

        Singer singerBean = ctx.getBean(Singer.class);
        singerBean.sing();
    }
}

```

Finding one bean of type `Inspiration`, the Spring IoC container will inject that bean in the `inspirationBean` field of the singer bean. That is why when running the code in Listing 3-17 the main class prints in the console *For all my running, I can understand*.

However, there are a few drawbacks, and this is why **using field injection is not recommended**. Here is the list of drawbacks:

- *A risk of violating the single responsibility principle:* Having more dependencies means more responsibilities for a class, which might lead to difficulty separating concerns at refactoring time. The situation when a class becomes bloated is easier to see when dependencies are set using constructors or setters but is quite well hidden when using field injection.
- *Dependency hiding:* The responsibility of injecting dependencies is passed to the container in Spring, but the class should clearly communicate the type of dependencies needed using a public interface, through methods or constructors. Using field injection, it can become unclear what type of dependency is really needed and if the dependency is mandatory or not. *(It's pretty similar to how some partners don't communicate their needs but expect you to magically read their minds and satisfy them.)*

- *Dependency on the Spring IoC:* Field injection introduces a dependency of the Spring container, as the `@Autowired` annotation is a Spring component; thus, the bean is no longer a POJO and cannot be instantiated independently. (Unless you use `@Resource` or `@Inject` and a different container, that is.)
- *Field injection cannot be used for final fields:* This type of field can only be initialized using constructor injection.
- *Difficulties writing tests:* Field injection introduces difficulties when writing tests because the dependencies must be injected manually.

However, it is practical to use `@Autowired` in instance variables *only* for `@Configuration` and `@Test` classes—for the latter based with Integration Testing where a Spring context is necessary.

## Using Injection Parameters

In previous examples, we briefly mentioned that other components and values can be injected into a bean by using both setter injection and constructor injection. Spring supports a myriad of options for injection parameters, allowing you to inject not only other components and simple values but also Java collections, externally defined properties, and even beans in another factory. Let's delve into this a little more.

### Injecting Simple Values

Injecting simple values into your beans is easy. To do so, simply specify the value in the `@Value` annotation. By default, not only can the `@Value` annotation read `String` values, but it can also convert these values to any primitive or primitive wrapper class. The code snippet in Listing 3-18 shows a simple bean that has a variety of properties exposed for injection.

**Listing 3-18.** `InjectSimpleDemo` Class Used to Show Injecting Value in Properties of Various Types

```
package com.apress.prospring6.three.valinject;
// import statements omitted

@Component("injectSimple")
public class InjectSimpleDemo {

    @Value("John Mayer")
    private String name;
    @Value("40")
    private int age;
    @Value("1.92")
    private float height;
    @Value("false")
    private boolean developer;
    @Value("1241401112")
    private Long ageInSeconds;

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(InjectSimpleDemo.class);
        ctx.refresh();
    }
}
```

```

InjectSimpleDemo simple = (InjectSimpleDemo) ctx.getBean("injectSimple");
out.println(simple);
}

public String toString() {
    return "Name: " + name + "\n"
        + "Age: " + age + "\n"
        + "Age in Seconds: " + ageInSeconds + "\n"
        + "Height: " + height + "\n"
        + "Is Developer?: " + developer;
}
}

```

The `@Value` annotation can be used directly on fields as well, and is used like this in the `InjectSimpleDemo` class to keep things simple and avoid the boilerplate of setters code. If you run this class, the console output is as expected, shown in Listing 3-19.

**Listing 3-19.** Console Output Resulting from Running the Class in Listing 3-18

```

Name: John Mayer
Age: 39
Age in Seconds: 1241401112
Height: 1.92
Is Programmer?: false

```

## Injecting Values Using SpEL

The example in Listing 3-18 shows the capabilities of automatic conversion that Spring has when injecting property values. However, the example is still quite basic since the values are hard-coded in the `@Value` annotation. This is where SpEL makes things interesting.

One powerful feature that was introduced in Spring 3 is the **Spring Expression Language (SpEL)**. SpEL enables you to evaluate an expression dynamically and then use it in Spring's `ApplicationContext`. You can use the result for injection into Spring beans. In this section, we look at how to use SpEL to inject properties from other beans, by using the example in the preceding section.

Suppose now we want to externalize the values to be injected into a Spring bean in a configuration class, as shown in the code Listing 3-20.

**Listing 3-20.** Spring Configuration Class Providing a Few Values As Fields

```

package com.apress.prospring6.three.valinject;
// import statements omitted

@Component("injectSimpleConfig")
class InjectSimpleConfig {

    private String name = "John Mayer";
    private int age = 40;
    private float height = 1.92f;
    private boolean developer = false;
    private Long ageInSeconds = 1_241_401_112L;
}

```

```

public String getName() {
    return name;
}

public int getAge() {
    return age;
}

public float getHeight() {
    return height;
}

public boolean isDeveloper() {
    return developer;
}

public Long getAgeInSeconds() {
    return ageInSeconds;
}
}

```

The first thing to do is to edit the `@Value` annotations and replace the hard-coded values with SpEL expressions referencing properties of this bean. The second thing to do is to add a bean of this type to the configuration. Both are shown in Listing 3-21.

**Listing 3-21.** `@Value` Annotations Customized to Use SpEL Expressions

```

package com.apress.prospring6.three.valinject;
// import statements omitted

@Component("injectSimpleSpEL")
public class InjectSimpleSpELDemo {
    @Value("#{injectSimpleConfig.name.toUpperCase()}")
    private String name;

    @Value("#{injectSimpleConfig.age + 1}")
    private int age;

    @Value("#{injectSimpleConfig.height}")
    private float height;

    @Value("#{injectSimpleConfig.developer}")
    private boolean developer;

    @Value("#{injectSimpleConfig.ageInSeconds}")
    private Long ageInSeconds;

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(InjectSimpleConfig.class, InjectSimpleSpELDemo.class);
        ctx.refresh();
    }
}

```



```

        InjectSimpleSpELDemo simple = (InjectSimpleSpELDemo) ctx.getBean("injectSimpleSpEL");
        out.println(simple);
    }

    // other code omitted
}

```

Notice that we use the SpEL `#{injectSimpleConfig.name}` in referencing the property of the other bean. Notice also how there is no getter called, but the SpEL expression contains the bean and property name concatenated by a `''` (dot) and Spring knows exactly what to do. SpEL supports String manipulation and arithmetic operations as well, as shown by calling `toUpperCase()` on the name property before injection and by adding 1 to the value of the bean property before injection. If you run the `main(...)` method of the `InjectSimpleSpELDemo` class, the output depicted in Listing 3-22 should be printed in the console.

**Listing 3-22.** Console Output Resulting from Running the Class in Listing 3-21

```

Name: JOHN MAYER
Age: 41
Age in Seconds: 1241401112
Height: 1.92
Is Developer?: false

```

Since the `toUpperCase()` call was added to the name property, the output is almost identical to the example where values were hard-coded. Using SpEL, you can access any Spring-managed beans and properties and manipulate them for application use by Spring's support of sophisticated language features and syntax.

## Injection and ApplicationContext Nesting

So far, the beans we have been injecting have been located in the same `ApplicationContext` (and hence the same `BeanFactory`) as the beans they are injected into. However, Spring supports a hierarchical structure for `ApplicationContext` so that one context (and hence the associating `BeanFactory`) is considered the parent of another. By allowing `ApplicationContext` instances to be nested, Spring allows you to split your configuration into different files, which is a godsend on larger projects with lots of beans.

When nesting `ApplicationContext` instances, Spring allows beans in what is considered the child context to reference beans in the parent context. In XML this was easy to do, because of the `<ref/>` tag, which could be configured to reference a bean in the parent context via its parent attribute. Using Java configuration and annotation, the task is a little more tedious but still doable. Let us show you the magic.

`ApplicationContext` nesting using `AnnotationConfigApplicationContext` is simple to understand. To nest one `AnnotationConfigApplicationContext` inside another, simply call the `setParent()` method in the child `ApplicationContext` as shown in the code in Listing 3-23.

**Listing 3-23.** Nesting Application Contexts

```

package com.apress.prospring6.three.nesting;
// import statements omitted

public class ContextNestingDemo {

    public static void main(String... args) {
        var parentCtx = new AnnotationConfigApplicationContext();
    }
}

```

```

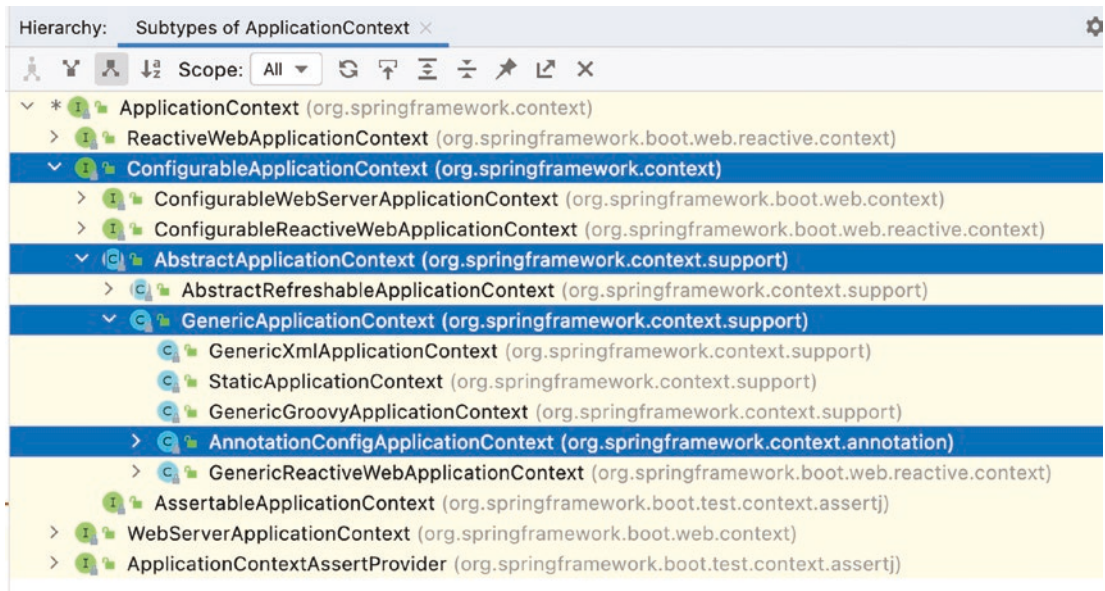
parentCtx.register(ParentConfig.class);
parentCtx.refresh();

var childCtx = new AnnotationConfigApplicationContext();
childCtx.register(ChildConfig.class);
childCtx.setParent(parentCtx);
childCtx.refresh();

Song song1 = (Song) childCtx.getBean("song1");
Song song2 = (Song) childCtx.getBean("song2");
Song song3 = (Song) childCtx.getBean("song3");
out.println("from parent ctx: " + song1.getTitle());
out.println("from child ctx: " + song2.getTitle());
out.println("from child ctx: " + song3.getTitle());
}
}

```

This method is inherited from the `org.springframework.context.support.GenericApplicationContext`, that is a superclass of `AnnotationConfigApplicationContext`. The method is, however, declared higher in the hierarchy, in the `org.springframework.context.ConfigurableApplicationContext` interface that provides facilities to configure an application context in addition to the application context client methods in the `ApplicationContext` interface. The full hierarchy that `AnnotationConfigApplicationContext` is part of is depicted in Figure 3-5.



**Figure 3-5.** *AnnotationConfigApplicationContext hierarchy*

The context nesting is easy to set up, but accessing beans from the parent...not so much.

The `Song` class is very simple, just a very simple POJO with a field named `title`. To declare song title depending on the context, a class named `TitleProvider` is used. This class can be instantiated with various titles via a static builder method. This class is very simple as well. Both these classes are shown in Listing 3-24.

**Listing 3-24.** Song and TitleProvider Classes

```
package com.apress.prospring6.three.nesting;
```

```
// Song.java
```

```
public class Song {
    private String title;

    public Song(String title) {
        this.title = title;
    }

    public String getTitle() {
        return title;
    }
}
```

```
// TitleProvider.java
```

```
import org.apache.commons.lang3.StringUtils;
```

```
public class TitleProvider {
    private String title = "Gravity";

    public String getTitle() {
        return title;
    }

    public void setTitle(String title) {
        this.title = title;
    }

    // builder method
    public static TitleProvider instance(final String title){
        var childProvider = new TitleProvider();
        if(StringUtils.isNotBlank(title)) {
            childProvider.setTitle(title);
        }
        return childProvider;
    }
}
```

The ParentConfig class is simple and declares two TitleProvider beans named parentProvider and childProvider as shown in Listing 3-25.

**Listing 3-25.** ParentConfig Class Declaring Two TitleProvider Beans

```
package com.apress.prospring6.three.nesting;
```

```
// import statements omitted
```

```
@Configuration
```

```
public class ParentConfig {
```

```

@Bean
public TitleProvider parentProvider(){
    return TitleProvider.instance(null);
}

@Bean
public TitleProvider childProvider(){
    return TitleProvider.instance("Daughters");
}
}

```

The ChildConfig class declares three Song beans, each of which has a title injected from a TitleProvider bean:

- song1 is injected with the title value provided by the bean named parentProvider; since there is a single bean named parentProvider in the parent context, which the child context inherits, the injected value is *Gravity*.
- song2 is injected with the title value provided the bean named childProvider declared in the parent context; since there is a bean named childProvider in the child context as well, to access the one from the parent context, some *coding acrobatics* are required (this is way easier using XML configuration):
  - To access the bean from the parent context, access to the current context is needed. This is done by implementing the ApplicationContextAware interface and declaring a property of type ApplicationContext that will be initialized by Spring with a reference to the current application context by calling the setApplicationContext(..) method.
  - Once we have a reference to the current context, we write a complicated SpEL expression designed to get a reference to the parent context, access the childProvider, and get the title value, which is expected to be *Daughters*.
- song3 is injected with the title value provided the bean named childProvider; since there is a bean named childProvider in the current context, the injected value is *No Such Thing*.

The code is depicted in Listing 3-26.

**Listing 3-26.** Injecting Beans Properties from a Parent Context in Beans in a Child Context

```

package com.apress.prospring6.three.nesting;

import org.springframework.beans.BeansException;
import org.springframework.context.ApplicationContextAware;
// import statements omitted

@Configuration
public class ChildConfig implements ApplicationContextAware {

    public ApplicationContext applicationContext;

    @Bean // overrides {@code childProvider} bean from parent context
    public TitleProvider childProvider(){

```

```

        return TitleProvider.instance("No Such Thing");
    }

    @Bean
    public Song song1(@Value("#{parentProvider.title}") String title){
        return new Song(title);
    }

    @Bean
    public Song song2(@Value("#{childConfig.applicationContext.parent.
    getBean(\"childProvider\").title}") String title){
        return new Song(title);
    }

    @Bean
    public Song song3(@Value("#{childProvider.title}") String title){
        return new Song(title);
    }

    @Override
    public void setApplicationContext(ApplicationContext applicationContext) throws
    BeansException {
        this.applicationContext = applicationContext;
    }
}

```

The SpEL expression in the @Value annotation for bean song2 seems complicated, but it really isn't. Remember how we accessed beans in every demo class so far? This is exactly what this expression does, only instead of accessing the bean from the current context, it does so from its parent. Let us explain:

- The expression needs to start with childConfig because this is the name of the configuration bean. It was mentioned before that SpEL can access bean properties. The current application context is referenced by the applicationContext property of the bean childConfig.
- parent is a property of an ApplicationContext that references the parent context. If there is no parent, it is null, but in this example, we know that we have one.
- getBean("childProvider") is the typical method we've used before to obtain a reference to a bean using its name. In Java code, a conversion to the appropriate type was needed, whereas SpEL figures it out on its own.

Listing 3-27 is the output from running the ContextNestingDemo class.

**Listing 3-27.** Injecting Beans Properties from a Parent Context in Beans in a Child Context

```

from parent ctx: Gravity
from parent ctx: No Such Thing
from child ctx: Daughters

```

As expected, the song1 and song2 beans both get a title value from beans in the parent ApplicationContext, whereas the song3 bean gets a title value from a bean in the child ApplicationContext.

## Injecting Collections

Often your beans need access to collections of objects rather than just individual beans or values. Therefore, it should come as no surprise that Spring allows you to inject a collection of objects into one of your beans. In the previous edition of this book, lists, sets, maps, and properties values were configured using XML. Since this book is not focused on that, let's see how we can declare collections using Java configuration. It's quite easy, really: just declare methods annotated with `@Bean` in a configuration class that returns `List<E>`, `Set<E>`, `Properties`, or `Map<K,V>`. This section covers only the `List<E>` type, but the sources for the book contain examples for all types.

For the next example, we'll make use of the `Song` class used in the previous section. The type `CollectionConfig` declares a `List<Song>` bean and is depicted in Listing 3-28.

**Listing 3-28.** Configuration Class Declaring a Bean of Type `List<Song>`

```
package com.apress.prospring6.three.collectioninject;
// import statements omitted

@Configuration
public class CollectionConfig {

    @Bean
    public List<Song> list(){
        return List.of(
            new Song("Not the end"),
            new Song("Rise Up")
        );
    }

    @Bean
    public Song song1(){
        return new Song("Here's to hoping");
    }

    @Bean
    public Song song2(){
        return new Song("Wishing the best for you");
    }
}
```

The `CollectionConfig` class also declares two beans of type `Song`. The purpose of these beans will become obvious a bit further in this section.

The `CollectingBean` is a type for the bean where the list bean is injected and the values are printed by invoking the `printCollections()` method. The `CollectionInjectionDemo` class is where the `main(..)` method is declared containing the code to create the application context, get a reference to a `CollectingBean` bean, and invoke the `printCollections()` method on to check that the list value was injected. The code in Listing 3-29 shows both classes.

**Listing 3-29.** Demo Class for Testing Configuration Class Declaring a Bean of Type List<Song>

```

package com.apress.prospring6.three.collectioninject;
// import statements omitted

@Component
class CollectingBean {

    @Autowired
    List<Song> songList;

    public void printCollections(){
        songList.forEach(s -> out.println(s.getTitle()));
    }
}

public class CollectionInjectionDemo {
    public static void main(String... args) {

        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(CollectionConfig.class, CollectingBean.class);
        ctx.refresh();

        var collectingBean = ctx.getBean(CollectingBean.class);
        collectingBean.printCollections();
    }
}

```

The code looks simple enough, but when we run it, here's what is printed:

```

Here's to hoping
Wishing the best for you

```

Wait, what? Yup, the two extra Song beans have been added to a list and injected into the songList property, instead of the list bean, as we expected. What happened here? The behavior you are seeing is caused by the @Autowired annotation. The @Autowired annotation is semantically defined in a way that it always treats arrays, collections, and maps as sets of corresponding beans, with the target bean type derived from the declared collection value type. Our class has an attribute of type List<Song> and has the @Autowired annotation on it, thus Spring will try to inject all beans of type Song within the current ApplicationContext into this property, which will result in either the unexpected dependencies being injected or Spring throwing an exception if no bean of type Song was defined.

So, for collection type injection, we have to explicitly instruct Spring to perform injection by specifying the bean name, and this can be done by using the Spring @Qualifier annotation, the one in the org.springframework.beans.factory.annotation. This statement is necessary because there is a @Qualifier annotation in the Jakarta Inject library too, and it has a different purpose. This means annotating the songList dependency with @Autowired @Qualifier("list") ensures the expected behavior. However, there are three additional ways to do it:

- @Inject @Named("list"): Both annotations can be found in the jakarta.inject package. The @Inject annotation is the Jakarta equivalent of Spring's @Autowired and the @Named annotation is the equivalent of Spring's @Qualifier.

- `@Resource(name="list")`: This annotation, mentioned previously, can be found in the `jakarta.annotation` package and it is one of the preferred ways to do collection injection because using one annotation is better than using two of them.
- `@Value("#{collectionConfig.list}")`: Since it is preferable to keep it in the Spring domain, and add as little dependencies to your application as possible, this is actually the recommended way to inject collections, and there is no doubt what will be injected.



The behavior described for injecting collections applies for `Set` and `Map` too, with the only difference being that in a `Map` Spring will inject `{beanName, bean}` key-value pairs.

---

## Using Method Injection

Beside constructor and setter injection, another less frequently used DI feature that Spring provides is *Method Injection*. Spring's Method Injection capabilities come in two loosely related forms, Lookup Method Injection and Method Replacement. Lookup Method Injection provides another mechanism by which a bean can obtain one of its dependencies. Method Replacement allows you to replace the implementation of any method on a bean arbitrarily, without having to change the original source code. To provide these two features, Spring uses the dynamic bytecode enhancement capabilities of CGLIB. CGLIB is a powerful, high-performance, and high-quality code generation library. It can extend Java classes and implement interfaces at runtime. It is open source, and you can find the official repository at <https://github.com/cglib/cglib>.

### Lookup Method Injection

*Lookup Method Injection* was added to Spring in version 1.1 to overcome the problems encountered when a bean depends on another bean with a different life cycle, specifically, when a singleton depends on a non-singleton. In this situation, both setter and constructor injection result in the singleton maintaining a single instance of what should be a non-singleton bean. In some cases, you will want to have the singleton bean obtain a new instance of the non-singleton every time it requires the bean in question.

Consider a scenario in which a `LockOpener` class provides the service of opening any locker. The `LockOpener` class relies on a `KeyHelper` class for opening the locker, which was injected into `LockOpener`. However, the design of the `KeyHelper` class involves some internal states that make it not suitable for reuse. Every time the `openLock()` method is called, a new `KeyHelper` instance is required. In this case, `LockOpener` will be a singleton. However, if we inject the `KeyHelper` class by using the normal mechanism, the same instance of the `KeyHelper` class (which was instantiated when Spring performed the injection the first time) will be reused. To make sure that a new instance of the `KeyHelper` instance is passed into the `openLock()` method every time it is invoked, we need to use Lookup Method Injection.

Typically, you can achieve this by having the singleton bean implement the `ApplicationContextAware` interface (we discuss this interface in **Chapter 4**). Then, using the `ApplicationContext` instance, the singleton bean can look up a new instance of the non-singleton dependency every time it needs it. Lookup Method Injection allows the singleton bean to declare that it requires a non-singleton dependency and that it will receive a new instance of the non-singleton bean each time it needs to interact with it, without needing to implement any Spring-specific interfaces.

Lookup Method Injection works by having your singleton declare a method, the lookup method, which returns an instance of the non-singleton bean. When you obtain a reference to the singleton in your application, you are actually receiving a reference to a dynamically created subclass on which Spring



has implemented the lookup method. A typical implementation involves defining the lookup method, and thus the bean class, as abstract. This prevents any strange errors from creeping in when you forget to configure the Method Injection and you are working directly against the bean class with the empty method implementation instead of the Spring-enhanced subclass. This topic is quite complex and is best shown by example.

In this example, we create one non-singleton bean and two singleton beans that both implement the same interface. One of the singletons obtains an instance of the non-singleton bean by using “traditional” setter injection; the other uses Method Injection. The code sample in Listing 3-30 depicts the `KeyHelper` class, which in this example is the type of the non-singleton bean, which means instances of this type are created every time one is required to be injected as a dependency.

**Listing 3-30.** Non-Singleton Bean

```
package com.apress.prospring6.three.methodinject;

import org.springframework.context.annotation.Scope;
// import statements omitted

@Component("keyHelper")
@Scope("prototype")
class KeyHelper {
    public void open(){
    }
}
```

This class is decidedly unexciting, but it serves the purposes of this example perfectly. Next, in Listing 3-31 you can see the `LockOpener` interface, which is implemented by both of the singleton bean classes.

**Listing 3-31.** Singleton Bean Interface Type

```
package com.apress.prospring6.three.methodinject;

interface LockOpener {
    KeyHelper getMyKeyOpener();
    void openLock();
}
```

This bean has two methods: `getMyKeyOpener()` and `openLock()`. The sample application uses the `getMyKeyOpener()` method to get a reference to a `KeyHelper` instance and, in the case of the method lookup bean, to perform the actual method lookup. The `openLock()` method is a simple method that depends on the `KeyHelper` instance to do its processing. The code in Listing 3-32 shows the `StandardLockOpener` class, which uses setter injection to obtain an instance of the `KeyHelper` class.

**Listing 3-32.** `StandardLockOpener` Class Configured Using Autowiring to Obtain a Dependency of Type `KeyHolder`

```
package com.apress.prospring6.three.methodinject;
// import statements omitted

@Component("standardLockOpener")
class StandardLockOpener implements LockOpener {
```

```

private KeyHelper keyHelper;

@Autowired
@Qualifier("keyHelper")
public void setKeyHelper(KeyHelper keyHelper) {
    this.keyHelper = keyHelper;
}

@Override
public KeyHelper getMyKeyOpener() {
    return keyHelper;
}

@Override
public void openLock() {
    keyHelper.open();
}
}

```

This code should all look familiar, but notice that the `openLock()` method uses the stored instance of `KeyHelper` to complete its processing. In the code in Listing 3-33, you can see the `AbstractLockOpener` class, which uses Method Injection to obtain an instance of the `KeyHelper` class, configured using the `org.springframework.beans.factory.annotation.Lookup` annotation.

**Listing 3-33.** `AbstractLockOpener` Class Configured Using Method Injection to Obtain a Dependency of Type `KeyHolder`

```

package com.apress.prospring6.three.methodinject;

import org.springframework.beans.factory.annotation.Lookup;
// import statements omitted

@Component("abstractLockOpener")
abstract class AbstractLockOpener implements LockOpener {

    @Lookup("keyHelper")
    @Override
    public abstract KeyHelper getMyKeyOpener() ;

    @Override
    public void openLock() {
        getMyKeyOpener().open();
    }
}

```

Notice that the `getMyKeyOpener()` method is declared as abstract and that this method is called by the `openLock()` method to obtain a `KeyHelper` instance. Populating an application context with the bean definitions in this section might require writing more code than writing a simple configuration class, thus in code Listing 3-34 the configuration class is depicted.

**Listing 3-34.** The Java Configuration Class for This Section

```

package com.apress.prospring6.three.methodinject;
// import statements omitted

@Configuration
@ComponentScan
class LookupConfig {}

```

The configuration for the `keyHelper` and `standardLockOpener` beans should look familiar to you by now. For `abstractLockOpener`, you need to configure the lookup method by using the `@Lookup` annotation. This tells Spring which method on the bean it should override. This method must not accept any arguments, and the return type should be that of the bean you want to return from the method. In this case, the method should return a class of type `KeyHelper`, or its subclasses. The annotation attribute value tells Spring which bean the lookup method should return. The code snippet in Listing 3-35 shows the final piece of code for this example, which is the class containing the `main()` method used to run the example.

**Listing 3-35.** Main Class to Test Method Injection

```

package com.apress.prospring6.three.methodinject;
import org.springframework.util.StopWatch;
// import statements omitted

public class MethodInjectionDemo {
    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(LookupConfig.class);

        var abstractLockOpener = ctx.getBean("abstractLockOpener", LockOpener.class);
        var standardLockOpener = ctx.getBean("standardLockOpener", LockOpener.class);

        displayInfo("abstractLockOpener", abstractLockOpener);
        displayInfo("standardLockOpener", standardLockOpener);
    }

    public static void displayInfo(String beanName, LockOpener lockOpener) {
        KeyHelper keyHelperOne = lockOpener.getMyKeyOpener();
        KeyHelper keyHelperTwo = lockOpener.getMyKeyOpener();

        out.println "[" + beanName + "]: KeyHelper Instances the Same? " + (keyHelperOne ==
        keyHelperTwo));

        StopWatch stopWatch = new StopWatch();
        stopWatch.start("lookupDemo");

        for (int x = 0; x < 100_000; x++) {
            KeyHelper keyHelper = lockOpener.getMyKeyOpener();
            keyHelper.open();
        }
        stopWatch.stop();
        out.println("100000 gets took " + stopWatch.getTotalTimeMillis() + " ms");
    }
}

```

In this code, you can see that the `abstractLockOpener` and the `standardLockOpener` from the `AnnotationConfigApplicationContext` are retrieved and each reference is passed to the `displayInfo()` method. The instantiation of the abstract class is supported only when using Lookup Method Injection, in which Spring will use CGLIB to generate a subclass of the `AbstractLockOpener` class that overrides the method dynamically. The first part of the `displayInfo()` method creates two local variables of `KeyHelper` type and assigns them each a value by calling `getMyKeyOpener()` on the bean passed to it. Using these two variables, it writes a message to the console indicating whether the two references point to the same object. For the `abstractLockOpener` bean, a new instance of `KeyHelper` should be retrieved for each call to `getMyKeyOpener()`, so the references should not be the same. For `standardLockOpener`, a single instance of `Singer` is passed to the bean by setter injection, and this instance is stored and returned for every call to `getMyKeyOpener()`, so the two references should be the same.



The `Stopwatch` class used in the previous example is a utility class available with Spring. You'll find `Stopwatch` very useful when you need to perform simple performance tests and when you are testing your applications.

---

The final part of the `displayInfo()` method runs a simple performance test to see which bean is faster. Clearly, `standardLockOpener` should be faster because it returns the same instance each time, but it is interesting to see the difference. We can now run the `MethodInjectionDemo` class for testing. Here is the output we received from this example:

```
[abstractLockOpener]: KeyHelper Instances the Same? false
100000 gets took 431 ms
[standardLockOpener]: KeyHelper Instances the Same? true
100000 gets took 1 ms
```

As you can see, the `KeyHelper` instances are, as expected, the same when we use `standardLockOpener` and different when we use `abstractLockOpener`. There is a noticeable performance difference when you use `standardLockOpener`, but that is to be expected.

## Considerations for Lookup Method Injection

Lookup Method Injection is intended for use when you want to work with two beans of different life cycles. Avoid the temptation to use Lookup Method Injection when the beans share the same life cycle, especially if they are singletons. The output of running the previous example shows a noticeable difference in performance between using Method Injection to obtain new instances of a dependency and using standard DI to obtain a single instance of a dependency. Also, make sure you don't use Lookup Method Injection needlessly, even when you have beans of different life cycles.

Consider a situation in which you have three singletons that share a dependency in common. You want each singleton to have its own instance of the dependency, so you create the dependency as a non-singleton, but you are happy with each singleton using the same instance of the collaborator throughout its life. In this case, setter injection is the ideal solution; Lookup Method Injection just adds unnecessary overhead.

When you are using Lookup Method Injection, there are a few design guidelines that you should keep in mind when building your classes. In the earlier examples, we declared the `lookup` method in an interface. The only reason we did this was that we did not have to duplicate the `displayInfo()` method twice for two different bean types. As mentioned earlier, generally you do not need to pollute a business interface with

unnecessary definitions that are used solely for IoC purposes. Another point is that although you don't have to make your lookup method abstract, doing so prevents you from forgetting to configure the lookup method and then using a blank implementation by accident.

## Understanding Bean Naming

Spring supports quite a complex bean-naming structure that allows you the flexibility to handle many situations. Every bean must have at least one name that is unique within the containing `ApplicationContext`. Spring follows a simple resolution process to determine what name is used for the bean. When using XML configuration, if you give the `<bean>` tag an `id` attribute, the value of that attribute is used as the unique name within the application context.

When using Java configuration, unless explicitly configured, Spring generates bean names using a few strategies, which will be covered in this section. When retrieving beans from the application, bean names or bean types can be used, or both can be used. If multiple beans of the same type without `id` or `name` are declared, Spring will throw an `org.springframework.beans.factory.NoSuchBeanDefinitionException` exception during `ApplicationContext` initialization. Using Java configuration, it is pretty difficult to cause collisions, but it might happen, so it is better to know what to expect.

### Default Bean Naming Style for Beans Declared with `@Component`

For the purpose of this section, the configuration class enables component scanning for the `com.apress.prospring6.three.naming` package. We'll start by declaring a very simple bean, as shown in Listing 3-36.

**Listing 3-36.** The Simplest Bean Type

```
@Component
class SimpleBean { }
```

To figure out how Spring names the beans by default, we create an `ApplicationContext` based on a configuration that includes the `SimpleBean` class. This class is annotated with `@Component` and is discovered via component scanning. The `ApplicationContext` provides methods to retrieve references to the beans, but also to retrieve all the bean names in the context. In Listing 3-37, all the names of the beans in the context are printed in the console using a `Logback` logger.

**Listing 3-37.** Printing All Bean Names

```
package com.apress.prospring6.three.naming;

import org.springframework.context.annotation.AnnotationConfigApplicationContext;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
// other import statements omitted

import java.util.Arrays;

public class BeanNamingDemo {
    private static Logger logger = LoggerFactory.getLogger(BeanNamingDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(BeanNamingCfg.class);
```

```

        Arrays.stream(ctx.getBeanDefinitionNames()).forEach(beanName -> logger.
            debug(beanName));
    }
}

```

The console output is depicted in Listing 3-38.

**Listing 3-38.** Console Log Showing All Bean Names in the Context

```

DEBUG: BeanNamingDemo - org.springframework.context.annotation.
internalConfigurationAnnotationProcessor
DEBUG: BeanNamingDemo - org.springframework.context.annotation.
internalAutowiredAnnotationProcessor
DEBUG: BeanNamingDemo - org.springframework.context.annotation.
internalCommonAnnotationProcessor
DEBUG: BeanNamingDemo - org.springframework.context.event.internalEventListenerProcessor
DEBUG: BeanNamingDemo - org.springframework.context.event.internalEventListenerFactory
DEBUG: BeanNamingDemo - beanNamingCfg
DEBUG: BeanNamingDemo - simpleBean

```

In the list you can see a few bean names that start with `org.springframework`. These are what we call *infrastructure beans* and are internally used by Spring to process bean definitions and create beans. The beans that are not obviously Spring infrastructure beans are beans declared within the application configuration. In the output in Listing 3-37 there are two beans that should spark your interest:

- `beanNamingCfg`: This bean name is the same as the simple name of the configuration class `BeanNamingCfg`. The `@Configuration` annotation is annotated itself with `@Component`, and this means any configuration class is in essence a bean definition.
- `simpleBean`: This bean name is the same as the simple name of the bean class `SimpleBean`.



As proven by the `beanNamingCfg` and `simpleBean` names, when bean names are not configured explicitly, Spring takes the simple name of the type declaring the bean, changes the first letter to lowercase, and uses the resulting value to name the bean.

---

## Customizing Bean Naming Style

Before going further and explaining how beans declared with `@Beans` are named, we'll show you a neat trick. As in almost everything with Spring, if there is a default behavior, it can be customized. Thus, bean naming can be customized. The `@Configuration` annotation has an attribute named `nameGenerator`. The attribute value must be a class implementing `org.springframework.beans.factory.support.BeanNameGenerator` or extending any of the implementations provided by Spring. Listing 3-39 shows the `SimpleBeanNameGenerator` class and the `BeanNamingCfg`.

**Listing 3-39.** Console Log Showing All Bean Names in the Context

```

package com.apress.prospring6.three.generator;

import org.springframework.beans.factory.config.BeanDefinition;
import org.springframework.beans.factory.support.BeanDefinitionRegistry;
import org.springframework.context.annotation.AnnotationBeanNameGenerator;
import java.util.UUID;
// other import statements omitted

@Configuration
@ComponentScan(nameGenerator = SimpleBeanNameGenerator.class)
class BeanNamingCfg {
}

class SimpleBeanNameGenerator extends AnnotationBeanNameGenerator {
    @Override
    protected String buildDefaultBeanName(BeanDefinition definition, BeanDefinitionRegistry
registry) {
        var beanName = definition.getBeanClassName().substring(definition.
getBeanClassName().lastIndexOf(".") + 1).toLowerCase(Locale.ROOT);
        var uid = UUID.randomUUID().toString().replace("-", "").substring(0,8);
        return beanName + "-" + uid;
    }
}

```

The `org.springframework.context.annotation.AnnotationBeanNameGenerator` class is the `BeanNameGenerator` implementation for bean classes annotated with the `@Component` annotation or with another annotation that is itself annotated with `@Component`. The `SimpleBeanNameGenerator` extends this class and overrides the `buildDefaultBeanName(..)` method to return a bean name composed from the lowercase simple class name concatenated with a unique identifier. When creating an application context and printing the bean names, the output looks pretty similar to that shown in Listing 3-40.

**Listing 3-40.** Console Log Showing All Bean Names in the Context

```

# infrastructure bean names omitted
DEBUG: BeanNameGeneratorDemo - beanNamingCfg
DEBUG: BeanNameGeneratorDemo - simplebean-07f01cdc

```



Notice that, even if the configuration class is annotated with `@Configuration`, which is annotated itself with `@Component`, the resulting bean name is not generated by the `SimpleBeanNameGenerator` bean. This is because this class is not discovered through component scanning, since this is the class that enables component scanning with the custom bean generator being processed by Spring before the `SimpleBeanNameGenerator` bean is enabled.

---

## Bean Naming Style for Beans Declared with @Bean

We mentioned previously that beans configured by methods annotated with @Bean are named as the methods that configure them. The easiest way to show this is to modify one of our previous examples and declare a SimpleBean in the BeanNamingCfg configuration class using the @Bean annotation. Listing 3-41 depicts the new configuration and the code to execute to list the bean names within the context.

**Listing 3-41.** Console Log Showing All Bean Names in the Context

```

package com.apress.prospring6.three.naming;

import org.springframework.context.annotation.Bean;
// other import statements omitted

public class BeanNamingDemo {

    private static Logger logger = LoggerFactory.getLogger(BeanNamingDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(BeanNamingCfg.class);
        Arrays.stream(ctx.getBeanDefinitionNames()).forEach(beanName -> logger.
            debug(beanName));
    }
}

@Configuration
@ComponentScan
class BeanNamingCfg {

    @Bean
    public SimpleBean anotherSimpleBean(){
        return new SimpleBean();
    }
}

@Component
class SimpleBean { }

```

Running the code in Listing 3-41 produces the output shown in Listing 3-42.

**Listing 3-42.** Console Log Showing All Bean Names in the Context

```

# infrastructure bean names omitted
DEBUG: BeanNamingDemo - beanNamingCfg
DEBUG: BeanNamingDemo - simpleBean
DEBUG: BeanNamingDemo - anotherSimpleBean

```

As you can see, an entry named anotherSimpleBean is listed, which means that a SimpleBean was created and named as the method that created it.

Default naming of beans is practical only when one bean of a certain type is needed in the context of an application, but when this is not the case, explicitly naming the beans is the only option.



In the code in Listing 3-41, the two `SimpleBean` beans were configured through different methods, and thus the names were generated using different approaches. This means that retrieving a bean of type `SimpleBean` by calling `ctx.getBean(SimpleBean.class)` no longer works as intended, because that method expects one bean of type `SimpleBean` to be found. Calling that method will result in the following exception being thrown:

```
Exception in thread "main" org.springframework.beans.factory.
NoUniqueBeanDefinitionException:
No qualifying bean of type 'com.apress.prospring6.three.naming.SimpleBean' available:
    expected single matching bean but found 2: simpleBean, anotherSimpleBean
```

The exception message is pretty clear about what the issue is though.

If you need all the beans of a certain type from the application, there is a method for that, shown in Listing 3-43.

**Listing 3-43.** Code to List All `SimpleBean` Bean Names in the Context

```
var beans = ctx.getBeansOfType(SimpleBean.class);
beans.entrySet().forEach(b -> System.out.println(b.getKey()));
```

`ctx.getBeansOfType(String.class)` is used to obtain a map with all beans of type `SimpleBean` and their IDs that exist within `ApplicationContext`. The keys of the map are the bean IDs that are printed using the lambda expression in the previous code. With the configuration used so far in the section, this is the output:

```
simpleBean
anotherSimpleBean
```

## Explicit Bean Naming

Configuring a bean explicitly is very easy to do. When the bean is declared with `@Component`, or any other stereotype annotation (`@Service`, `@Repository`, etc.), there is a default attribute named `value` that can be initialized with a value to be used as a name for the bean. Listing 3-44 shows a `SimpleBean` bean being configured with name `simpleBeanOne`.

**Listing 3-44.** Bean with Custom Name, Declared with `@Component`

```
@Component(value = "simpleBeanOne")
class SimpleBean { }
```

When an annotation attribute is declared to be default, this means when using the annotation, the name of the attribute can be skipped, so `@Component(value = "simpleBeanOne")` is equivalent to `@Component("simpleBeanOne")`.

The `@Bean` annotation has a default attribute, named `value` as well, used for a similar purpose. It can be initialized with a value to be used as a name for the bean, but when an array of values is used, the first one in the array becomes the name and the rest become aliases. The code in Listing 3-45 shows how to configure beans with aliases using `@Bean`, but also how to print the names and aliases for a bean.

**Listing 3-45.** Bean with Custom Name, Declared with @Bean

```

package com.apress.prospring6.three.explicit;
// import statements omitted

public class ExplicitBeanNamingDemo {
    private static Logger logger = LoggerFactory.getLogger(ExplicitBeanNamingDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(BeanNamingCfg.class);

        var simpleBeans = ctx.getBeansOfType(SimpleBean.class);
        simpleBeans.forEach((k,v) -> {
            var aliases = ctx.getAliases(k);
            if(aliases.length > 0) {
                logger.debug("Aliases for {} ", k);
                Arrays.stream(aliases).forEach(a -> logger.debug("\t {}", a));
            }
        });
    }
}

@Configuration
@ComponentScan
class BeanNamingCfg {

    //@Bean(name="simpleBeanTwo")
    //@Bean(value= "simpleBeanTwo")
    @Bean("simpleBeanTwo")
    public SimpleBean simpleBean2(){
        return new SimpleBean();
    }

    //@Bean(name= {"simpleBeanThree", "three", "numero_tres"})
    //@Bean(value= {"simpleBeanThree", "three", "numero_tres"})
    @Bean({"simpleBeanThree", "three", "numero_tres"})
    public SimpleBean simpleBean3(){
        return new SimpleBean();
    }
}

```

In the code snippet in Listing 3-45, all the possibilities to name a bean and specify aliases are covered; the annotations in the comments are equivalent to the annotation that is not commented. `simpleBeanTwo` doesn't have any aliases. `simpleBeanThree` has two of them. When the code snippet is run, the output in Listing 3-46 is produced.

**Listing 3-46.** Output Showing Bean Aliases

```

DEBUG: ExplicitBeanNamingDemo - simpleBeanTwo
DEBUG: ExplicitBeanNamingDemo - simpleBeanThree
DEBUG: ExplicitBeanNamingDemo - Aliases for simpleBeanThree
DEBUG: ExplicitBeanNamingDemo -     three
DEBUG: ExplicitBeanNamingDemo -     numero_tres

```

## The @AliasFor Annotation

When it comes to aliases, in Spring 4.2 the @AliasFor annotation was introduced. This annotation is used to declare aliases for annotation attributes, and most Spring annotations make use of it. For example, the @Bean annotation has two attributes, name and value, which are declared as aliases for each other. The code snippet in Listing 3-47 is a snapshot of the @Bean annotation code and is taken from the official Spring GitHub repository. The code and documentation that are not relevant at the moment are omitted.

**Listing 3-47.** Code Snippet from the @Bean Annotation

```

package org.springframework.context.annotation;
import java.lang.annotation.Documented;
import java.lang.annotation.ElementType;
import java.lang.annotation.Retention;
import java.lang.annotation.RetentionPolicy;
import java.lang.annotation.Target;
import org.springframework.core.annotation.AliasFor;
// other import statements omitted

@Target({ElementType.METHOD, ElementType.ANNOTATION_TYPE})
@Retention(RetentionPolicy.RUNTIME)
@Documented
public @interface Bean {
    @AliasFor("name")
    String value() default {};

    @AliasFor("value")
    String name() default {};

    // code omitted
}

```

This configuration using @AliasFor is what makes for @Bean(name= {"simpleBeanThree", "three", "numero\_tres"}) to be equivalent to @Bean(value= {"simpleBeanThree", "three", "numero\_tres"}).

Something more interesting can be done with the @AliasFor annotation: aliases for meta-annotation attributes can be declared. In Listing 3-48 you can see an annotation named @Award that declares an attribute named prize and an annotation named @Trophy that is meta-annotated with @Award. This annotation declares an attribute that is an alias for the prize attribute in the @Award interface.

**Listing 3-48.** Usage of @AliasFor

```

package com.apress.prospring6.three.alias;

// Award.java
import java.lang.annotation.*;

@Target({ElementType.TYPE})
@Retention(RetentionPolicy.RUNTIME)
@Documented
public @interface Award {

    String[] prize() default {};
}

```

```
// Trophy.java
import org.springframework.core.annotation.AliasFor;

@Award
public @interface Trophy {
    @AliasFor(annotation = Award.class, attribute = "value")
    String[] name() default {};
}
```

With these two annotations, a `NonSingletonDemo` class can be declared and annotated with `@Award` or `@Trophy`, as shown in Listing 3-49.

**Listing 3-49.** `NonSingletonDemo` Class Annotated with Alias Annotations

```
package com.apress.prospring6.three.alias;

import org.springframework.stereotype.Component;

@Component("johnMayer")
//@Award(prize = {"grammy", "platinum disk"})
@Trophy(name={"grammy", "platinum disk"})
public class Singer {
    private String lyric = "I used to crave the sight of you";

    public void sing() {
        System.out.println(lyric);
    }
}
```



Creating aliases for attributes of annotations using yet another annotation `@AliasFor` does have limitations. `@AliasFor` cannot be used on any stereotype annotations (`@Component` and its specializations). The reason is that the special handling of these value attributes was in place years before `@AliasFor` was invented. Consequently, because of backward-compatibility issues, it is simply not possible to use `@AliasFor` with such value attributes. When writing code to do just so (aliasing value attributes in stereotype annotations), no compile errors will be shown to you, and the code might even run, but any argument provided for the alias will be ignored. The same goes for the `@Qualifier` annotation.

---

## Understanding Bean Instantiation Mode

Earlier in this chapter the term **singleton** was used to describe beans that are created only once within the context, and **non-singleton** was used to describe beans that are created every time they are requested from the context. By default, all beans in Spring are singletons. This means Spring maintains a single instance of the bean, all dependent objects use the same instance, and all calls to `ApplicationContext.getBean(..)` return the same instance. We demonstrated this in the previous section, where we were able to use identity comparison (`==`) rather than the `equals()` comparison to check whether the beans were the same.

The term *singleton* is used interchangeably in Java to refer to two distinct concepts: an object that has a single instance within the application, and the Singleton design pattern. We refer to the first concept as a singleton and to the Singleton pattern as Singleton. The Singleton design pattern was popularized in the seminal *Design Patterns: Elements of Reusable Object-Oriented Software*, by Erich Gamma et al. (Addison-Wesley, 1994). The problem arises when people confuse the need for singleton instances with the need to apply the *Singleton* pattern. The code in Listing 3-50 shows a typical implementation of the Singleton pattern in Java.

**Listing 3-50.** Singleton Pattern in Java

```
package com.apress.prospring6.three;

public class Singleton {
    private static final Singleton instance;

    static {
        instance = new Singleton();
    }

    public static Singleton getInstance() {
        return instance;
    }
}
```

This pattern achieves its goal of allowing you to maintain and access a single instance of a class throughout your application, but it does so at the expense of increased coupling. Your application code must always have explicit knowledge of the `Singleton` class in order to obtain the instance—completely removing the ability to code to interfaces.

In reality, the *Singleton* pattern is actually two patterns in one. The first, and desired, pattern involves maintenance of a single instance of an object. The second, and less desirable, is a pattern for object lookup that completely removes the possibility of using interfaces. Using the Singleton pattern also makes it difficult to swap out implementations arbitrarily because most objects that require the Singleton instance access the Singleton object directly. This can cause all kinds of headaches when you are trying to unit test your application, because you are unable to replace the Singleton with a mock for testing purposes.

Fortunately, with Spring you can take advantage of the singleton instantiation model without having to work around the Singleton design pattern. All beans in Spring are, by default, created as singleton instances, and Spring uses the same instances to fulfill all requests for that bean. Of course, Spring is not just limited to the use of the Singleton instance; it can still create a new instance of the bean to satisfy every dependency and every call to `getBean()`. It does all of this without any impact on your application code, and for this reason, we like to refer to Spring as being **instantiation mode agnostic**. This is a powerful concept. If you start off with an object that is a singleton but then discover it is not really suited to multithread access, you can change it to a non-singleton (*prototype*) without affecting any of your application code.



Although changing the instantiation mode of your bean won't affect your application code, it does cause some problems if you rely on Spring's life-cycle interfaces. We cover this in more detail in **Chapter 4**.

---

Changing the instantiation mode from singleton to non-singleton is simple. The configuration in Listing 3-51 depicts using `@Scope` with the `scopeName` attribute set to configure a bean as non-singleton.

**Listing 3-51.** Configure a Bean As Non-Singleton

```

package com.apress.prospring6.three.scope;

import org.springframework.context.annotation.Scope;
// other import statements omitted

@Component("nonSingleton")
@Scope(scopeName = "prototype")
public class Singer {

    private String name = "unknown";

    public Singer(@Value("John Mayer") String name) {
        this.name = name;
    }
}

```

As you can see, the only difference between this bean declaration and any of the declarations you have seen so far is that we add the scope attribute and set the value to prototype. Spring defaults the scope to the value singleton. The prototype scope instructs Spring to instantiate a new instance of the bean every time a bean instance is requested by the application. The code snippet in Listing 3-52 shows the effect this setting has on your application.

**Listing 3-52.** Accessing Non-Singleton Beans from the Context

```

package com.apress.prospring6.three.scope;
// other import statements omitted

public class NonSingletonDemo {

    private static Logger logger = LoggerFactory.getLogger(BeanNameGerneratorDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(Singer.class);
        ctx.refresh();
        var singer1 = ctx.getBean("nonSingleton", Singer.class);
        var singer2 = ctx.getBean("nonSingleton", Singer.class);

        logger.info("Identity Equal?: " + (singer1 == singer2));
        logger.info("Value Equal:?" + singer1.equals(singer2));

        logger.info(singer1.toString());
        logger.info(singer2.toString());
    }
}

```

Running this example gives you the output in Listing 3-53, which proves without a doubt that `ctx.getBean("nonSingleton", Singer.class)` returns two different instances.

**Listing 3-53.** Output of Code in Listing 3-52

```
INFO : NonSingletonDemo - Identity Equal?: false
INFO : NonSingletonDemo - Value Equal:? false
INFO : NonSingletonDemo - com.apress.prospring6.three.scope.Singer@6631f5ca[name=John Mayer]
INFO : NonSingletonDemo - com.apress.prospring6.three.scope.Singer@5ace1ed4[name=John Mayer]
```

You can see from this that although the values of the two String objects are clearly equal, the identities are not, even though both instances were retrieved using the same bean name.

## Choosing an Instantiation Mode

In most scenarios, it is quite easy to see which instantiation mode is suitable. Typically, you will find that singleton is the default mode for your beans. In general, singletons should be used in the following scenarios:

- *Shared object with no state:* You have an object that maintains no state and has many dependent objects. Because you do not need synchronization if there is no state, you do not need to create a new instance of the bean each time a dependent object needs to use it for some processing.
- *Shared object with read-only state:* This is similar to the previous point, but you have some read-only state. In this case, you still do not need synchronization, so creating an instance to satisfy each request for the bean is just adding overhead.
- *Shared object with shared state:* If you have a bean that has state that must be shared, singleton is the ideal choice. In this case, ensure that your synchronization for state writes is as granular as possible.
- *High-throughput objects with writable state:* If you have a bean that is used a great deal in your application, you may find that keeping a singleton and synchronizing all write access to the bean state allows for better performance than constantly creating hundreds of instances of the bean. When using this approach, try to keep the synchronization as granular as possible without sacrificing consistency. You will find that this approach is particularly useful when your application creates a large number of instances over a long period of time, when your shared object has only a small amount of writable state, or when the instantiation of a new instance is expensive.

You should consider using non-singletons in the following scenarios:

- *Objects with writable state:* If you have a bean that has a lot of writable state, you may find that the cost of synchronization is greater than the cost of creating a new instance to handle each request from a dependent object.
- *Objects with private state:* Some dependent objects need a bean that has private state so that they can conduct their processing separately from other objects that depend on that bean. In this case, singleton is clearly not suitable, and you should use non-singleton.

The main positive you gain from Spring's instantiation management is that your applications can immediately benefit from the lower memory usage associated with singletons, with very little effort on your part. Then, if you find that singleton mode does not meet the needs of your application, it is a trivial task to modify your configuration to use non-singleton mode.

## Additional Bean Scopes

In addition to the singleton and prototype scopes, other scopes exist when defining a Spring bean for more specific purposes. You can also implement your own custom scope and register it in Spring's `ApplicationContext`. The following bean scopes are supported as of version 6:

- **singleton:** The default singleton scope. Only one object will be created per Spring IoC container.
- **prototype:** A new instance will be created by Spring when requested by the application.
- **request:** For web application use. When using Spring MVC for web applications, beans with `request` scope will be instantiated for every HTTP request and then destroyed when the request is completed.
- **session:** For web application use. When using Spring MVC for web applications, beans with `session` scope will be instantiated for every HTTP session and then destroyed when the session is over.
- **application:** Scopes a single bean definition to the life cycle of a `ServletContext`. The application scope is only valid in a Spring web application.
- **thread:** A new bean instance will be created by Spring when requested by a new thread, while for the same thread, the same bean instance will be returned. Note that this scope is not registered by default.
- **custom:** Custom bean scope that can be created by implementing the interface `org.springframework.beans.factory.config.Scope` and registering the custom scope in Spring's configuration (for XML, use the class `org.springframework.beans.factory.config.CustomScopeConfigurer`).
- **websocket:** Scopes a single bean definition to the life cycle of a `WebSocket`. The `websocket` scope is only valid in a Spring web application.

## Resolving Dependencies

Spring is able to resolve dependencies by simply looking at your configuration files or annotations in your classes. Unfortunately, Spring is not aware of any dependencies that exist between beans in your code that are not specified in the configuration. For instance, take one bean, named `johnMayer`, of type `Singer`, which obtains an instance of another bean, called `gopher`, of type `Guitar` using `ctx.getBean()` and uses it when the `johnMayer.sing()` method is called. In this method, you get an instance of type `Guitar` by calling `ctx.getBean("gopher")`, without asking Spring to inject the dependency for you. In this case, Spring is unaware that `johnMayer` depends on `gopher`, and, as a result, it may instantiate the `johnMayer` bean before the `gopher` bean.

You can provide Spring with additional information about your bean dependencies by using the `@DependsOn` annotation. The configuration snippet in Listing 3-54 shows how the scenario for `johnMayer` and `gopher` beans would be configured.



**Listing 3-54.** Configuring Dependencies with @DependsOn

```

package com.apress.prospring6.three.dependson;

import org.springframework.beans.BeansException;
import org.springframework.context.ApplicationContext;
import org.springframework.context.ApplicationContextAware;
import org.springframework.context.annotation.AnnotationConfigApplicationContext;
import org.springframework.context.annotation.DependsOn;

@Component("gopher")
class Guitar {
    public void sing(){
        System.out.println("Cm Eb Fm Ab Bb");
    }
}

@DependsOn("gopher")
@Component("johnMayer")
class Singer implements ApplicationContextAware {
    private ApplicationContext ctx;

    @Override
    public void setApplicationContext(ApplicationContext applicationContext) throws
    BeansException {
        this.ctx = applicationContext;
    }

    private Guitar guitar;

    public Singer(){
    }

    public void sing() {
        guitar = ctx.getBean("gopher", Guitar.class);
        guitar.sing();
    }
}

```

In this configuration, we are declaring that bean `johnMayer` depends on bean `gopher`. Spring should take this into consideration when instantiating the beans and ensure that `gopher` is created before `johnMayer`. For the `johnMayer` bean, to retrieve the dependency on its own, it needs to access `ApplicationContext`. Thus, we also have to tell Spring to inject this reference, so when the `johnMayer.sing()` method will be called, it can be used to procure the `gopher` bean. This is done by making the `Singer` class implement the `ApplicationContextAware` interface. This is a Spring-specific interface that forces an implementation of a setter for an `ApplicationContext` object. It is automatically detected by the Spring IoC container, and the `ApplicationContext` that the bean is created in is injected into it. This is done after the constructor of the bean is called, so obviously using `ApplicationContext` in the constructor will lead to a `NullPointerException`.

The class to test the configuration is simple, and involves just creating a context, retrieving the `johnMayer` bean, and calling the `sing()` method on it. Since it introduces nothing that was not shown before in the book, it won't be listed again. The class is named `DependsOnDemo` and is part of the `com.apress.prospring6.three.dependson` package. When run, the output will be *"Cm Eb Fm Ab Bb."*

When developing your applications, avoid designing them to use this feature; instead, define your dependencies by means of setter and constructor injection contracts. However, if you are integrating Spring with legacy code, you may find that the dependencies defined in the code require you to provide extra information to the Spring Framework.

## Autowiring Your Bean

*Autowiring* is the process of implicitly injecting beans into beans depending on them. Spring supports five modes for autowiring:

- `byName`: When using `byName` autowiring, Spring attempts to wire each property to a bean of the same name. So, if the target bean has a property named `foo` and a `foo` bean is defined in `ApplicationContext`, the `foo` bean is assigned to the `foo` property of the target.
- `byType`: When using `byType` autowiring, Spring attempts to wire each of the properties on the target bean by automatically using a bean of the same type in `ApplicationContext`.
- `constructor`: This functions just like `byType` wiring, except that it uses constructors rather than setters to perform the injection. Spring attempts to match the greatest numbers of arguments it can in the constructor. So, if your bean has two constructors, one that accepts a `String` and one that accepts `String` and an `Integer`, and you have both a `String` and an `Integer` bean in your `ApplicationContext`, Spring uses the two-argument constructor.
- `default`: Spring will choose between the `constructor` and `byType` modes automatically. If your bean has a default (no-arguments) constructor, Spring uses `byType`; otherwise, it uses `constructor`.
- `no`: No autowiring; this is the default.

Autowiring mode can be configured explicitly through metadata when using XML configuration, by specifying the value for the `autowire` attribute on the `<bean/>` element. Since this book does not cover XML, let's focus on annotation configuration.

## Constructor Autowiring

When a dependency is provided using constructor injection, autowiring obviously is done through the constructor. If the class has more than one constructor, the constructor to be used is chosen based on a few conditions.

If none of the constructors is annotated with `@Autowired`, the most suitable will be used. If more than one is suitable, Spring just uses the no-argument constructor if there is one. If there is none, a `BeanInstantiationException` is thrown. Take a look at the sample in Listing 3-55.

**Listing 3-55.** Example Showing Autowiring by Type

```

package com.apress.prospring6.three.autowiring;
import org.springframework.context.annotation.Lazy;
// other import statements omitted

public class AutowiringDemo {
    private static Logger logger = LoggerFactory.getLogger(AutowiringDemo.class);

    public static void main(String... args) {

        var ctx = new AnnotationConfigApplicationContext(AutowiringCfg.class);

        var target = ctx.getBean(Target.class);
        logger.info("Created target? {}" , target != null);
        logger.info("Injected bar? {}" , target.bar != null);
        logger.info("Injected fooOne? {}" , target.fooOne != null ? target.fooOne.id : "");
        logger.info("Injected fooTwo? {}" , target.fooTwo != null ? target.fooTwo.id : "");
    }
}

@Configuration
@ComponentScan
class AutowiringCfg {}

@Component
@Lazy
class Target {

    private static Logger logger = LoggerFactory.getLogger(Target.class);
    Foo fooOne;
    Foo fooTwo;
    Bar bar;

    public Target() {
        logger.info(" --> Target() called");
    }

    public Target(Foo foo) {
        this.fooOne = foo;
        logger.info(" --> Target(Foo) called");
    }

    public Target(Foo foo, Bar bar) {
        this.fooOne = foo;
        this.bar = bar;
        logger.info(" --> Target(Foo, Bar) called");
    }
}

```

```

@Component
class Foo {
    String id = UUID.randomUUID().toString().replace("-", "").substring(0,8);
}

@Component
class Bar {}

```

In this code, you can see that the Target class has three constructors:

- A no-argument constructor
- A constructor that accepts a Foo instance
- A constructor that accepts a Foo instance and a Bar instance

Each of these constructors writes a message to console output when it is called. The `main()` method simply retrieves the Target bean declared in `ApplicationContext`, triggering the autowiring process. A few logging statements print details about the Target bean.

In addition to these constructors, the Target bean has three properties:

- Two of type Foo
- One of type Bar

Foo and Bar are simple classes. Every Foo object receives a unique identifier(id) when instantiated. The `@Lazy` annotation is used to inform Spring to instantiate the bean only when it is first requested, rather than at startup, so that we can output the result in the correct place in the testing program.

When running this code, the output in Listing 3-56 is printed, proving without a doubt that when Spring is not told what to do, it just goes straight for the no-argument constructor, which means none of the properties will be injected.

**Listing 3-56.** Example Showing Autowiring by Constructor when No Constructor Is Annotated with `@Autowired`

```

INFO : Target - --> Target() called
INFO : AutowiringDemo - Created target? true
INFO : AutowiringDemo - Injected bar? false
INFO : AutowiringDemo - Injected fooOne?
INFO : AutowiringDemo - Injected fooTwo?

```

To change the behavior, just annotate any of the constructors with `@Autowired`. Since there are Foo and Bar beans declared in the application, any of the other two constructors can be used to initialize Target.

If the no-argument constructor is deleted, the following exception is thrown.

```

Caused by: org.springframework.beans.BeanInstantiationException:
Failed to instantiate [com.apress.prospring6.three.autowiring.Target]:
No default constructor found;
nested exception is java.lang.NoSuchMethodException:
com.apress.prospring6.three.autowiring.Target.<init>()

```

The compiler allows you to annotate both of the remaining constructors with `@Autowired`, because the Java compiler does not really care about what Spring allows or not, but running the code will confuse it and it won't be able to create the `Target` bean. It will throw a `BeanCreationException` and the following snippet shows the partial stacktrace, when the `Target` class has two annotated constructors:

```
Exception in thread "main" org.springframework.beans.factory.BeanCreationException: Error
creating bean with name 'target':
Invalid autowire-marked constructor: public com.apress.prospring6.three.autowiring.
Target(com.apress.prospring6.three.autowiring.
    Foo,com.apress.prospring6.three.autowiring.Bar).
    Found constructor with 'required' Autowired annotation already: public com.apress.
    prospring6.three.autowiring.Target(com.apress.prospring6.three.autowiring.Foo)
...
    at com.apress.prospring6.three.autowiring.AutowiringDemo.main(AutowiringDemo.java:51)
```

## byType Autowiring

When there are no constructors declared, but there are setters annotated with `@Autowired`, Spring will use them and will identify the beans to be injected based on their type. Listing 3-57 shows a class named `AnotherTarget` that is pretty similar to the `Target` class, but the properties are injected using setters.

**Listing 3-57.** Example Showing Autowiring by Type Using Setters

```
package com.apress.prospring6.three.autowiring;
// import statements omitted

public class AutowiringDemo {
    private static Logger logger = LoggerFactory.getLogger(AutowiringDemo.class);

    public static void main(String... args) {

        var ctx = new AnnotationConfigApplicationContext(AutowiringCfg.class);
        var anotherTarget = ctx.getBean(AnotherTarget.class);
        logger.info("anotherTarget: Created anotherTarget? {}", anotherTarget != null);
        logger.info("anotherTarget: Injected bar? {}", anotherTarget.bar != null);
        logger.info("anotherTarget: Injected fooOne? {}", anotherTarget.fooOne != null ?
        anotherTarget.fooOne.id : "");
        logger.info("anotherTarget: Injected fooTwo? {}", anotherTarget.fooTwo != null ?
        anotherTarget.fooTwo.id : "");
    }
}

@Component
@Lazy
class AnotherTarget {

    private static Logger logger = LoggerFactory.getLogger(AnotherTarget.class);
    Foo fooOne;
    Foo fooTwo;
    Bar bar;
```

```

@Autowired
public void setFooOne(Foo fooOne) {
    logger.info(" --> AnotherTarget#setFooOne(Foo) called");
    this.fooOne = fooOne;
}

@Autowired
public void setFooTwo(Foo fooTwo) {
    logger.info(" --> AnotherTarget#setFooTwo(Foo) called");
    this.fooTwo = fooTwo;
}

@Autowired
public void setBar(Bar bar) {
    logger.info(" --> AnotherTarget#setBar(Bar) called");
    this.bar = bar;
}
}

```

When running this code, the output in Listing 3-58 is printed.

**Listing 3-58.** Console Log Example Showing Autowiring by Type when Setters Are Annotated with `@Autowired`

```

INFO : AnotherTarget - --> AnotherTarget#setFooOne(Foo) called
INFO : AnotherTarget - --> AnotherTarget#setFooTwo(Foo) called
INFO : AnotherTarget - --> AnotherTarget#setBar(Bar) called
INFO : AutowiringDemo - anotherTarget: Created anotherTarget? true
INFO : AutowiringDemo - anotherTarget: Injected bar? true
INFO : AutowiringDemo - anotherTarget: Injected fooOne? a4eb2b71
INFO : AutowiringDemo - anotherTarget: Injected fooTwo? a4eb2b71

```

Spring injects dependencies by type when fields are directly annotated with `@Autowired` too, and since field injection is discouraged, the code won't be depicted in the book, but check out the `com.apress.prospring6.three.autowiring.FieldTarget` class in the project.

As you've seen so far, there is a single `Foo` bean declared and that bean is injected in both `fooOne` and `fooTwo` properties. If we declare another `Foo` bean, this will break the `Target`, the `AnotherTarget` and the `FieldTarget` beans definitions and Spring won't be able to create them anymore, since dependencies are autowired by type and there are two dependencies of type `Foo` being required and Spring cannot figure out which of the two `Foo` beans are required where. The code in Listing 3-59 shows the `AutowiringCfg` class being updated to declare a bean of type `Foo`.

**Listing 3-59.** `AutowiringCfg` Class Declaring a Bean of Type `Foo`

```

@Configuration
@ComponentScan
class AutowiringCfg {

    @Bean
    Foo anotherFoo() {
        return new Foo();
    }
}

```

If you run the `AutowiringDemo` class, the following `org.springframework.beans.factory.NoUniqueBeanDefinitionException` exception will be thrown:

```
Caused by: org.springframework.beans.factory.NoUniqueBeanDefinitionException:
    No qualifying bean of type 'com.apress.prospring6.three.autowiring.Foo'
    available: expected single matching bean but found 2: foo,anotherFoo
```

To get Spring out of this pickle, the solution is to specify which bean we want injected where, which means switching from autowiring by type to autowiring by name.

## byName Autowiring

Listing 3-60 shows the `Target` class with the constructors modified to receive specific beans as arguments. The `@Qualifier` annotation, previously used to inject collections, is what saves the day here as well.

**Listing 3-60.** Target Bean Class Configured Using Constructor Autowiring by Name

```
package com.apress.prospring6.three.autowiring;
import org.springframework.beans.factory.annotation.Qualifier;
// other import statements omitted

@Component
@Lazy
class Target {

    private static Logger logger = LoggerFactory.getLogger(Target.class);
    Foo fooOne;
    Foo fooTwo;
    Bar bar;

    @Autowired
    public Target(@Qualifier("foo") Foo foo) {
        this.fooOne = foo;
        logger.info(" --> Target(Foo) called");
    }

    public Target(@Qualifier("foo") Foo foo, Bar bar) {
        this.fooOne = foo;
        this.bar = bar;
        logger.info(" --> Target(Foo, Bar) called");
    }
}
```

Notice that the `@Qualifier` is placed on the argument, not on the constructor. If you use `@Inject` instead of `@Autowired` to inject dependencies, use `@Named` instead of `@Qualifier`. To fix the `AnotherTarget` class, the `@Qualifier` is placed on the setter arguments as shown in Listing 3-61.

**Listing 3-61.** AnotherTarget Bean Class Configured Using Setter Autowiring by Name

```

package com.apress.prospring6.three.autowiring;
import org.springframework.beans.factory.annotation.Qualifier;
// other import statements omitted

@Component
@Lazy
class AnotherTarget {

    private static Logger logger = LoggerFactory.getLogger(AnotherTarget.class);
    Foo fooOne;
    Foo fooTwo;
    Bar bar;

    @Autowired
    public void setFooOne(@Qualifier("foo")Foo fooOne) {
        logger.info(" --> AnotherTarget#setFooOne(Foo) called");
        this.fooOne = fooOne;
    }

    @Autowired
    public void setFooTwo(@Qualifier("anotherFoo")Foo fooTwo) {
        logger.info(" --> AnotherTarget#setFooTwo(Foo) called");
        this.fooTwo = fooTwo;
    }

    @Autowired
    public void setBar(Bar bar) {
        logger.info(" --> AnotherTarget#setBar(Bar) called");
        this.bar = bar;
    }
}

```

Running the `AutowiringDemo`, accessing the `AnotherTarget`, and inspecting its dependencies prints the details in Listing 3-62, which makes it clear that there are two different `Foo` beans being injected.

**Listing 3-62.** Console Output Example Showing Autowiring by Name when Setters Are Annotated with `@Autowired`

```

INFO : AnotherTarget - --> AnotherTarget#setFooOne(Foo) called
INFO : AnotherTarget - --> AnotherTarget#setFooTwo(Foo) called
INFO : AnotherTarget - --> AnotherTarget#setBar(Bar) called
INFO : AutowiringDemo - anotherTarget: Created anotherTarget? true
INFO : AutowiringDemo - anotherTarget: Injected bar? true
INFO : AutowiringDemo - anotherTarget: Injected fooOne? baa24632
INFO : AutowiringDemo - anotherTarget: Injected fooTwo? 0d74b352

```

As for the `FieldTarget`, things are even simpler; the `@Qualifier` annotation gets placed directly on the field being autowired, as shown in Listing 3-63.



**Listing 3-63.** FieldTarget Bean Class Configured Using Field Autowiring by Name

```

package com.apress.prospring6.three.autowiring;
import org.springframework.beans.factory.annotation.Qualifier;
// other import statements omitted

@Component
@Lazy
class FieldTarget {

    private static Logger logger = LoggerFactory.getLogger(FieldTarget.class);

    @Autowired @Qualifier("foo") Foo fooOne;
    @Autowired @Qualifier("anotherFoo") Foo fooTwo;
    @Autowired Bar bar;

}

```

## Yet Another Pickle

When autowiring by type, things get complicated when bean types are related, and exceptions are thrown when you have more classes that implement the same interface and the property requiring to be autowired specifies the interface as the type, because Spring does not know which bean to inject. To create such a scenario, we'll transform `Foo` into an interface and declare two bean types implementing it, each with its bean declaration. The configuration is the default one with bean names generated by Spring, as shown in Listing 3-64.

**Listing 3-64.** Foo Implementation Classes and Configuration

```

package com.apress.prospring6.three.pickle;
// other import statements omitted

interface Foo {
// empty interface, used as a marker interface
}

class FooImplOne implements Foo {
    String id = "one:" + UUID.randomUUID().toString().replace("-", "").substring(0,8);

    @Override
    public String toString() {
        return new ToStringBuilder(this).append("id", id).toString();
    }
}

class FooImplTwo implements Foo {
    String id = "two:" + UUID.randomUUID().toString().replace("-", "").substring(0,8);

    @Override
    public String toString() {

```

```

        return new ToStringBuilder(this).append("id", id).toString();
    }
}

class Bar { }

@Configuration
@ComponentScan
class AutowiringCfg {

    @Bean
    public Foo fooImplOne() { return new FooImplOne(); }

    @Bean
    public Foo fooImplTwo() { return new FooImplTwo(); }

    @Bean
    public Bar bar() { return new Bar(); }

    @Bean
    public TrickyTarget trickyTarget() { return new TrickyTarget(); }
}

class TrickyTarget {
    Foo fooOne;
    Foo fooTwo;
    Bar bar;

    // constructors and setters omitted
}

```

The `TrickyTarget` code is pretty similar to the `Target` class, and when dependencies are injected by type, with the configuration in Listing 3-64, Spring is unable to create this bean and a `NoUniqueBeanDefinitionException` is thrown:

```

Caused by: org.springframework.beans.factory.NoUniqueBeanDefinitionException:
No qualifying bean of type 'com.apress.prospring6.three.pickle.Foo'
available: expected single matching bean but found 2: fooImplOne,fooImplTwo

```

The console output is way longer, but the first lines in the previous output reveal the problem in quite a readable manner. When Spring does not know what bean to autowire, it throws an `NoUniqueBeanDefinitionException` with an explicit message. It tells you what beans were found but that it cannot choose which to use where. There are two ways to fix this problem.

The first way is to use the `@Primary` annotation in the bean definition that you want Spring to consider first for autowiring. This resolves the problem in a pretty weird way, because in both `fooOne` and `fooTwo`, the bean annotated with `@Primary` is injected. The configuration and resulting output is shown in Listing 3-65.

**Listing 3-65.** Configuration Using `@Primary`

```

package com.apress.prospring6.three.pickle;
// import statements omitted
import org.springframework.context.annotation.Primary;

@Configuration
@ComponentScan
class AutowiringCfg {

    @Bean @Primary
    public Foo fooImplOne() { return new FooImplOne(); }

    @Bean
    public Foo fooImplTwo() { return new FooImplTwo(); }

    @Bean
    public Bar bar() { return new Bar(); }

    @Bean
    public TrickyTarget trickyTarget() { return new TrickyTarget(); }
}

// Log for configuration using @Primary
INFO : TrickyTarget - --> Property fooOne set
INFO : TrickyTarget - --> Property fooTwo set
INFO : TrickyTarget - --> Property bar set
INFO : PickleAutowiringDemo - target: Created target? true
INFO : PickleAutowiringDemo - target: Injected bar? true
INFO : PickleAutowiringDemo - target: Injected fooOne? com.apress.prospring6.three.pickle.Fo
oImplOne@2eea88a1[id=one:7ab78d36]
INFO : PickleAutowiringDemo - target: Injected fooTwo? com.apress.prospring6.three.pickle.Fo
oImplOne@2eea88a1[id=one:7ab78d36]

```

So, it's all back to normal, but still, using `@Primary` is a solution only when there are just two bean-related types. If there are more, using it will not get rid of the `NoUniqueBeanDefinitionException`.

What will do the job is the second way, which will give you full control over which bean gets injected where, and this is to name your beans and configure them where to be injected using `@Qualifier` as shown in the previous section. Listing 3-66 shows the `TrickyTarget` class with setters configured with `@Qualifier` and the resulting output when the class `PickleAutowiringDemo` is run.

**Listing 3-66.** Configuration Using `@Qualifier` and Resulting Output

```

package com.apress.prospring6.three.pickle;
// import statements omitted
import org.springframework.beans.factory.annotation.Qualifier;

class TrickyTarget {
    private static Logger logger = LoggerFactory.getLogger(TrickyTarget.class);
    Foo fooOne;
    Foo fooTwo;
    Bar bar;
}

```

```

public TrickyTarget() {
    logger.info(" --> TrickyTarget() called");
}

@Autowired
@Qualifier("fooImplOne")
public void setFooOne(Foo fooOne) {
    this.fooOne = fooOne;
    logger.info(" --> Property fooOne set");
}

@Autowired
@Qualifier("fooImplTwo")
public void setFooTwo(Foo foo) {
    this.fooTwo = foo;
    logger.info(" --> Property fooTwo set");
}

@Autowired
public void setBar(Bar bar) {
    this.bar = bar;
    logger.info(" --> Property bar set");
}
}

// Log for configuration using @Qualifier
INFO : TrickyTarget - --> TrickyTarget() called
INFO : TrickyTarget - --> Property fooOne set
INFO : TrickyTarget - --> Property fooTwo set
INFO : TrickyTarget - --> Property bar set
INFO : PickleAutowiringDemo - target: Created target? true
INFO : PickleAutowiringDemo - target: Injected bar? true
INFO : PickleAutowiringDemo - target: Injected fooOne? com.apress.prospring6.three.pickle.FooImplOne@7fd7a283[id=one:8efc8d31]
INFO : PickleAutowiringDemo - target: Injected fooTwo? com.apress.prospring6.three.pickle.FooImplTwo@22f59fa[id=two:a5d9ed75]

```

## When to Use Autowiring

When writing Spring applications, autowiring cannot be avoided; the whole idea behind Spring is that you can create your classes as you like and have Spring work for you. The question is not when you should use autowiring, but which type of autowiring is suitable for certain parts of your application. You may be tempted to use `byType` until you realize that you can have only one bean for each type in your `ApplicationContext`—a restriction that is problematic when you need to maintain beans with different configurations of the same type. The same argument applies to the use of constructor autowiring. In some cases, autowiring can save you time, but it does not really take that much extra effort to define your wiring explicitly, and you benefit from explicit semantics and full flexibility on property naming and on how many instances of the same type you manage.

## Summary

In this chapter, we covered a lot of ground with both Spring Core and IoC in general. We showed you examples of the types of IoC and presented the pros and cons of using each mechanism in your applications. We looked at which IoC mechanisms Spring provides and when (and when not) to use each within your applications. While exploring IoC, we introduced the Spring `BeanFactory`, which is the core component for Spring's IoC capabilities, and then `ApplicationContext`, which extends `BeanFactory` and provides additional functionalities.

For `ApplicationContext`, we focused on `AnnotationConfigApplicationContext`, which allows external configuration of Spring by using annotation. We also discussed another method to declare DI requirements for `ApplicationContext`, by using Java annotations.

This chapter also introduced you to the basics of Spring's IoC feature set including setter injection, constructor injection, Method Injection, autowiring, and bean inheritance. In the discussion of configuration, we demonstrated how you can configure your bean properties with a wide variety of values, including other beans.

This chapter only scratched the surface of Spring and Spring's IoC container. In the next chapter, you'll look at some IoC-related features specific to Spring, and you'll take a more detailed look at other functionality available in Spring Core.

## CHAPTER 4



# Advanced Spring Configuration and Spring Boot

In the previous chapter, we presented a detailed look at the concept of inversion of control (IoC) and how it fits into the Spring Framework. However, we have really only scratched the surface of what Spring Core can do. Spring provides a wide array of services that supplement and extend its basic IoC capabilities. In this chapter, you are going to explore these in detail. Specifically, you will be looking at the following:

- *Managing the bean life cycle*: So far, all the beans you have seen have been fairly simple and completely decoupled from the Spring container. In this chapter, we present some strategies you can employ to enable your beans to receive notifications from the Spring container at various points throughout their life cycles. You can do this either by implementing specific interfaces laid out by Spring, by specifying methods that Spring can call via reflection, or by using JavaBeans<sup>1</sup> life-cycle annotations.
- *Making your beans “Spring aware”*: In some cases, you want a bean to be able to interact with the `ApplicationContext` instance that configured it. For this reason, Spring offers two interfaces, `BeanNameAware` and `ApplicationContextAware` (introduced at the end of **Chapter 3**), that allow your bean to obtain its assigned name and reference its `ApplicationContext`, respectively. The section corresponding to this topic covers implementing these interfaces and gives some practical considerations for using them in your application.
- *Using FactoryBeans*: As its name implies, the `FactoryBean` interface is meant to be implemented by any bean that acts as a factory for other beans. The `FactoryBean` interface provides a mechanism by which you can easily integrate your own factories with the Spring `BeanFactory` interface.
- *Working with JavaBeans PropertyEditor implementations*: The `PropertyEditor` interface is a standard interface provided in the `java.beans` package. `PropertyEditors` are used to convert property values to and from `String` representations. Spring uses `PropertyEditors` extensively, mainly to read values specified in the `BeanFactory` configuration and convert them into the correct types.

---

<sup>1</sup><https://jcp.org/en/jsr/detail?id=250>

In this chapter, we discuss the set of `PropertyEditors` supplied with Spring and how you can use them within your application. We also take a look at implementing custom `PropertyEditors`.

- *Learning more about the Spring application context:* As you know, `ApplicationContext` is an extension of `BeanFactory` intended for use in full applications. The `ApplicationContext` interface provides a useful set of additional functionalities, including internationalized message support, resource loading, and event publishing. In this chapter, we present a detailed look at the features in addition to IoC that `ApplicationContext` offers. We also jump ahead of ourselves a little to show you how `ApplicationContext` simplifies the use of Spring when you are building web applications.
- *Testing Spring applications:* **Chapter 3** explained how to build a Spring `ApplicationContext` and demonstrated that it is well constructed—beans were created as expected—by running a `main(...)` method. However, this is not the best way, because classes containing these methods are only compiled, not run, during the build, so any change in the bean declarations, or library upgrades that cause issues, might not become obvious until later in development. So, in this chapter we show how Spring test contexts can be created to test Spring applications.
- *Using Spring Boot:* Spring application configuration is made even more practical by using Spring Boot. This Spring project makes it easy to create stand-alone, production-grade, Spring-based applications that you can “just run.”
- *Using configuration enhancements:* We present features that make application configuration easier, such as profile management, environment and property source abstraction, and so on. The section presenting those features shows how to use them to address specific configuration needs.
- *Using Groovy for configuration:* Spring 4.0 introduced the ability to configure bean definitions in the Groovy language, which, as you’ll see, can be used as an alternative/supplement to the old XML and Java configuration styles.

## Spring’s Impact on Application Portability

Most of the features discussed in this chapter are specific to Spring and, in many cases, are not available in other IoC containers. Although many IoC containers offer life-cycle management functionality, they probably do so through a different set of interfaces than Spring. If the portability of your application between different IoC containers is truly important, you might want to avoid using some features that couple your application to Spring.

Remember, however, that by setting a constraint—meaning that your application is portable between IoC containers—you are losing out on the wealth of functionality Spring offers. Because you are likely to be making a strategic choice to use Spring, it makes sense that you use it to the best of its ability.

Be careful not to create a requirement for portability out of thin air. In many cases, the end users of your application do not care whether the application can run on three different IoC containers; they just want it to run. In our experience, it is often a mistake to try to build an application on the lowest common denominator of features available in your chosen technology. Doing so often sets your application at a disadvantage right from the get-go. However, if your application requires IoC container portability, do not see this as a drawback—it is a true requirement and, therefore, one your application should fulfill. In *Expert One-on-One: J2EE Development without EJB* (Wrox, 2004), Rod Johnson and Jürgen Höller describe these types of requirements as phantom requirements and provide a much more detailed discussion of them and how they can affect your project.

Although using these features may couple your application to the Spring Framework, in reality you are increasing the portability of your application in the wider scope. Consider that you are using a freely available, open source framework that has no particular vendor affiliation. An application built using Spring's IoC container runs anywhere Java runs. For Java enterprise applications, Spring opens up new possibilities for portability. Spring provides many of the same capabilities as JEE and also provides classes to abstract and simplify many other aspects of JEE. In many cases, it is possible to build a web application using Spring that runs in a simple servlet container but with the same level of sophistication as an application targeted at a full-blown JEE application server. By coupling to Spring, you can increase your application's portability by replacing many features that either are vendor-specific or rely on vendor-specific configuration with equivalent features in Spring.

## Bean Life-Cycle Management

An important part of any IoC container, Spring included, is that beans can be constructed in such a way that they receive notifications at certain points in their life cycle. This enables your beans to perform relevant processing at certain points throughout their life. In general, two life-cycle events are particularly relevant to a bean: *post-initialization* and *pre-destruction*.



In the context of Spring, the *post-initialization* event is raised as soon as Spring finishes setting all the property values on the bean and finishes any dependency checks that you configured it to perform.



The *pre-destruction* event is fired just before Spring destroys the bean instance.

---

However, for beans with prototype scope, the *pre-destruction* event will not be fired by Spring. The design of Spring is that the initialization life-cycle callback methods will be called on objects regardless of bean scope, while for beans with prototype scope, the destruction life-cycle callback methods will not be called.

Spring provides three mechanisms a bean can use to hook into each of these events and perform some additional processing:

- *Interface-based mechanism:* Your bean implements an interface specific to the type of notification it wants to receive, and Spring notifies the bean via a callback method defined in the interface.
- *Method-based mechanism:* Spring allows you to specify, in your `ApplicationContext` configuration, the name of a method to call when the bean is initialized and the name of a method to call when the bean is destroyed.
- *Annotation-based mechanism:* You can use JSR-250 annotations to specify the method that Spring should call after construction or before destruction.

In the case of both events, the mechanisms achieve exactly the same goal. The interface-based mechanism is used extensively throughout Spring so that you don't have to remember to specify the initialization or destruction each time you use one of Spring's components. However, in your own beans, you may be better served using the method-based or annotation-based mechanism because your beans do not need to implement any Spring-specific interfaces. Although we stated that portability often isn't as important a requirement as many books lead you to believe, this does not mean you should sacrifice



portability when a perfectly good alternative exists. That said, if you are coupling your application to Spring in other ways, using the interface method allows you to specify the callback once and then forget about it. If you are defining a lot of beans of the same type that need to take advantage of the life-cycle notifications, then using the interface-based mechanism can avoid the need for specifying the life-cycle callback methods for every bean in the bean configuration. Using JSR-250 annotations is a standard defined by the JCP and you are also not coupled to Spring’s specific annotations. Just make sure that the IoC container you are running your application on supports the JSR-250 standard.

Overall, the choice of which mechanism you use for receiving life-cycle notifications depends on your application requirements. When using annotation-type configuration, just make sure you are using an IoC container that supports JSR-250. If you are not too concerned about portability or you are defining many beans of the same type that need the life-cycle notifications, using the interface-based mechanism is the best way to ensure that your beans always receive the notifications they are expecting. If you plan to use a bean across different Spring projects, you almost certainly want the functionality of that bean to be as self-contained as possible, so you should definitely use the interface-based mechanism.

Figure 4-1 shows a high-level overview of how Spring manages the life cycle of the beans within its container.

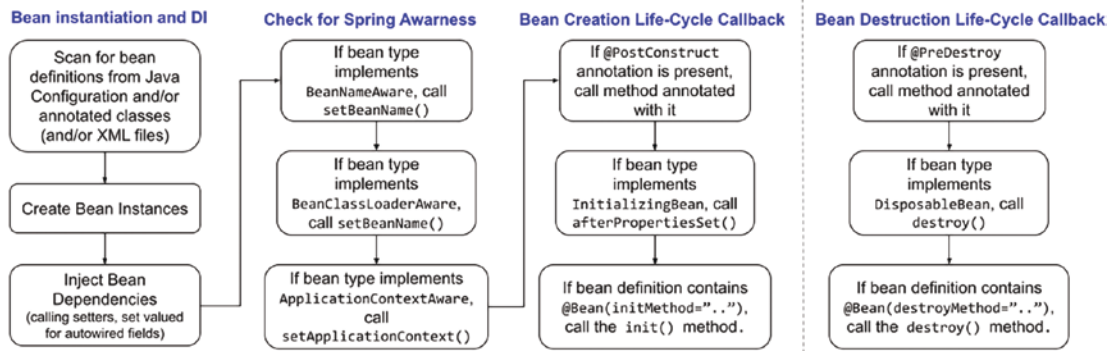


Figure 4-1. Spring beans life cycle

## Hooking into Bean Creation

By being aware of when it is initialized, a bean can check whether all its required dependencies are satisfied. Although Spring can check dependencies for you, it is pretty much an all-or-nothing approach, and it doesn’t offer any opportunities for applying additional logic to the dependency resolution procedure. Consider a bean that has four dependencies declared as setters, two of which are required and one of which has a suitable default in the event that no dependency is provided. Using an initialization callback, your bean can check for the dependencies it requires, throwing an exception or providing a default as needed.

A bean cannot perform these checks in its constructor because, at this point, Spring has not had an opportunity to provide values for the dependencies it can satisfy. The initialization callback in Spring is called after Spring finishes providing the dependencies that it can and performs any dependency checks that you ask of it.

You are not limited to using the initialization callback just to check dependencies; you can do anything you want in the callback, but it is most useful for the purpose we have described. In many cases, the initialization callback is also the place to trigger any actions that your bean must take automatically in response to its configuration. For instance, if you build a bean to run scheduled tasks, the initialization callback provides the ideal place to start the scheduler—after all, the configuration data is set on the bean.



You will not have to write a bean to run scheduled tasks because this is something Spring can do automatically through its built-in scheduling feature or via integration with the Quartz scheduler. We cover this in more detail in **Chapter 12**.

## Executing a Method When a Bean Is Created

As we mentioned previously, one way to receive the initialization callback is to designate a method on your bean as an initialization method and tell Spring to use this method as an initialization method. As discussed, this callback-based mechanism is useful when you have only a few beans of the same type or when you want to keep your application decoupled from Spring. Another reason for using this mechanism is to enable your Spring application to work with beans that were built previously or were provided by third-party vendors. Specifying a callback method is simply a case of specifying the name of the method as a value for the `initMethod` attribute in the `@Bean` annotation. This annotation is used to declare beans in Java configuration classes. Although Java configuration is covered a bit later in this chapter, the bean initialization part belongs here.

Listing 4-1 shows a basic bean with two dependencies.

### Listing 4-1. Bean Type with Two Dependencies

```
package com.apress.prospring6.four.initmethod;

import org.apache.commons.lang3.builder.ToStringBuilder;
// import statements omitted

class Singer {
    private static Logger logger = LoggerFactory.getLogger(Singer.class);

    private static final String DEFAULT_NAME = "No Name";
    private String name;
    private int age;

    public void setName(String name) {
        logger.info("Calling setName for bean of type {}.", Singer.class);
        this.name = name;
    }

    public void setAge(int age) {
        logger.info("Calling setAge for bean of type {}.", Singer.class);
        this.age = age;
    }

    public void init() {
        logger.info("Initializing bean");
        if (name == null) {
            logger.info("Using default name");
            name = DEFAULT_NAME;
        }
    }
}
```

```

        if (age == Integer.MIN_VALUE) {
            throw new IllegalArgumentException(
                "You must set the age property of any beans of type " + Singer.class);
        }
    }

    @Override
    public String toString() {
        return new ToStringBuilder(this)
            .append("name", name)
            .append("age", age)
            .toString();
    }
}

public class InitMethodDemo {
    private static Logger logger = LoggerFactory.getLogger(InitMethodDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(SingerConfiguration.class);

        getBean("singerOne", ctx);
        getBean("singerTwo", ctx);
        getBean("singerThree", ctx);
    }

    public static Singer getBean(String beanName, ApplicationContext ctx) {
        try {
            Singer bean = (Singer) ctx.getBean(beanName);
            logger.info("Found: {}", bean);
            return bean;
        } catch (BeanCreationException ex) {
            logger.error("An error occurred in bean configuration: " + ex.getMessage());
            return null;
        }
    }
}

```

Notice that we have defined a method, `init()`, to act as the initialization callback. The `init()` method checks whether the name property has been set, and if it has not, it uses the default value stored in the `DEFAULT_NAME` constant. The `init()` method also checks whether the age property is set and throws `IllegalArgumentException` if it is not.

The `main()` method of the `InitMethodDemo` class attempts to obtain three beans from `AnnotationConfigApplicationContext`, all of type `Singer`, using its own `getBean()` method. Notice that in the `getBean()` method, if the bean is obtained successfully, its details are written to console output. If an exception is thrown in the `init()` method, as will occur in this case if the age property is not set, then Spring wraps that exception in `BeanCreationException`. The `getBean()` method catches these exceptions and writes a message to the console output informing us of the error, as well as returns a null value.

Listing 4-2 shows an `ApplicationContext` configuration that defines the beans used in the previous code snippet.

**Listing 4-2.** SingerConfiguration Configuring a Spring ApplicationContext with Three Singer Beans

```
package com.apress.prospring6.four.initmethod;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;

@Configuration
class SingerConfiguration {

    @Bean(initMethod = "init")
    Singer singerOne(){
        Singer singer = new Singer();
        singer.setName("John Mayer");
        singer.setAge(43);
        return singer;
    }

    @Bean(initMethod = "init")
    Singer singerTwo(){
        Singer singer = new Singer();
        singer.setAge(42);
        return singer;
    }

    @Bean(initMethod = "init")
    Singer singerThree(){
        Singer singer = new Singer();
        singer.setName("John Butler");
        return singer;
    }
}
```

As you can see, the `@Bean` annotation for each of the three beans has an `initMethod` attribute that tells Spring that it should invoke the `init()` method as soon as it finishes configuring the bean. The `singerOne` bean has values for both the name and age properties, so it passes through the `init()` method with absolutely no changes. The `singerTwo` bean has no value for the name property, meaning that in the `init()` method, the name property is given the default value. Finally, the `singerThree` bean has no value for the age property. The logic defined in the `init()` method treats this as an error, so `IllegalArgumentException` is thrown.

Running the `InitMethodDemo` class yields the output in Listing 4-3.

**Listing 4-3.** Output Produced by Running `InitMethodDemo`

```
INFO : Singer - Calling setName for bean of type class com.apress.prospring6.four.
initmethod.Singer.
INFO : Singer - Calling setAge for bean of type class com.apress.prospring6.four.
initmethod.Singer.
INFO : Singer - Initializing bean
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean 'singerTwo'
INFO : Singer - Calling setAge for bean of type class com.apress.prospring6.four.
initmethod.Singer.
```

```

INFO : Singer - Initializing bean
INFO : Singer - Using default name
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean
'singerThree'
INFO : Singer - Calling setName for bean of type class com.apress.prospring6.four.
initmethod.Singer.
INFO : Singer - Initializing bean
WARN : AbstractApplicationContext - Exception encountered during context initialization -
cancelling refresh attempt: org.springframework.beans.factory.BeanCreationException: Error
creating bean with name 'singerThree' defined in com.apress.prospring6.four.initmethod.
SingerConfiguration: Invocation of init method failed; nested exception is java.lang.
IllegalArgumentException: You must set the age property of any beans of type class com.
apress.prospring6.four.initmethod.Singer
Exception in thread "main" org.springframework.beans.factory.BeanCreationException: Error
creating bean with name 'singerThree' defined in com.apress.prospring6.four.initmethod.
SingerConfiguration: Invocation of init method failed; nested exception is java.lang.
IllegalArgumentException: You must set the age property of any beans of type class com.
apress.prospring6.four.initmethod.Singer

```

From this output, you can see that `singerOne` was configured correctly with the values that we specified in the configuration file. For `singerTwo`, the default value for the name property was used because no value was specified in the configuration. Finally, for `singerThree`, no bean instance was created since the `init()` method raised an error because of the lack of a value for the age property.

As you can see, using the initialization method is an ideal way to ensure that your beans are configured correctly. By using this mechanism, you can take full advantage of the benefits of IoC without losing any of the control you get from manually defining dependencies.



The only constraint on your initialization method is that it cannot accept any arguments. You can define any return type, although it is ignored by Spring, and you can even use a static method, but the method must accept no arguments.

---

The benefits of this mechanism are negated when using a static initialization method, because you cannot access any of the bean's state to validate it. If your bean is using static state as a mechanism for saving memory and you are using a static initialization method to validate this state, then you should consider moving the static state to instance state and using a nonstatic initialization method. If you use Spring's singleton management capabilities, the end effect is the same, but you have a bean that is much simpler to test, and you also have the increased effect of being able to create multiple instances of the bean with their own state when necessary. Of course, in some instances, you need to use static state shared across multiple instances of a bean, in which case you can always use a static initialization method.

## Implementing the InitializingBean Interface

The `InitializingBean` interface defined in Spring allows you to define inside your bean code for Spring to execute after it has finished configuring the bean. In the same way as when you are using an initialization method, this gives you the opportunity to check the bean configuration to ensure that it is valid, providing any default values along the way. The `InitializingBean` interface defines a single method,

afterPropertiesSet(), that serves the same purpose as the init() method introduced in the previous section. Listing 4-4 shows a reimplementaion of the previous example using the InitializingBean interface in place of the initialization method.

**Listing 4-4.** Singer Class Implementing InitializingBean

```

package com.apress.prospring6.four.intf;
import org.springframework.beans.factory.InitializingBean;
// other import statements omitted

class Singer implements InitializingBean {
    private static Logger logger = LoggerFactory.getLogger(Singer.class);

    private static final String DEFAULT_NAME = "No Name";
    private String name;
    private int age = Integer.MIN_VALUE;

    public void setName(String name) {
        logger.info("Calling setName for bean of type {}.", Singer.class);
        this.name = name;
    }

    public void setAge(int age) {
        logger.info("Calling setAge for bean of type {}.", Singer.class);
        this.age = age;
    }

    @Override
    public void afterPropertiesSet() throws Exception {
        logger.info("Initializing bean using 'afterPropertiesSet()'");
        if (name == null) {
            logger.info("Using default name");
            name = DEFAULT_NAME;
        }
        if (age == Integer.MIN_VALUE) {
            throw new IllegalArgumentException(
                "You must set the age property of any beans of type " + Singer.class);
        }
    }

    @Override
    public String toString() {
        return new ToStringBuilder(this)
            .append("name", name)
            .append("age", age)
            .toString();
    }
}

@Configuration
class SingerConfiguration {

```

```

@Bean
Singer singerOne(){
    Singer singer = new Singer();
    singer.setName("John Mayer");
    singer.setAge(43);
    return singer;
}
// other bean declarations omitted
}

public class InitializingBeanDemo {
    private static Logger logger = LoggerFactory.getLogger(InitializingBeanDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(SingerConfiguration.class);

        getBean("singerOne", ctx);
        getBean("singerTwo", ctx);
        getBean("singerThree", ctx);
    }
    // getBean(..) method omitted, identical to the one in Listing 4-1.
}

```

As you can see, not much in this example has changed. The only differences are that this class implements `InitializingBean` and that the initialization logic has moved into the `afterPropertiesSet()` method. The configuration no longer requires the `initMethod` attribute, and if you run the `InitializingBeanDemo` you will see an identical output.

## Using the JSR-250 `@PostConstruct` Annotation

JSR-250 annotations were described in [Chapter 4](#) in connection to dependency autowiring using `@Resource`. In this section you will be shown how to use the JSR-250 life-cycle annotation, `@PostConstruct`. Starting from Spring 2.5, JSR-250 annotations are also supported to specify the method that Spring should call if the corresponding annotation relating to the bean's life cycle exists in the class. [Listing 4-5](#) shows the previous example written to make use of the `@PostConstruct` annotation.

*Listing 4-5.* Singer Class Implemented Using `@PostConstruct`

```

package com.apress.prospring6.four.jsr250;

import jakarta.annotation.PostConstruct;

class Singer {
    private static Logger logger = LoggerFactory.getLogger(Singer.class);
    private static final String DEFAULT_NAME = "No Name";
    private String name;
    private int age = Integer.MIN_VALUE;

    public void setName(String name) {
        logger.info("Calling setName for bean of type {}. ", Singer.class);
        this.name = name;
    }
}

```

```

public void setAge(int age) {
    logger.info("Calling setAge for bean of type {}.", Singer.class);
    this.age = age;
}

@PostConstruct
public void postConstruct() throws Exception {
    logger.info("Initializing bean using 'postConstruct()'");
    if (name == null) {
        logger.info("Using default name");
        name = DEFAULT_NAME;
    }
    if (age == Integer.MIN_VALUE) {
        throw new IllegalArgumentException(
            "You must set the age property of any beans of type " + Singer.class);
    }
}

// toString() omitted
}

```

The program is the same as using the `@Bean(initMethod=..)` and `InitializingBean` approach; the `@PostConstruct` annotation is applied to the initialization method instead. The method is renamed to `postConstruct` in this scenario to make it even more obvious as to what the purpose of this method is. Note that you can name the method any way you want to.



The configuration and the class used to test this new `Singer` bean type are identical to the one in the `InitializingBean` example and so is the produced output, so it won't be repeated here, but feel free to execute the `com.apress.prospring6.four.jsr250.PostConstructDemo` class in the project for this book yourself to test this affirmation.

---

All three approaches have their benefits and drawbacks:

- Using an initialization method, you have the benefit of keeping your application decoupled from Spring, but you must remember to configure the initialization method for every bean that needs it.
- Using the `InitializingBean` interface, you have the benefit of being able to specify the initialization callback once for all instances of your bean class, but you have to couple your application to Spring to do so.
- Using annotations, you need to apply the annotation to the method and make sure that the IoC container supports JSR-250.

In the end, you should let the requirements of your application drive the decision about which approach to use. If portability is an issue, use the initialization or annotation method; otherwise, use the `InitializingBean` interface to reduce the amount of configuration your application needs and the chance of errors creeping into your application because of misconfiguration.





When configuring initialization with `@Bean(initMethod=..)` or `@PostConstruct`, there is the advantage of declaring the initialization method with a different access right. Initialization methods should be called only once by the Spring IoC, at bean creation time. Subsequent calls will lead to unexpected results or even failures. External additional calls can be prohibited by making the initialization method private. The Spring IoC will be able to call it via reflection, but any additional calls in the code won't be permitted.

## Understanding Order of Resolution

All initialization mechanisms can be used on the same bean instance. In this case, Spring invokes the method annotated with `@PostConstruct` first and then `afterPropertiesSet()`, followed by the initialization method specified in the `@Bean` annotation. There is a technical reason for this order, and by following the path in Figure 4-1, we can notice the following steps in the bean creation process:

1. The constructor is called first to create the bean.
2. The dependencies are injected (setters are called). If there are dependencies, the `BeanPostProcessor` infrastructure bean is consulted to call the setters. This is a Spring-specific infrastructure bean that performs bean modifications after they are created. The `@Autowired` annotation is registered by the `AutowiredAnnotationBeanPostProcessor` so this bean will call the setter methods found annotated with `@Autowired`.
3. Now that the beans exist and the dependencies were provided, the pre-initialization `BeanPostProcessor` infrastructure beans are consulted to see whether they want to call anything from this bean. These are Spring-specific infrastructure beans that perform bean modifications after they are created. The `@PostConstruct` annotation is registered by the `CommonAnnotationBeanPostProcessor` bean, so this bean will call the method found annotated with `@PostConstruct`. This method is executed right after the bean has been constructed and before the class is put into service<sup>2</sup>, before the actual initialization of the bean (before `afterPropertiesSet` and `initMethod`).
4. The `InitializingBean`'s `afterPropertiesSet` is executed right after the dependencies are injected. The `afterPropertiesSet()` method is invoked by a `BeanFactory` after it has set all the bean properties supplied and has satisfied `BeanFactoryAware` and `ApplicationContextAware`.
5. The method specified by name in the `initMethod` attribute is executed last because this is the actual initialization method of the bean.

The `AllInitMethodsDemo` set of classes shown in Listing 4-6 can be used to demonstrate all the previous affirmations.

<sup>2</sup>Check out this snippet from JEE official Javadoc: <https://docs.oracle.com/javaee/7/api/javax/annotation/PostConstruct.html>

**Listing 4-6.** AllInitMethodsDemo Example to Show Order of Initialization Methods

```

package com.apress.prospring6.four.all;
// import statement omitted

class Dependency { // very simple bean type
}

class MultiInit implements InitializingBean {
    private static Logger logger = LoggerFactory.getLogger(MultiInit.class);
    private Dependency dependency;

    public MultiInit() {
        logger.info("1. Calling constructor for bean of type {}.", MultiInit.class);
    }

    public Dependency getDependency() {
        return dependency;
    }

    @Autowired
    public void setDependency(Dependency dependency) {
        logger.info("2. Calling setDependency for bean of type {}.", MultiInit.class);
        this.dependency = dependency;
    }

    @PostConstruct
    private void postConstruct() throws Exception {
        logger.info("3. Calling postConstruct() for bean of type {}.", MultiInit.class);
    }

    @Override
    public void afterPropertiesSet() throws Exception {
        logger.info("4. Calling afterPropertiesSet() for bean of type {}.",
            MultiInit.class);
    }

    private void initMe() throws Exception {
        logger.info("5. Calling initMethod() for bean of type {}.", MultiInit.class);
    }
}

@Configuration
class MultiInitConfiguration {

    @Bean
    Dependency dependency (){
        return new Dependency();
    }

    @Bean(initMethod = "initMe")
    MultiInit multiInitBean(){

```

```

        return new MultiInit();
    }
}

public class AllInitMethodsDemo {

    public static void main(String... args) {
        new AnnotationConfigApplicationContext(MultiInitConfiguration.class);
    }
}

```

When running the `main(..)` method in class `AllInitMethodsDemo` with `DEBUG` logs enabled for the `org.springframework` package, the output in Listing 4-7 is produced.

**Listing 4-7.** AllInitMethodsDemo Console Output

```

...
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean 'org.
springframework.context.annotation.internalConfigurationAnnotationProcessor'
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean 'org.
springframework.context.event.internalEventListenerProcessor'
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean 'org.
springframework.context.event.internalEventListenerFactory'
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean 'org.
springframework.context.annotation.internalAutowiredAnnotationProcessor'
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean 'org.
springframework.context.annotation.internalCommonAnnotationProcessor'
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean
'multiInitConfiguration'
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean
'dependency'
DEBUG: DefaultSingletonBeanRegistry - Creating shared instance of singleton bean
'multiInitBean'
INFO : MultiInit - 1. Calling constructor for bean of type class com.apress.prospring6.four.
all.MultiInit.
INFO : MultiInit - 2. Calling setDependency for bean of type class com.apress.prospring6.
four.all.MultiInit.
INFO : MultiInit - 3. Calling postConstruct() for bean of type class com.apress.prospring6.
four.all.MultiInit.
INFO : MultiInit - 4. Calling afterPropertiesSet() for bean of type class com.apress.
prospring6.four.all.MultiInit.
INFO : MultiInit - 5. Calling initMethod() for bean of type class com.apress.prospring6.
four.all.MultiInit.

```

If you look at the detailed log of the Spring application, you might notice a few Spring-specific infrastructure beans. Their names hint to their type and responsibilities. For example, the `org.springframework.context.annotation.internalCommonAnnotationProcessor` bean is the `CommonAnnotationBeanPostProcessor` bean that provides support for the `@PostConstruct` annotation, and the `org.springframework.context.annotation.internalAutowiredAnnotationProcessor` bean is the

AutowiredAnnotationBeanPostProcessor bean that provides support for the @Autowired annotation. If you want to identify other types of Spring-specific infrastructure beans using their names take a look at the source code of the AnnotationConfigUtils<sup>3</sup>.

## Hooking into Bean Destruction

When using an ApplicationContext implementation that wraps the DefaultListableBeanFactory interface (such as AnnotationConfigApplicationContext, via the getDefaultListableBeanFactory() method), you can signal to BeanFactory that you want to destroy all singleton instances with a call to ConfigurableBeanFactory.destroySingletons(). Typically, you do this when your application shuts down, and it allows you to clean up any resources that your beans might be holding open, thus allowing your application to shut down gracefully. This callback also provides the perfect place to flush any data you are storing in memory to persistent storage and to allow your beans to end any long-running processes they may have started.

To allow your beans to receive notification that destroySingletons() has been called, you have three options, all similar to the mechanisms available for receiving an initialization callback. The destruction callback is often used in conjunction with the initialization callback. In many cases, you create and configure a resource in the initialization callback and then release the resource in the destruction callback.



The name of the method destroySingletons() gives a hint about an important detail. Spring only performs bean destruction for singleton beans. Beans with other scopes than singleton do not have their life cycle fully managed by Spring. For example, for prototype beans, the Spring container instantiates, configures, and otherwise assembles a prototype object, and hands it to the client, with no further record of that prototype instance

---

## Executing a Method When a Bean Is Destroyed

To designate a method to be called when a bean is destroyed, you simply specify the name of the method in the destroyMethod attribute of the bean's definition @Bean annotation. Spring calls it just before it destroys the singleton instance of the bean (Spring will not call this method for those beans with prototype scope). The code snippet in Listing 4-8 provides an example of using a destroy-method callback.

**Listing 4-8.** Example Showing How to Configure a Destroy Method Using the @Bean Annotation

```
package com.apress.prospring6.four.destroymethod;
// import statements omitted

class FileManager {
    private static Logger logger = LoggerFactory.getLogger(FileManager.class);
    private Path file;

    public FileManager() {
        logger.info("Creating bean of type {}", FileManager.class);
    }
}
```

<sup>3</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-context/src/main/java/org/springframework/context/annotation/AnnotationConfigUtils.java>

```

    try {
        file = Files.createFile(Path.of("sample"));
    } catch (IOException e) {
        logger.error("Could not create file");
    }
}

private void destroyMethod() throws IOException {
    logger.info("Destroying bean of type {}", FileManager.class);
    if (file != null) {
        Files.deleteIfExists(file);
    }
}
}

@Configuration
class DemoConfig {

    @Bean(destroyMethod = "destroyMethod")
    FileManager fileManager() {
        return new FileManager();
    }
}

public class DestroyMethodDemo {
    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(DemoConfig.class);
        ctx.close(); // needed to close the context
    }
}

```

Class `FileManager` defines a `destroyMethod()` method, in which the file that is created by its constructor gets deleted. The `main()` method retrieves a bean of type `FileManager` from the context and then invokes its `destroyMethod()` method (which will, in turn, invoke the `ConfigurableBeanFactory.destroySingletons()` method that was wrapped by the `ApplicationContext`), instructing Spring to destroy all the singletons managed by it. Both the constructor and the destroy method write a message to console output informing us that they have been called.

## Implementing the DisposableBean Interface

As with initialization callbacks, Spring provides an interface, in this case `DisposableBean`, that can be implemented by your beans as a mechanism for receiving destruction callbacks. The `DisposableBean` interface defines a single method, `destroy()`, which is called just before the bean is destroyed. Using this mechanism is orthogonal to using the `InitializingBean` interface to receive initialization callbacks. The code snippet in Listing 4-9 shows a modified implementation of the `FileManager` class that implements the `DisposableBean` interface.

**Listing 4-9.** Example Showing How to Configure a Destroy Method Using the DisposableBean Interface

```

package com.apress.prospring6.four.intf;

import org.springframework.beans.factory.DisposableBean;
// other import statements omitted

class FileManager implements DisposableBean {
    private static Logger logger = LoggerFactory.getLogger(FileManager.class);
    private Path file;

    public FileManager() {
        logger.info("Creating bean of type {}", FileManager.class);
        try {
            file = Files.createFile(Path.of("sample"));
        } catch (IOException e) {
            logger.error("Could not create file");
        }
    }

    @Override
    public void destroy() throws Exception {
        logger.info("Calling destroy() on bean of type {}", FileManager.class);
        if (file != null) {
            Files.deleteIfExists(file);
        }
    }
}

```

There is not much difference between the code that uses the callback method mechanism configured with `@Bean(destroyMethod="..")` and the code that uses the callback interface mechanism. The configuration is identical to that in the previous section, except for the missing `(destroyMethod="..")`, which is no longer necessary. The code to run the example is the same as well. Thus, we can skip showing these two implementations and jump to the next way of configuring a destroy method.

## Using the JSR-250 `@PreDestroy` Annotation

The third way to define a method to be called before a bean is destroyed is to use the JSR-250 life-cycle `@PreDestroy` annotation, which is the inverse of the `@PostConstruct` annotation. The code snippet in Listing 4-10 is a version of `FileManager` that uses `@PreDestroy` to perform destroy actions.

**Listing 4-10.** Example Showing How to Configure a Destroy Method Using the `@PreDestroy` Annotation

```

package com.apress.prospring6.four.jsr250;

import jakarta.annotation.PreDestroy;
// import statements omitted

class FileManager {
    private static Logger logger = LoggerFactory.getLogger(FileManager.class);
    private Path file;

```

```

public FileManager() {
    logger.info("Creating bean of type {}", FileManager.class);
    try {
        file = Files.createFile(Path.of("sample"));
    } catch (IOException e) {
        logger.error("Could not create file");
    }
}

@PreDestroy
private void preDestroy() throws IOException {
    logger.info("Calling preDestroy() on bean of type {}",FileManager.class);
    if (file != null) {
        Files.deleteIfExists(file);
    }
}
}

```

Running any of the examples declaring destroy callbacks results in a console log pretty similar to the one shown in Listing 4-11.

**Listing 4-11.** Log Sample Showing Bean Destruction

```

...
INFO : FileManager - Creating bean of type class com.apress.prospring6.four.*.FileManager
DEBUG: AbstractApplicationContext - Closing org.springframework.context.annotation.AnnotationConfigApplicationContext@79be0360, started on Fri Mar 25 12:05:49 GMT 2022
INFO : FileManager - Calling destroy()/destroyMethod()/preDestroy() on bean of type class
com.apress.prospring6.four.*.FileManager

```

The destruction callback is an ideal mechanism for ensuring that your applications shut down gracefully and do not leave resources open or in an inconsistent state. However, you still have to decide how to use the destruction method callback: using the `@Bean(destroyMethod="...")`, the `DisposableBean` interface, or the `@PreDestroy` annotation. Again, let the requirements of your application drive your decision in this respect; use the method callback where portability is an issue, and use the `DisposableBean` interface or a JSR-250 annotation to reduce the amount of configuration required.

## Understanding Order of Resolution

As with the case of bean creation, you can use all mechanisms on the same bean instance for bean destruction. In this case, Spring invokes the method annotated with `@PreDestroy` first and then `DisposableBean.destroy()`, followed by your destroy method configured in your `@Bean` definition.

## Using a Shutdown Hook

The only drawback of the destruction callbacks in Spring is that they are not fired automatically; you need to remember to call `ctx.close()` before your application is closed. When your application runs as a servlet, you can simply call `destroy()` in the servlet's `destroy()` method.

However, in a stand-alone application, things are not quite so simple, especially if you have multiple exit points out of your application. Fortunately, there is a solution. Java allows you to create a *shutdown hook*, which is a thread that is executed just before the application shuts down. This is the perfect way to invoke the `destroy()` method of your context (which was being extended by all concrete `ApplicationContext` implementations). The easiest way to take advantage of this mechanism is to use `AbstractApplicationContext`'s `registerShutdownHook()` method. The method automatically instructs Spring to register a shutdown hook of the underlying JVM runtime. The bean declaration and configuration stay the same as before; the only thing that changes is the main method: the call of `ctx.registerShutdownHook` is added, and calls to `ctx.destroy()` or `close()` will be removed.

Running the code in Listing 4-12 produces the same output as the output displayed in Listing 4-11.

**Listing 4-12.** Log Sample Showing Bean Destruction

```
package com.apress.prospring6.four.jsr250;
// import and some code omitted

public class PreDestroyDemo {
    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(DemoConfig.class);
        ctx.registerShutdownHook();
    }
}
```

## Making Your Beans “Spring Aware”

One of the biggest selling points of dependency injection over dependency lookup as a mechanism for achieving inversion of control is that your beans do not need to be aware of the implementation of the container that is managing them. To a bean that uses constructor or setter injection, the Spring container is the same as the container provided by Google Guice or PicoContainer. However, in certain circumstances, you may need a bean that is using dependency injection to obtain its dependencies so it can interact with the container for some other reason. An example of this may be a bean that automatically configures a shutdown hook for you, and thus it needs access to `ApplicationContext`. In other cases, a bean may want to know what its name is (that is, the bean name that was assigned within the current `ApplicationContext`) so it can perform some additional processing based on this name.

That said, this feature is really intended for internal Spring use. Giving the bean name some kind of business meaning is generally a bad idea and can lead to configuration problems as bean names have to be artificially manipulated to support their business meaning. However, we have found that being able to have a bean find out its name at runtime is really useful for logging. Say you have many beans of the same type running under different configurations. The bean name can be included in log messages to help you differentiate between the one that is generating errors and the ones that are working fine when something goes wrong.

## Using the `BeanNameAware` Interface

The `BeanNameAware` interface, which can be implemented by a bean that wants to obtain its own name, has a single method: `setBeanName(String)`. Spring calls the `setBeanName()` method after it has finished configuring your bean but before any life-cycle callbacks (initialization or destroy) are called (refer to Figure 4-1). In most cases, the implementation of the `setBeanName()` interface is just a single line that stores the value passed in by the container in a field for use later. The code snippet in Listing 4-13 shows a simple bean that obtains its name by using `BeanNameAware` and then later uses this bean name to print to the console.



**Listing 4-13.** BeanNameAware Sample Implementation

```

package com.apress.prospring6.four.aware;
// other imports omitted
import org.springframework.beans.factory.BeanNameAware;

class NamedSinger implements BeanNameAware {
    private static Logger logger = LoggerFactory.getLogger(NamedSinger.class);
    private String name;

    @Override /** @Implements {@link BeanNameAware#setBeanName(String)} */
    public void setBeanName(String beanName) {
        this.name = beanName;
    }

    public void sing() {
        logger.info("Singer " + name + " - sing()");
    }
}

```

This implementation is fairly trivial. Remember that `BeanNameAware.setBeanName()` is called before the first instance of the bean is returned to your application via a call to `ApplicationContext.getBean()`, so there is no need to check whether the bean name is available in the `sing()` method. As you can see, no special configuration is required to take advantage of the `BeanNameAware` interface. In Listing 4-14, you can see a simple example configuration and application that retrieves the `NamedSinger` instance from `ApplicationContext` and then calls the `sing()` method.

**Listing 4-14.** BeanNameAware Example Usage

```

package com.apress.prospring6.four.aware;
// other import statements omitted

@ComponentScan
class AwareConfig {

    @Bean
    NamedSinger johnMayer(){
        return new NamedSinger();
    }
}

public class AwareDemo {

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(AwareConfig.class);
        ctx.registerShutdownHook();

        var singer = ctx.getBean(NamedSinger.class);
        singer.sing();
    }
}

```

When run, this example generates a very simple output:

```
INFO : NamedSinger - Singer johnMayer - sing() ;
```

Notice the inclusion of the bean name in the log message for the call to the `sing()` method.

Using the `BeanNameAware` interface is really quite simple, and it is put to good use when you are improving the quality of your log messages. Avoid being tempted to give your bean names business meaning just because you can access them; by doing so, you are coupling your classes to Spring for a feature that brings negligible benefit. If your beans need some kind of name internally, have them implement an interface such as `Nameable` (which is specific to your application) with a method `setName()` and then give each bean a name by using dependency injection. This way, you can keep the names you use for configuration concise, and you won't need to manipulate your configuration unnecessarily to give your beans names with business meaning.

## Using the `ApplicationContextAware` Interface

`ApplicationContextAware` was introduced at the end of **Chapter 3** to show how Spring can be used to deal with beans that require other beans to function that are not injected using constructors or setters in the configuration (the `@DependsOn` example in Listing 3-54).

Using the `ApplicationContextAware` interface, it is possible for your beans to get a reference to the `ApplicationContext` instance that configured them. The main reason this interface was created is to allow a bean to access Spring's `ApplicationContext` in your application, for example, to acquire other Spring beans programmatically, using `getBean()`. You should, however, avoid this practice and use dependency injection to provide your beans with their collaborators. If you use the lookup-based `getBean()` approach to obtain dependencies when you can use dependency injection, you are adding unnecessary complexity to your beans and coupling them to the Spring Framework without good reason.

Of course, `ApplicationContext` isn't used just to look up beans; it performs a great many other tasks. As you saw previously, one of these tasks is to destroy all singletons, notifying each of them in turn before doing so. In the previous section, you saw how to create a shutdown hook to ensure that `ApplicationContext` is instructed to destroy all singletons before the application shuts down. By using the `ApplicationContextAware` interface, you can build a bean that can be configured in `ApplicationContext` to create and configure a shutdown hook bean automatically. Listing 4-15 shows the code for this bean.

**Listing 4-15.** `ApplicationContextAware` Implementation Example

```
package com.apress.prospring6.four.aware;

import org.springframework.context.ApplicationContextAware;
// other import statements omitted

class ShutdownHookBean implements ApplicationContextAware {
    private ApplicationContext ctx;
    /** @Implements {@link ApplicationContextAware#setApplicationContext(Application
    Context)} */
    public void setApplicationContext(ApplicationContext ctx) throws BeansException {
        if (ctx instanceof GenericApplicationContext) {
            ((GenericApplicationContext) ctx).registerShutdownHook();
        }
    }
}
```

Most of this code should seem familiar to you by now. The `ApplicationContextAware` interface defines a single method, `setApplicationContext(ApplicationContext)`, that Spring calls to pass your bean a reference to its `ApplicationContext`. In the previous code snippet, the `ShutdownHookBean` class checks whether `ApplicationContext` is of type `GenericApplicationContext`, meaning it supports the `registerShutdownHook()` method; if it does, it will register a shutdown hook to `ApplicationContext`. Listing 4-16 shows how to configure this bean to work with the `FileManager` bean introduced in the previous section.

**Listing 4-16.** `ApplicationContextAware` Bean Configuration and Code to Bootstrap the Spring Application Based on This Configuration

```

package com.apress.prospring6.four.aware;
// other import statements omitted

@ComponentScan
class AwareConfig {

    @Bean
    FileManager fileManager() {
        return new FileManager();
    }

    @Bean
    ShutdownHookBean shutdownHookBean() {
        return new ShutdownHookBean();
    }
}

public class AwareDemo {

    public static void main(String... args) {
        new AnnotationConfigApplicationContext(AwareConfig.class);
    }
}

```

Notice that no special configuration is required. The code to build a Spring application is simple too, as depicted by the new `AwareDemo` class. Calling `ctx.registerShutdownHook()` is no longer needed because this is done by the `ShutdownHookBean`. Running the previous example will generate a console output ending in

```
INFO : FileManager - Calling preDestroy() on bean of type class com.apress.prospring6.four.
aware.FileManager
```

Even without a call to `ctx.registerShutdownHook()` or `ctx.close()` that closes the application context removing the hooks, the `preDestroy()` method is called before the application shuts down, because the `ShutdownHookBean.setApplicationContext(ApplicationContext ctx)` method does shutdown hook registering.

## Use of FactoryBeans

One of the problems that you will face when using Spring is how to create and then inject dependencies that cannot be created simply by using the new operator. To overcome this problem, Spring provides the `FactoryBean` interface that acts as an adapter for objects that cannot be created and managed using the standard Spring semantics. Typically, you use `FactoryBean` implementations to create beans that you cannot create by using the new operator, such as those you access through static factory methods, although this is not always the case. Simply put, a `FactoryBean` is a bean that acts as a factory for other beans. `FactoryBeans` are configured within your `ApplicationContext` like any normal bean, but when Spring uses the `FactoryBean` interface to satisfy a dependency or lookup request, it does not return `FactoryBean`; instead, it invokes the `FactoryBean.getObject()` method and returns the result of that invocation.



Spring automatically calls the `getObject()` method; it is a bad practice call that method manually.

---

`FactoryBeans` are used to great effect in Spring; the most noticeable uses are the creation of transactional proxies, which we cover in [Chapter 9](#), and the automatic retrieval of resources from a JNDI context. However, `FactoryBeans` are useful not just for building the internals of Spring; you'll find them really useful when you build your own applications because they allow you to manage many more resources by using IoC than would otherwise be available.

### FactoryBean Example: The `MessageDigestFactoryBean`

Often the projects that we work on require some kind of cryptographic processing; typically, this involves generating a message digest or hash of a user's password to be stored in a database. In Java, the `MessageDigest` class provides functionality for creating a digest of any arbitrary data. `MessageDigest` itself is abstract, and you obtain concrete implementations by calling `MessageDigest.getInstance()` and passing in the name of the digest algorithm you want to use. For instance, if we want to use the MD5 algorithm to create a digest, we use the following code to create the `MessageDigest` instance:

```
MessageDigest md5 = MessageDigest.getInstance("MD5");
```

If we want to use Spring to manage the creation of the `MessageDigest` object, the best we can do without a `FactoryBean` is to have a property named `algorithmName` on our bean and then use an initialization callback to call `MessageDigest.getInstance()`. Using a `FactoryBean`, we can encapsulate this logic inside a bean. Then, any beans that require a `MessageDigest` instance can simply declare a property, `messageDigest`, and use the `FactoryBean` to obtain the instance. [Listing 4-17](#) shows an implementation of `FactoryBean` that does this.

**Listing 4-17.** MessageDigestFactoryBean Implementation

```

package com.apress.prospring6.four.factory;

import org.springframework.beans.factory.FactoryBean;
import java.security.MessageDigest;
// other import statements omitted

public class MessageDigestFactoryBean implements FactoryBean<MessageDigest>,
InitializingBean {
    private String algorithmName = "MD5";

    private MessageDigest messageDigest = null;

    @Override /** @Implements {@link FactoryBean#getObject()} */
    public MessageDigest getObject() throws Exception {
        return messageDigest;
    }

    @Override /** @Implements {@link FactoryBean#getObjectType()} */
    public Class<MessageDigest> getObjectType() {
        return MessageDigest.class;
    }

    @Override /** @Implements {@link FactoryBean#isSingleton()} */
    public boolean isSingleton() {
        return true;
    }

    @Override /** @Implements {@link InitializingBean#afterPropertiesSet()} */
    public void afterPropertiesSet() throws Exception {
        messageDigest = MessageDigest.getInstance(algorithmName);
    }

    public void setAlgorithmName(String algorithmName) {
        this.algorithmName = algorithmName;
    }
}

```

Spring calls the `getObject()` method to retrieve the object created by the `FactoryBean`. This is the actual object that is passed to other beans that use the `FactoryBean` as a collaborator. `MessageDigestFactoryBean` passes a clone of the stored `MessageDigest` instance that is created in the `InitializingBean.afterPropertiesSet()` callback.

The `getObjectType()` method allows you to tell Spring what type of object your `FactoryBean` will return. This can be null if the return type is unknown in advance (for example, the `FactoryBean` creates different types of objects depending on the configuration, which will be determined only after the `FactoryBean` is initialized), but if you specify a type, Spring can use it for autowiring purposes. We return `MessageDigest` as our type (in this case, a class, but try to return an interface type and have the `FactoryBean` instantiate the concrete implementation class, unless necessary). The reason is that we do not know what concrete type will be returned (not that it matters, because all beans will define their dependencies by using `MessageDigest` anyway).

The `isSingleton()` property allows you to inform Spring whether the `FactoryBean` is managing a singleton instance. Remember that by annotating the `FactoryBean`'s definition with `@Scope(scopeName = "singleton")`, you tell Spring about the singleton status of the `FactoryBean` itself, not the objects it is returning. Now let's see how the `FactoryBean` is employed in an application. In Listing 4-18, you can see a simple bean that maintains two `MessageDigest` instances and then displays the digests of a message passed to its `digest()` method.

**Listing 4-18.** Simple Bean Maintaining Two `MessageDigest` Instances

```

package com.apress.prospring6.four.factory;

import java.security.MessageDigest;

public class MessageDigester {
    private static Logger logger = LoggerFactory.getLogger(MessageDigester.class);

    private MessageDigest digest1;
    private MessageDigest digest2;

    public void setDigest1(MessageDigest digest1) {
        this.digest1 = digest1;
    }

    public void setDigest2(MessageDigest digest2) {
        this.digest2 = digest2;
    }

    public void digest(String msg) {
        logger.info("Using digest1");
        digest(msg, digest1);

        logger.info("Using digest2");
        digest(msg, digest2);
    }

    private void digest(String msg, MessageDigest digest) {
        logger.info("Using algorithm: " + digest.getAlgorithm());
        digest.reset();
        byte[] bytes = msg.getBytes();
        byte[] out = digest.digest(bytes);
        // we are printing the actual byte values
        logger.info("Original Message: {} ", bytes);
        logger.info("Encrypted Message: {} ", out);
    }
}

```

The snippet in Listing 4-19 shows an example configuration for two `MessageDigestFactoryBean` classes, one for the SHA1 algorithm and the other using the default (MD5) algorithm. The same listing also shows the `FactoryBeanDemo` class that retrieves the `MessageDigester` bean from the `BeanFactory` and creates the digest of a simple message.

**Listing 4-19.** Simple Configuration for MessageDigestFactoryBean and Code to Bootstrap a Spring Application to Test It

```

package com.apress.prospring6.four.factory;
// import statements omitted

@Configuration
@ComponentScan
class MessageDigestConfig {

    @Bean
    public MessageDigestFactoryBean shaDigest(){
        MessageDigestFactoryBean shaDigest = new MessageDigestFactoryBean();
        shaDigest.setAlgorithmName("SHA1");
        return shaDigest;
    }

    @Bean
    public MessageDigestFactoryBean defaultDigest(){
        return new MessageDigestFactoryBean();
    }

    @Bean
    public MessageDigerster digester() throws Exception {
        MessageDigerster messageDigerster = new MessageDigerster();
        messageDigerster.setDigest1(shaDigest().getObject());
        messageDigerster.setDigest2(defaultDigest().getObject());
        return messageDigerster;
    }
}

public class FactoryBeanDemo {

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(MessageDigestConfig.class);
        MessageDigerster digester = ctx.getBean("digester", MessageDigerster.class);
        digester.digest("Hello World!");

        ctx.close();
    }
}

```

As you can see, we not only have configured the two MessageDigestFactoryBean classes, but also have configured a MessageDigerster, using the two MessageDigestFactoryBean classes, to provide values for the digest1 and digest2 properties. For the defaultDigest bean, since the algorithmName property was not specified, no injection will happen, and the default algorithm (MD5) that was coded in the class will be used. In Listing 4-20, you can see the console log produced by running the code in Listing 4-19.

**Listing 4-20.** Simple Message Digest Generated by the Application Configured by the MessageDigestConfig Class

```
INFO : MessageDigester - Using digest1
INFO : MessageDigester - Using algorithm: SHA1
INFO : MessageDigester - Original Message: [72, 101, 108, 108, 111, 32, 87, 111, 114, 108,
100, 33]
INFO : MessageDigester - Encrypted Message: [46, -9, -67, -26, 8, -50, 84, 4, -23, 125, 95,
4, 47, -107, -8, -97, 28, 35, 40, 113]
INFO : MessageDigester - Using digest2
INFO : MessageDigester - Using algorithm: MD5
INFO : MessageDigester - Original Message: [72, 101, 108, 108, 111, 32, 87, 111, 114, 108,
100, 33]
INFO : MessageDigester - Encrypted Message: [-19, 7, 98, -121, 83, 46, -122, 54, 94, -124,
30, -110, -65, -59, 13, -116]
```

We chose to print the numeric byte values instead of the messages as text to show the changes that encryption makes at the byte level. As you can see, the MessageDigest bean is provided with two MessageDigest implementations, SHA1 and MD5, even though no MessageDigest beans are configured in the BeanFactory. This is the FactoryBean at work.

FactoryBeans are the perfect solution when you are working with classes that cannot be created by using the new operator. If you work with objects that are created by using a factory method and you want to use these classes in a Spring application, create a FactoryBean to act as an adapter, allowing your classes to take full advantage of Spring's IoC capabilities.



The power of using FactoryBeans becomes obvious when XML configuration is used, since Spring automatically satisfies any references to a FactoryBean by the objects produced by that FactoryBean. This allows for the MessageDigester bean to be configured like shown in the previous edition of this book:

```
<beans ...>
  <bean id="shaDigest"
    class="com.apress.prospring5.ch4.MessageDigestFactoryBean"
    p:algorithmName="SHA1"/>
  <bean id="defaultDigest"
    class="com.apress.prospring5.ch4.MessageDigestFactoryBean"/>

  <bean id="digester"
    class="com.apress.prospring5.ch4.MessageDigester"
    p:digest1-ref="shaDigest"
    p:digest2-ref="defaultDigest"/>
</beans>
```

---

## Accessing a FactoryBean Directly

Given that Spring automatically satisfies any references to a FactoryBean<T> by the objects produced by that FactoryBean, you may be wondering whether you can actually access the FactoryBean directly. The answer is *yes*. Accessing FactoryBean is simple: you prefix the bean name with an ampersand in the call to `getBean()`, as shown in Listing 4-21.



**Listing 4-21.** Accessing a FactoryBean Directly

```

package com.apress.prospring6.four.factory;
// import statements omitted

public class FactoryBeanDemo {
    private static Logger logger = LoggerFactory.getLogger(FactoryBeanDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(MessageDigestConfig.class);

        MessageDigestFactoryBean factoryBean = (MessageDigestFactoryBean) ctx.
        getBean("&shaDigest");
        try {
            MessageDigest shaDigest = factoryBean.getObject();
            logger.info("Explicit use digest bean: {}", shaDigest.digest("Hello world".
            getBytes()));
        } catch (Exception ex) {
            logger.error("Could not find MessageDigestFactoryBean ", ex);
        }

        ctx.close();
    }
}

```

This feature is used in a few places in the Spring code, but your application should really have no reason to use it. The `FactoryBean` is intended to be used as a piece of supporting infrastructure to allow you to use more of your application's classes in an IoC setting. Avoid accessing `FactoryBean` directly and invoking its `getObject()` manually, and let Spring do it for you; if you do this manually, you are making extra work for yourself and are unnecessarily coupling your application to a specific implementation detail that could quite easily change in the future.

## JavaBeans PropertyEditors

If you are not entirely familiar with JavaBeans concepts, a `PropertyEditor` is an interface that converts a property's value to and from its native type representation into a `String`. Originally, this was conceived as a way to allow property values to be entered, as `String` values, into an editor and have them transformed into the correct type. However, because `PropertyEditor` implementations are inherently lightweight classes, they have found uses in many settings, including Spring.

Since a good portion of property values in a Spring-based application start life in the `BeanFactory` configuration file, they are essentially `Strings`. However, the property that these values are set on might not be `String`-typed. So, to save you from having to create a load of `String`-typed properties artificially, Spring allows you to define `PropertyEditor` beans to manage the conversion of `String`-based property values into the correct types. Figure 4-2 shows the full list of `PropertyEditor` implementations that are part of the Spring Framework, most of them being grouped in the `spring-beans` package; you can see this list with any smart Java editor, but in IntelliJ you can see all the implementations of a specific interface by opening its source code, selecting its name, and pressing `Ctrl+H` (macOS) or `Ctrl+E` (Windows).

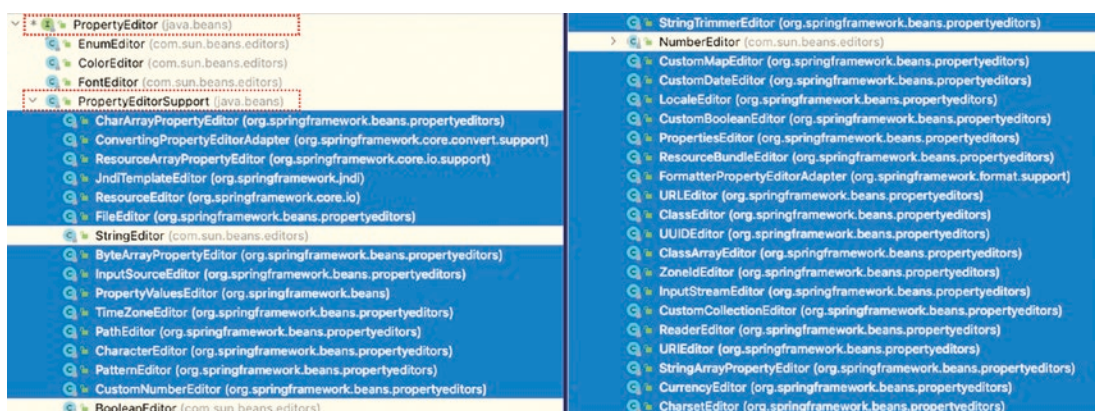


Figure 4-2. Spring PropertyEditor implementations

The list in Figure 4-2 shows that the root of the hierarchy is the `java.beans.PropertyEditor` interface. All Spring implementations actually extend the `java.beans.PropertyEditorSupport` class that provides support for building a custom property editor or to delegate to an existing one. For example, the `java.beans.StringEditor` that handles implicit conversion of `String` literals into property values to be injected in beans is pre-registered with `BeanFactory` and does not require additional configuration.

## Using the Built-in PropertyEditors

Listing 4-22 shows a simple bean that declares 14 properties, one for each of the types supported by the built-in `PropertyEditor` implementations.

Listing 4-22. Bean with Types of All Property Types Supported by Default in Spring Applications

```
package com.apress.prospring6.four;

import org.springframework.beans.PropertyEditorRegistrar;
import org.springframework.beans.PropertyEditorRegistry;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.beans.propertyeditors.CustomDateEditor;
import org.springframework.beans.propertyeditors.StringTrimmerEditor;
// some import statements omitted

@Component("builtInSample")
public class DiverseValuesContainer {
    private byte[] bytes; // ByteArrayPropertyEditor
    private Character character; // CharacterEditor
    private Class<?> cls; // ClassEditor
    private Boolean trueOrFalse; // CustomBooleanEditor
    private List<String> stringList; // CustomCollectionEditor
    private Date date; // CustomDateEditor
    private Float floatValue; // CustomNumberEditor
    private File file; // FileEditor
    private InputStream stream; // InputStreamEditor
    private Locale locale; // LocaleEditor
}
```

```

private Pattern pattern;           // PatternEditor
private Properties properties;     // PropertiesEditor
private String trimString;        // StringTrimmerEditor
private URL url;                  // URLEditor

private static Logger logger = LoggerFactory.getLogger(DiverseValuesContainer.class);

@Value("A")
public void setCharacter(Character character) {
    logger.info("Setting character: {}", character);
    this.character = character;
}

@Value("java.lang.String")
public void setCls(Class<?> cls) {
    logger.info("Setting class: {}" , cls.getName());
    this.cls = cls;
}

@Value("#{systemProperties['java.io.tmpdir']}#{systemProperties['file.separator']}
test.txt")
public void setFile(File file) {
    logger.info("Setting file: {}" , file.getAbsolutePath());
    this.file = file;
}

@Value("en_US")
public void setLocale(Locale locale) {
    logger.info("Setting locale: {}" , locale.getDisplayName());
    this.locale = locale;
}

@Value("name=Ben age=41")
public void setProperties(Properties properties) {
    logger.info("Loaded {}" , properties.size() + " properties");
    this.properties = properties;
}

@Value("https://iuliana-cosmina.com")
public void setUrl(URL url) {
    logger.info("Setting URL: {}" , url.toExternalForm());
    this.url = url;
}

@Value("John Mayer")
public void setBytes(byte... bytes) {
    logger.info("Setting bytes: {}" , Arrays.toString(bytes));
    this.bytes = bytes;
}

@Value("true")
public void setTrueOrFalse(Boolean trueOrFalse) {

```

```

    logger.info("Setting Boolean: {}" , trueOrFalse);
    this.trueOrFalse = trueOrFalse;
}

@Value("#{valuesHolder.stringList}")
public void setStringList(List<String> stringList) {
    logger.info("Setting stringList with: {}" , stringList);
    this.stringList = stringList;
}

@Value("20/08/1981")
public void setDate(Date date) {
    logger.info("Setting date: {}" , date);
    this.date = date;
}

@Value("123.45678")
public void setFloatValue(Float floatValue) {
    logger.info("Setting float value: {}" , floatValue);
    this.floatValue = floatValue;
}

@Value("#{valuesHolder.inputStream}")
public void setStream(InputStream stream) {
    this.stream = stream;
    logger.info("Setting stream & reading from it: {}" ,
        new BufferedReader(new InputStreamReader(stream)).lines().parallel().
            collect(Collectors.joining("\n")));
}

@Value("a*b")
public void setPattern(Pattern pattern) {
    logger.info("Setting pattern: {}" , pattern);
    this.pattern = pattern;
}

@Value(" String need trimming ")
public void setTrimString(String trimString) {
    logger.info("Setting trim string: {}" , trimString);
    this.trimString = trimString;
}

public static class CustomPropertyEditorRegistrar implements PropertyEditorRegistrar {
    @Override
    public void registerCustomEditors(PropertyEditorRegistry registry) {
        SimpleDateFormat dateFormatter = new SimpleDateFormat("MM/dd/yyyy");
        registry.registerCustomEditor(Date.class,
            new CustomDateEditor(dateFormatter, true));

        registry.registerCustomEditor(String.class, new StringTrimmerEditor(true));
    }
}

```

```

@Component
class ValuesHolder {

    List<String> stringList;
    InputStream inputStream;

    public ValuesHolder(List<String> stringList) {
        this.stringList = List.of("Mayer", "Psihoza", "Mazikeen");
        try {
            this.inputStream = new FileInputStream(
                System.getProperty("java.io.tmpdir")
                    + System.getProperty("file.separator")
                    + "test.txt"
            );
        } catch (FileNotFoundException e) {
            e.printStackTrace(); // we are not interested in this exception
        }
    }
    // getters omitted
}

public static void main(String... args) throws Exception {
    File baseDir = new File(System.getProperty("java.io.tmpdir"));
    Path path = Files.createFile(Path.of(baseDir.getAbsolutePath(), "test.txt"));
    Files.writeString(path, "Hello World!");
    path.toFile().deleteOnExit();

    var ctx = new AnnotationConfigApplicationContext();
    ctx.register(ValuesHolder.class, DiverseValuesContainer.class);
    ctx.refresh();

    ctx.close();
}
}

```

As you can see, although all the properties in the `DiverseValuesContainer` are not `Strings`, the values for the properties are specified as simple `Strings`. Also note that we registered the `CustomDateEditor` with the desired formatter, and `StringTrimmerEditor`, since those two editors were not registered by default in Spring by providing an implementation for `org.springframework.beans.PropertyEditorRegistrar`. Running this example yields the output shown in Listing 4-23.

**Listing 4-23.** Output Showing the Properties Being Injected with the Converted Values

```

INFO : DiverseValuesContainer - Loaded 1 properties
INFO : DiverseValuesContainer - Setting locale: English (United States)
INFO : DiverseValuesContainer - Setting date: Sun Aug 08 00:00:00 BST 1982
INFO : DiverseValuesContainer - Setting class: java.lang.String
INFO : DiverseValuesContainer - Setting file: /var/folders/gg/nm_
cb2lx72q1lz7xwwdh7tnc0000gn/T/test.txt
INFO : DiverseValuesContainer - Setting URL: https://iuliana-cosmina.com
INFO : DiverseValuesContainer - Setting bytes: [74, 111, 104, 110, 32, 77, 97, 121,
101, 114]

```

```

INFO : DiverseValuesContainer - Setting stream & reading from it: Hello World!
INFO : DiverseValuesContainer - Setting pattern: a*b
INFO : DiverseValuesContainer - Setting character: A
INFO : DiverseValuesContainer - Setting Boolean: true
INFO : DiverseValuesContainer - Setting stringList with: [Mayer, Psihoza, Mazikeen]
INFO : DiverseValuesContainer - Setting float value: 123.45678
INFO : DiverseValuesContainer - Setting trim string:   String need trimming

```

As you can see, Spring has, using the built-in `PropertyEditors`, converted the `String` representations of the various properties to the correct types. Table 4-1 lists the most important built-in `PropertyEditors` available in Spring.

**Table 4-1.** *Spring PropertyEditors*

PropertyEditor	Description
<code>ByteArrayPropertyEditor</code>	Converts <code>String</code> values to their corresponding byte representations.
<code>CharacterEditor</code>	Populates a property of type <code>Character</code> or <code>char</code> from a <code>String</code> value.
<code>ClassEditor</code>	Converts from a fully qualified class name into a <code>Class</code> instance. When using this <code>PropertyEditor</code> , be careful not to include any extraneous spaces on either side of the class name when using <code>GenericApplicationContext</code> because this results in a <code>ClassNotFoundException</code> .
<code>CustomBooleanEditor</code>	Converts a string into a Java <code>Boolean</code> type.
<code>CustomCollectionEditor</code>	Converts a source collection (e.g., represented by the valueHolder. <code>stringList</code> property SpEL expression) into the target <code>Collection</code> type.
<code>CustomDateEditor</code>	Converts a string representation of a date into a <code>java.util.Date</code> value. You need to register the <code>CustomDateEditor</code> implementation in Spring's <code>ApplicationContext</code> with the desired date format.
<code>FileEditor</code>	Converts a <code>String</code> file path into a <code>File</code> instance. Spring does not check whether the file exists.
<code>InputStreamEditor</code>	Converts a string representation of a resource (e.g., file resource using <code>file:///D:/temp/test.txt</code> or <code>classpath:test.txt</code> ) into an input stream property.
<code>LocaleEditor</code>	Converts the <code>String</code> representation of a locale, such as <code>en-GB</code> , into a <code>java.util.Locale</code> instance.
<code>PatternEditor</code>	Converts a <code>String</code> into the <code>JDK Pattern</code> object, or the other way around.
<code>PropertiesEditor</code>	Converts a <code>String</code> in the format <code>key1=value1 key2=value2 keyn=valuen</code> into an instance of <code>java.util.Properties</code> with the corresponding properties configured.
<code>StringTrimmerEditor</code>	Performs trimming on the <code>String</code> values before injection. You need to explicitly register this editor.
<code>URLEditor</code>	Converts a <code>String</code> representation of a URL into an instance of <code>java.net.URL</code> .

This set of `PropertyEditors` provides a good base for working with Spring and makes configuring your application with common components such as files and URLs much simpler.

## Creating a Custom `PropertyEditor`

Although the built-in `PropertyEditor` implementations cover most of the standard cases of property type conversion, there may come a time when you need to create your own `PropertyEditor` to support a class or a set of classes you are using in your application. Spring has full support for registering custom `PropertyEditor` implementations; the only downside is that the `java.beans.PropertyEditor` interface has a lot of methods, many of which are irrelevant to the task at hand, which is converting property types. Thankfully, starting with JDK 5 or newer the `PropertyEditorSupport` class can be used, which your own `PropertyEditors` can extend, leaving you to implement only a single method: `setAsText()`.

Let's consider a simple example to see the implementation of a custom property editor in action. Suppose we have a `FullName` class with just two properties, `firstName` and `lastName`, defined as shown in Listing 4-24.

**Listing 4-24.** `NamePropertyEditor` Class, a Custom `PropertyEditor`

```
package com.apress.prospring6.four.custom;

import org.apache.commons.lang3.builder.ToStringBuilder;

public class FullName {
    private String firstName;
    private String lastName;

    public FullName(String firstName, String lastName) {
        this.firstName = firstName;
        this.lastName = lastName;
    }
    // getters and toString(..) omitted
}
```

To simplify the application configuration, let's develop a custom editor that converts a `String` with a space separator into the `FullName` class's first name and last name, respectively. Listing 4-25 depicts the custom property editor implementation.

**Listing 4-25.** `FullName` Class, to Be Used in Showing How to Build a Custom `PropertyEditor`

```
package com.apress.prospring6.four.custom;

import java.beans.PropertyEditorSupport;

public class NamePropertyEditor extends PropertyEditorSupport {
    @Override
    public void setAsText(String text) throws IllegalArgumentException {
        String[] name = text.split("\\s");
        setValue(new FullName(name[0], name[1]));
    }
}
```

The implementation is simple. It extends JDK's `PropertyEditorSupport` class and implements the `setAsText()` method. In the method, we simply split the `String` into a string array with a space as the delimiter. Afterward, an instance of the `FullName` class is instantiated, passing in the `String` before the space character as the first name and passing the `String` after the space character as the last name. Finally, the converted value is returned by calling the `setValue()` method with the result. To use `NamePropertyEditor` in your application, you need to register the editor in Spring's `ApplicationContext`. Listing 4-26 shows an `ApplicationContext` configuration of a `CustomEditorConfigurer` and the `NamePropertyEditor` and the code to bootstrap a Spring application made of these beans.

**Listing 4-26.** Configuration and Bootstrap Code for a Spring Application Demonstrating a `PropertyEditor`

```

package com.apress.prospring6.four.custom;

import org.springframework.beans.factory.config.CustomEditorConfigurer;
// other import statements omitted

@Component
class Person {
    private FullName name;

    @Value("John Mayer")
    public void setName(FullName name) {
        this.name = name;
    }

    public FullName getName() {
        return name;
    }
}

@Configuration
@ComponentScan
class CustomPropertyEditorCfg {

    @Bean
    CustomEditorConfigurer customEditorConfigurer(){
        var cust = new CustomEditorConfigurer();
        cust.setCustomEditors(Map.of(FullName.class, NamePropertyEditor.class));
        return cust;
    }
}

public class CustomPropertyEditorDemo {
    private static Logger logger = LoggerFactory.getLogger(CustomPropertyEditorDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(CustomPropertyEditorCfg.class);

        var person = ctx.getBean(Person.class, "person");
        logger.info("Person full name = {}" , person.getName());
    }
}

```



```

        ctx.close();
    }
}

```

You should notice two things in this configuration:

- Custom `PropertyEditors` get injected into the `CustomEditorConfigurer` bean by using the Map-typed `customEditors` property.
- Each entry in the Map represents a single `PropertyEditor`, with the entry key being the class for which the `PropertyEditor` is used. As you can see, the key for `NamePropertyEditor` is `com.apress.prospring6.four.custom.FullName`, which signifies that this is the class for which this implementation should be used.

Feel free to run the code in Listing 4-26 and the output should be a simple:

```
INFO : CustomPropertyEditorDemo - Person full name = com.apress.prospring6.four.custom.FullName@5b38c1ec[first=John,last=Mayer]
```

This is the output from the `toString()` method implemented in the `FullName` class (that is not shown because it is quite basic and not relevant to this section), and you can see that the first name and last name of the `FullName` object were correctly populated by Spring by using the configured `NamePropertyEditor`. Starting from version 3, Spring introduced the Type Conversion API and the Field Formatting Service Provider Interface (SPI), which provide a simpler and well-structured API to perform type conversion and field formatting. It's especially useful for web application development. Both the Type Conversion API and the Field Formatting SPI are discussed in detail in **Chapter 11**.

## More Spring ApplicationContext Configuration

So far, although we are discussing Spring's `ApplicationContext`, most of the features that we have covered mainly surround the `BeanFactory` interface wrapped by `ApplicationContext`. In Spring, various implementations of the `BeanFactory` interface are responsible for bean instantiation, providing dependency injection and life-cycle support for beans managed by Spring. However, as stated earlier, being an extension of the `BeanFactory` interface, `ApplicationContext` provides other useful functionalities as well. The main function of `ApplicationContext` is to provide a much richer framework on which to build your applications.

`ApplicationContext` is much more aware of the beans (compared to `BeanFactory`) that you configure within it, and in the case of many of the Spring infrastructure classes and interfaces, such as `BeanFactoryPostProcessor`, it interacts with them on your behalf, reducing the amount of code you need to write in order to use Spring.

The biggest benefit of using `ApplicationContext` is that it allows you to configure and manage Spring and Spring-managed resources in a completely declarative way. This means that wherever possible, Spring provides support classes to load `ApplicationContext` into your application automatically, thus removing the need for you to write any code to access `ApplicationContext`. In practice, this feature is currently available only when you are building web applications with Spring, which allows you to initialize Spring's `ApplicationContext` in the web application deployment descriptor. When using a stand-alone application, you can also initialize Spring's `ApplicationContext` by simple coding, as you've been shown so far.

In addition to providing a model that is focused more on declarative configuration, `ApplicationContext` supports the following features:

- Internationalization
- Event publication

- Resource management and access
- Additional life-cycle interfaces
- Improved automatic configuration of infrastructure components

In the following sections, we discuss some of the most important features in `ApplicationContext` besides DI.

## Internationalization

One area where Spring really excels is in support for internationalization (i18n). Using the `MessageSource` interface, your application can access String resources, called *messages*, stored in a variety of languages. For each language you want to support in your application, you maintain a list of messages that are keyed to correspond to messages in other languages. For instance, if you wanted to display “*The quick brown fox jumped over the lazy dog*” in English and in Ukrainian, you would create two messages, both keyed as `msg`; the one for English would read “*The quick brown fox jumped over the lazy dog*” and the one for Ukrainian would read “*Те що Росія робить з Україною, є злочинном.*”

Although you don’t need to use `ApplicationContext` to use `MessageSource`, the `ApplicationContext` interface extends `MessageSource` and provides special support for loading messages and for making them available in your environment. The automatic loading of messages is available in any environment, but automatic access is provided only in certain Spring-managed scenarios, such as when you are using Spring’s MVC framework to build a web application. Although any class can implement `ApplicationContextAware` and thus access the automatically loaded messages, we suggest a better solution later in this chapter, in the section “Using `MessageSource` in Stand-Alone Applications.”

## Internationalization with `MessageSource`

Aside from `ApplicationContext`, Spring provides three `MessageSource` implementations:

- `ResourceBundleMessageSource`
- `ReloadableResourceBundleMessageSource`
- `StaticMessageSource`

The `StaticMessageSource` implementation should not be used in a production application because you can’t configure it externally, and this is generally one of the main requirements when you are adding i18n capabilities to your application. `ResourceBundleMessageSource` loads messages by using a Java `ResourceBundle`. `ReloadableResourceBundleMessageSource` is essentially the same, except it supports scheduled reloading of the underlying source files. All three `MessageSource` implementations also implement another interface called `HierarchicalMessageSource`, which allows for many `MessageSource` instances to be nested. This is key to the way `ApplicationContext` works with `MessageSource` instances. To take advantage of `ApplicationContext`’s support for `MessageSource`, you must define a bean in your configuration of type `MessageSource` and with the name `messageSource`. `ApplicationContext` takes this `MessageSource` and nests it within itself, allowing you to access the messages by using `ApplicationContext`. This can be hard to visualize, so take a look at the example presented in Listing 4-27, which shows a simple application that accesses a set of messages for both the English and Ukrainian locales.

**Listing 4-27.** MessageSource Configuration Using Spring ApplicationContext

```

package com.apress.prospring6.four;

import org.springframework.context.MessageSource;
import org.springframework.context.support.ResourceBundleMessageSource;
// other import statements omitted

@Configuration
class MessageSourceConfig {

    @Bean
    public MessageSource messageSource(){
        var messageSource = new ResourceBundleMessageSource();
        messageSource.setBasenames("labels");
        return messageSource;
    }
}

public class MessageSourceDemo {
    private static Logger logger = LoggerFactory.getLogger(MessageSourceDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(MessageSourceConfig.class);

        Locale english = Locale.ENGLISH;
        Locale ukrainian = new Locale("uk", "UA");
        logger.info(ctx.getMessage("msg", null, english));
        logger.info(ctx.getMessage("msg", null, ukrainian));
        logger.info(ctx.getMessage("nameMsg", new Object[]{ "Iuliana", "Cosmina" },
            english));
        logger.info(ctx.getMessage("nameMsg", new Object[]{ "Iuliana", "Cosmina" },
            ukrainian));
        ctx.close();
    }
}

```

Don't worry about the calls to `getMessage()` just yet; we will return to those shortly. For now, just know that they retrieve a keyed message for the specified locale.

In the `MessageSourceConfig` class we define a `ResourceBundleMessageSource` bean with the name `messageSource` as required by Spring. We configure it with a set of names to form the base of its file set. A Java `ResourceBundle`, which is used by `ResourceBundleMessageSource`, works on a set of properties files that are identified by base names. When looking for a message for a particular `Locale`, the `ResourceBundle` looks for a file that is named as a combination of the base name and the locale name. For instance, if the base name is `foo` and we are looking for a message in the `en-GB` (British English) locale, `ResourceBundle` looks for a file called `foo_en_GB.properties`.

For the previous example, the content of the properties files for English (`labels_en.properties`) and Ukrainian (`labels_uk_UA.properties`) is shown in Listing 4-28.

**Listing 4-28.** Content of `MessageSource` Resource Files

```
#labels_en.properties
msg=Witnessing and not stopping evil is condoning it
nameMsg=My name is {0} {1}

#labels_de_DE.properties
msg=Бути свідком зла і не зупиняти його – це брати участь у цьому
nameMsg=Мене звати {0} {1}
```

These files are located in the `resources` directory and are added to the application classpath.

Now, this example just raises even more questions. What do those calls to `getMessage()` mean? Why did we use `ApplicationContext.getMessage()` rather than access the `ResourceBundleMessageSource` bean directly? We'll answer each of these questions in turn.

## Using the `getMessage()` Method

The `MessageSource` interface defines three overloads for the `getMessage()` method. These are described in Table 4-2.

**Table 4-2.** `getMessage(..)` method signatures

Method Signature	Description
<code>getMessage(String, Object[], Locale)</code>	This is the standard <code>getMessage()</code> method. The <code>String</code> argument is the key of the message corresponding to the key in the properties file. In the previous code sample, the first call to <code>getMessage()</code> used <code>msg</code> as the key, and this corresponded to the following entry in the properties file for the <code>en</code> locale: <code>msg=The quick brown fox jumped over the lazy dog</code> . The <code>Object[]</code> array argument is used for replacements in the message. In the third call to <code>getMessage()</code> , we passed in an array of two <code>Strings</code> . The message keyed as <code>nameMsg</code> was <code>My name is {0} {1}</code> . The numbers in braces are placeholders, and each one is replaced with the corresponding entry in the argument array. The final argument, <code>Locale</code> , tells <code>ResourceBundleMessageSource</code> which properties file to look in. Even though the first and second calls to <code>getMessage()</code> in the example used the same key, they returned different messages that correspond to the <code>Locale</code> setting that was passed in to <code>getMessage()</code> .
<code>getMessage(String, Object[], String, Locale)</code>	This overload works in the same way as <code>getMessage(String, Object[], Locale)</code> , other than the second <code>String</code> argument, which allows us to pass in a default value in case a message for the supplied key is not available for the supplied <code>Locale</code> .
<code>getMessage(MessageSourceResolvable, Locale)</code>	This overload is a special case. We discuss it in further detail in the upcoming section “The <code>MessageSourceResolvable</code> Interface.”

## Why Use `ApplicationContext` As a `MessageSource`?

To answer this question, we need to jump a little ahead of ourselves and look at the web application support in Spring. The answer, in general, is that you shouldn't use `ApplicationContext` as a `MessageSource` because doing so couples your bean to `ApplicationContext` unnecessarily (this is discussed in more detail in the next section). You should use `ApplicationContext` when you are building a web application by using Spring's MVC framework.

The core interface in Spring MVC is `Controller`. Unlike frameworks such as Struts that require you to implement your controllers by inheriting from a concrete class, Spring simply requires that you implement the `Controller` interface (or annotate your controller class with the `@Controller` annotation). Having said that, Spring provides a collection of useful base classes that you will use to implement your own controllers. Each of these base classes is a subclass (directly or indirectly) of the `ApplicationObjectSupport` class, which is a convenient superclass for any application objects that want to be aware of `ApplicationContext`. Remember that in a web application setting, `ApplicationContext` is loaded automatically.

`ApplicationObjectSupport` accesses this `ApplicationContext`, wraps it in a `MessageSourceAccessor` object, and makes that available to your controller via the protected `getMessageSourceAccessor()` method. `MessageSourceAccessor` provides a wide array of convenient methods for working with `MessageSource` instances. This form of autoinjection is quite beneficial; it removes the need for all of your controllers to expose a `MessageSource` property.

However, this is not the best reason for using `ApplicationContext` as a `MessageSource` in your web application. The main reason to use `ApplicationContext` rather than a manually defined `MessageSource` bean is that Spring does, where possible, expose `ApplicationContext`, as a `MessageSource`, to the view tier. This means when you are using Spring's JSP tag library, the `<spring:message>` tag automatically reads messages from `ApplicationContext`, and when you are using JSTL, the `<fmt:message>` tag does the same.

All of these benefits mean that it is better to use the `MessageSource` support in `ApplicationContext` when you are building a web application, rather than manage an instance of `MessageSource` separately. This is especially true when you consider that all you need to do to take advantage of this feature is to configure a `MessageSource` bean with the name `messageSource`.

## Using `MessageSource` in Stand-Alone Applications

When you are using `MessageSource` in stand-alone applications, where Spring offers no additional support other than to nest the `MessageSource` bean automatically in `ApplicationContext`, it is best to make the `MessageSource` available by using dependency injection. You can opt to make your bean `ApplicationContextAware`, but doing so precludes its use in a `BeanFactory` context. Add to this that you complicate testing without any discernible benefit, and it is clear that you should stick to using dependency injection to access `MessageSource` objects in a stand-alone setting.

## The `MessageSourceResolvable` Interface

You can use an object that implements `MessageSourceResolvable` in place of a key and a set of arguments when you are looking up a message from a `MessageSource`. This interface is most widely used in the Spring validation libraries to link `Error` objects to their internationalized error messages.

## Events Publication

Another feature of `ApplicationContext` not present in `BeanFactory` is the ability to publish and receive events by using `ApplicationContext` as a broker. In this section, you will take a look at its usage.

## Using Application Events

An event is a class derived from `ApplicationEvent`, which itself derives from `java.util.EventObject`. Any bean can listen for events by implementing the `ApplicationListener<T>` interface; `ApplicationContext` automatically registers any bean that implements this interface as a listener when it is configured. Events are published using the `ApplicationEventPublisher.publishEvent()` method, so the publishing class must have knowledge of `ApplicationContext` (which extends the `ApplicationEventPublisher` interface). In a web application, this is simple because many of your classes are derived from Spring Framework classes that allow access to `ApplicationContext` through a protected method. In a stand-alone application, you can have your publishing bean implement `ApplicationContextAware` to enable it to publish events. Listing 4-29 shows an example of a basic event class.

**Listing 4-29.** Basic Spring `ApplicationEvent` Class

```
package com.apress.prospring6.four.events;

import org.springframework.context.ApplicationEvent;

public class MessageEvent extends ApplicationEvent {
    private String msg;

    public MessageEvent(Object source, String msg) {
        super(source);
        this.msg = msg;
    }

    public String getMessage() {
        return msg;
    }
}
```

This code is quite basic; the only point of note is that `ApplicationEvent` has a single constructor that accepts a reference to the source of the event. This is reflected in the constructor for `MessageEvent`. In Listing 4-30, you can see the code for the listener.

**Listing 4-30.** Basic Spring `ApplicationListener` Class

```
package com.apress.prospring6.four.events;

import org.springframework.context.ApplicationListener;
// other import statements omitted

@Component
public class MessageEventListener implements ApplicationListener<MessageEvent> {
    private static Logger logger = LoggerFactory.getLogger(MessageEventListener.class);

    @Override
    public void onApplicationEvent(MessageEvent event) {
        MessageEvent msgEvt = event;
        logger.info("Received: {}" , event.getMessage());
    }
}
```

The `ApplicationListener` interface defines a single method, `onApplicationEvent(..)`, that is called by Spring when an event is raised. `MessageEventListener` shows its interest only in events of type `MessageEvent` (or its subclasses) by implementing the strongly typed `ApplicationListener` interface. If a `MessageEvent` was received, it writes the message to `stdout`. Publishing events is simple; it is just a matter of creating an instance of the event class and passing it to the `ApplicationEventPublisher.publishEvent()` method, as shown in Listing 4-31.

**Listing 4-31.** Basic Spring `ApplicationContextAware` Class and Code to Test It

```

package com.apress.prospring6.four.events;

import org.springframework.context.ApplicationContextAware;
// other import statements omitted

@Configuration
@ComponentScan
class EventsConfig{ }

@Component
public class Publisher implements ApplicationContextAware {
    private ApplicationContext ctx;

    @Override /** @link
    ApplicationContextAware#setApplicationContext(ApplicationContext) */
    public void setApplicationContext(ApplicationContext applicationContext) throws
    BeansException {
        this.ctx = applicationContext;
    }

    public void publish(String message) {
        ctx.publishEvent(new MessageEvent(this, message));
    }

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(EventsConfig.class);

        Publisher pub = (Publisher) ctx.getBean("publisher");
        pub.publish("I send an SOS to the world... ");
        pub.publish("... I hope that someone gets my...");
        pub.publish("... Message in a bottle");
    }
}

```

A code shortcut artifice was used here to keep things simple: the `Publisher` bean type contains the `main(..)` methods as well, which retrieves an instance of itself from `ApplicationContext` and then, using the `publish()` method, publishes two `MessageEvent` instances to `ApplicationContext`. The `Publisher` bean instance accesses the `ApplicationContext` instance by implementing `ApplicationContextAware`. The `EventsConfig` configuration class is empty and is just declared to enable component scanning within the package, so the `Publisher` and the `MessageEventListener` bean definitions are picked up.

Running this example results in the output shown in Listing 4-32, proving that the `MessageEventListener` reacts to the events published by the `Publisher` bean using the injected `ApplicationContext`.

**Listing 4-32.** Output Produced by Running the Code in Listing 4-31

```
INFO : MessageEventListener - Received: I send an SOS to the world...
INFO : MessageEventListener - Received: ... I hope that someone gets my...
INFO : MessageEventListener - Received: ... Message in a bottle
```

## Considerations for Event Usage

In many cases in an application, certain components need to be notified of certain events. Often you do this by writing code to notify each component explicitly or by using a messaging technology such as JMS. The drawback of writing code to notify each component in turn is that you are coupling those components to the publisher, in many cases unnecessarily.

Consider a situation whereby you cache product details in your application to avoid trips to the database. Another component allows product details to be modified and persisted to the database. To avoid making the cache invalid, the update component explicitly notifies the cache that the user details have changed. In this example, the update component is coupled to a component that, really, has nothing to do with its business responsibility. A better solution would be to have the update component publish an event every time a product's details are modified and then have interested components, such as the cache, listen for that event. This has the benefit of keeping the components decoupled, which makes it simple to remove the cache if needed or to add another listener that is interested in knowing when a product's details change.

Using JMS in this case would be overkill because the process of invalidating the product's entry in the cache is quick and is not business critical. The use of the Spring event infrastructure adds very little overhead to your application.

Typically, we use events for reactionary logic that executes quickly and is not part of the main application logic. In the previous example, the invalidation of a product in cache happens in reaction to the updating of product details, it executes quickly (or it should), and it is not part of the main function of the application. For processes that are long-running and form part of the main business logic, it is recommended to use JMS or similar messaging systems such as RabbitMQ. The main benefits of using JMS are that it is more suited to long-running processes, and as the system grows, you can, if necessary, factor the JMS-driven processing of messages containing business information onto a separate machine.

## Accessing Resources

Often an application needs to access a variety of resources in different forms. You might need to access some configuration data stored in a file in the file system, some image data stored in a JAR file on the classpath, or maybe some data on a server elsewhere. Spring provides a unified mechanism for accessing resources in a protocol-independent way. This means your application can access a file resource in the same way, whether it is stored in the file system, in the classpath, or on a remote server.

At the core of Spring's resource support is the `org.springframework.core.io.Resource` interface. The `Resource` interface defines ten self-explanatory methods:

- `contentLength()`
- `exists()`
- `getDescription()`
- `getFile()`
- `getFileName()`



- `getURI()`
- `getURL()`
- `isOpen()`
- `isReadable()`
- `lastModified()`

In addition to these ten methods, there is one that is not quite so self-explanatory: `createRelative()`. The `createRelative()` method creates a new `Resource` instance by using a path that is relative to the instance on which it is invoked. You can provide your own `Resource` implementations, although that is outside the scope of this chapter, but in most cases, you use one of the built-in implementations for accessing a file (the `FileSystemResource` class), a classpath (the `ClassPathResource` class), or URL resources (the `UrlResource` class). Internally, Spring uses another interface, `ResourceLoader`, and the default implementation, `DefaultResourceLoader`, to locate and create `Resource` instances. However, you generally won't interact with `DefaultResourceLoader`, instead using another `ResourceLoader` implementation, called `ApplicationContext`. Listing 4-33 depicts an application that accesses three resources by using `ApplicationContext`.

**Listing 4-33.** Application Sample Accessing Various Spring Resources

```

package com.apress.prospring6.four;

import org.springframework.core.io.Resource;
// other import statements omitted

public class ResourceDemo {
    private static Logger logger = LoggerFactory.getLogger(ResourceDemo.class);

    public static void main(String... args) throws Exception{
        var ctx = new AnnotationConfigApplicationContext();

        File baseDir = new File(System.getProperty("java.io.tmpdir"));
        Path filePath = Files.createFile(Path.of(baseDir.getAbsolutePath(), "test.txt"));
        Files.writeString(filePath, "Hello World!");
        filePath.toFile().deleteOnExit();

        Resource res1 = ctx.getResource("file://" + filePath);
        displayInfo(res1);

        Resource res2 = ctx.getResource("classpath:test.txt");
        displayInfo(res2);

        Resource res3 = ctx.getResource("http://iuliana-cosmina.com");
        displayInfo(res3);
    }

    private static void displayInfo(Resource res) throws Exception{
        logger.info("Resource class: {}" , res.getClass());
        logger.info("Resource URL content: {}" ,
            new BufferedReader(new InputStreamReader((InputStream) res.getURL().
                getContent())).lines().parallel().collect(Collectors.joining("\n")));
    }
}

```

```

        logger.info(" -----");
    }
}

```

Notice that in each call to `getResource()`, we pass in a URI for each resource. You will recognize the common `file:` and `http:` protocols that we pass in for `res1` and `res3`. The `classpath:` protocol we use for `res2` is Spring-specific and indicates that `ResourceLoader` should look in the classpath for the resource.

Running this example results in the output depicted in Listing 4-34.

**Listing 4-34.** Output of Code in Listing 4-33

```

INFO : ResourceDemo - Resource class: class org.springframework.core.io.FileUrlResource
INFO : ResourceDemo - Resource URL content: Hello World!
INFO : ResourceDemo - -----
INFO : ResourceDemo - Resource class: class org.springframework.core.io.ClassPathResource
INFO : ResourceDemo - Resource URL content: Hello World from the classpath!
INFO : ResourceDemo - -----
INFO : ResourceDemo - Resource class: class org.springframework.core.io.UrlResource
INFO : ResourceDemo - Resource URL content: <html>
<center><h1>301 Moved Permanently</h1></center></body>
</html>
INFO : ResourceDemo - -----

```



The reason you are getting the 301 Moved Permanently response when trying to access the <http://iuliana-cosmina.com> site is because the site actually uses HTTPS. To extract the actual content of the main page, use `ctx.getResource("https://iuliana-cosmina.com")`.

---

Notice that for both the `file:` and `http:` protocols, Spring returns a `UrlResource` instance. Spring does include a `FileSystemResource` class, thus the `DefaultResourceLoader` does not use this class at all. It's because Spring's default resource-loading strategy treats the URL and file as the same type of resource with difference protocols (`file:` and `http:`). If an instance of `FileSystemResource` is required, use `FileSystemResourceLoader`. Once a `Resource` instance is obtained, you are free to access the contents as you see fit, using `getFile()`, `getInputStream()`, or `getURL()`. In some cases, such as when you are using the `http:` protocol, the call to `getFile()` results in a `FileNotFoundException`. For this reason, we recommend that you use `getInputStream()` to access resource contents because it is likely to function for all possible resource types.

## Advanced Java Configuration Classes

So far in the book Java configuration classes have been pretty basic. Let's proceed to more configuration options. Considering the `MessageRender` and `ConfigurableMessageProvider` introduced in **Chapter 3**, let's say we want to externalize the message into a properties file named `message.properties`. The `ConfigurableMessageProvider.message` property is to be injected with a value read from this file by using constructor injection. The content of `message.properties` is as follows:

```
message=Only hope can keep me together
```

Let's see the revised testing program, which loads the properties files by using the `@PropertySource` annotation and then injects them into the message provider implementation. Listing 4-35 shows the testing program, the configuration class enriched with annotations on bean declarations, and the simplified bean types.

**Listing 4-35.** `@PropertySource` Usage Example

```

package com.apress.prospring6.four;

import com.apress.prospring6.two.decoupled.MessageProvider;
import com.apress.prospring6.two.decoupled.MessageRenderer;
import org.springframework.core.env.Environment;
// other import statements omitted

public class PropertySourcesDemo {

    public static void main(String... args) {
        ApplicationContext ctx =
            new AnnotationConfigApplicationContext(PropertySourcesCfg.class);
        MessageRenderer mr = ctx.getBean("messageRenderer", MessageRenderer.class);
        mr.render();
    }
}

@Configuration
@PropertySource(value = "classpath:message.properties")
class PropertySourcesCfg {
    @Autowired
    Environment env;

    @Bean
    @Lazy
    public MessageProvider messageProvider() {
        return new ConfigurableMessageProvider(env.getProperty("message"));
    }

    @Bean(name = "messageRenderer")
    @Scope(value="prototype")
    @DependsOn(value="messageProvider")
    public MessageRenderer messageRenderer() {
        MessageRenderer renderer = new StandardOutMessageRenderer();
        renderer.setMessageProvider(messageProvider());
        return renderer;
    }
}

class ConfigurableMessageProvider implements MessageProvider {

    private String message;

    public ConfigurableMessageProvider(@Value("Configurable message") String message) {
        this.message = message;
    }
}

```

```

@Override
public String getMessage() {
    return message;
}
}

class StandardOutMessageRenderer implements MessageRenderer {
    private static Logger logger = LoggerFactory.getLogger(StandardOutMessageRenderer.class);

    private MessageProvider messageProvider;

    @Override
    public void setMessageProvider(MessageProvider provider) {
        this.messageProvider = provider;
    }

    @Override
    public MessageProvider getMessageProvider() {
        return this.messageProvider;
    }

    @Override
    public void render() {
        logger.info(messageProvider.getMessage());
    }
}

```

Listing 4-35 introduces a few annotations that are explained in Table 4-3. Some of them have been used in Chapter 3 already, but they were not explained at the time. Beans that are defined using a stereotype annotation like `@Component`, `@Service`, and others can be used in a Java configuration class, by enabling component scanning and autowiring them where needed. In the example shown in Listing 4-36, we declare `ConfigurableMessageProvider` as a service bean.

**Table 4-3.** Java Configuration Annotations Table

Annotation	Description
<code>@PropertySource</code>	This annotation is used to load properties files into Spring's <code>ApplicationContext</code> , which accepts the location as the argument (more than one location can be provided).
<code>@Lazy</code>	This annotation instructs Spring to instantiate the bean only when requested. This annotation has a default value attribute that is <code>true</code> by default; thus, using <code>@Lazy(value=true)</code> is equivalent to using <code>@Lazy</code> .
<code>@Scope</code>	This annotation is used to define the bean scope, when the desired scope is other than <code>singleton</code> .
<code>@DependsOn</code>	This annotation tells Spring that a certain bean depends on some other beans, so Spring will make sure that those beans are instantiated first.
<code>@Autowired</code>	This annotation is used here on the env variable, which is of <code>Environment</code> type. This is the <code>Environment</code> abstraction feature that Spring provides. We discuss it later in this chapter.

An application can have multiple configuration classes, which can be used to decouple configuration and organize beans by purpose (for example, one class can be dedicated to DAO beans declaration, one for the service beans declaration, and so forth). To show this, we can modify the previous example and define the `ConfigurableMessageProvider` as a service and declare a configuration class named `ServiceConfig` declaring this bean type. The configuration class declaring the `MessageRenderer` bean will use `@Import` annotation to access the `MessageProvider` bean declared by the `ServiceConfig` class. Listing 4-36 shows these configuration classes.

**Listing 4-36.** `@Import` Usage Example

```

package com.apress.prospring6.four.multiple;

import org.springframework.context.annotation.Import;
import org.springframework.stereotype.Service;
// other import statements omitted

@Service("provider")
class ConfigurableMessageProvider implements MessageProvider {
    // same code as in previous listings
}

class StandardOutMessageRenderer implements MessageRenderer {
    // same code as in previous listings
}

@Configuration
@ComponentScan
class ServiceConfig {
}

@Configuration
@Import(ServiceConfig.class)
class TheOtherConfig {

    @Autowired
    MessageProvider provider;

    @Bean(name = "messageRenderer")
    public MessageRenderer messageRenderer() {
        MessageRenderer renderer = new StandardOutMessageRenderer();
        renderer.setMessageProvider(provider);
        return renderer;
    }
}

public class ImportDemo {
    public static void main(String... args) {
        ApplicationContext ctx = new AnnotationConfigApplicationContext(TheOtherConfig.class);
        MessageRenderer mr = ctx.getBean("messageRenderer", MessageRenderer.class);
        mr.render();
    }
}

```

In the main method in class `ImportDemo`, only the `TheOtherConfig` class is required when the application context is created, since this class imports all the bean definitions that are declared within or discovered via scanning by the `ServiceConfig` imported class.

## Profiles

Another interesting feature that Spring provides is the concept of configuration profiles. Basically, a profile instructs Spring to configure only the `ApplicationContext` instance that was defined when the specified profile was active. In this section, we demonstrate how to use profiles in a simple program.

### An Example of Using the Spring Profiles Feature

Let's say there is a service called `FoodProviderService` that is responsible for providing food to schools, including kindergarten and high school. The `FoodProviderService` interface has only one method called `provideLunchSet()`, which produces the lunch set to each student for the calling school. A lunch set is a list of `Food` objects, which is a simple class that has only a name attribute. Listing 4-37 shows the `Food` class.

**Listing 4-37.** Food Bean Type

```
package com.apress.prospring6.four.profile;

public class Food {
    private String name;

    public Food() {
    }

    public Food(String name) {
        this.name = name;
    }
    // getters and setters omitted
}
```

The `FoodProviderService` interface is depicted in Listing 4-38.

**Listing 4-38.** FoodProviderService Interface

```
package com.apress.prospring6.four.profile;

import java.util.List;

public interface FoodProviderService {
    List<Food> provideLunchSet();
}
```

Now suppose that there are two providers for the lunch set, one for kindergarten and one for high school. The lunch set produced by them is different, although the service they provide is the same, that is, to provide lunch to pupils/students. So, now let's create two implementations of `FoodProviderService`, using the same name but putting them into different packages to identify their target school. The two classes are shown in Listing 4-39.

**Listing 4-39.** FoodProviderService Implementations

```
// chapter04/src/main/java/com/apress/prospring6/four/profile/
kindergarten/FoodProviderServiceImpl.java
package com.apress.prospring6.four.profile.kindergarten;

import com.apress.prospring6.four.profile.Food;
import com.apress.prospring6.four.profile.FoodProviderService;

import java.util.List;

public class FoodProviderServiceImpl implements FoodProviderService {

    @Override
    public List<Food> provideLunchSet() {
        return List.of(new Food("Milk"), new Food("Biscuits"));
    }
}

// chapter04/src/main/java/com/apress/prospring6/four/profile/
highschool/FoodProviderServiceImpl.java
package com.apress.prospring6.four.profile.highschool;
// same imports as above

public class FoodProviderServiceImpl implements FoodProviderService {

    @Override
    public List<Food> provideLunchSet() {
        return List.of(new Food("Coke"), new Food("Hamburger"), new Food("Fries"));
    }
}
```

From the previous listings, you can see that the two implementations provide the same `FoodProviderService` interface but produce different combinations of food in the lunch set. So, now suppose a kindergarten wants the provider to deliver the lunch set for their students; let's see how we can use Spring's profile configuration to achieve this. We will run through the Java configuration first. We will create two configuration classes, one for the kindergarten profile and the other for the high-school profile. Listing 4-40 depicts the two profile configurations.

**Listing 4-40.** Profiles configuration

```
package com.apress.prospring6.four.profile.highschool;

import org.springframework.context.annotation.Profile;
// other import statements omitted

@Configuration
@Profile("highschool")
public class HighSchoolConfig {

    @Bean
    FoodProviderService foodProviderService(){
```

```

        return new FoodProviderServiceImpl();
    }
}

package com.apress.prospring6.four.profile.kindergarten;
// other import statements omitted

@Configuration
@Profile("kindergarten")
public class KindergartenConfig {

    @Bean
    FoodProviderService foodProviderService(){
        return new FoodProviderServiceImpl();
    }
}

```

In the two configuration classes, notice the `@Profile` annotation declared with "highschool" and "kindergarten" respectively. This annotation tells Spring that those beans in the file should be instantiated only when the specified profile is active. To activate the correct profile when using Spring's `ApplicationContext` in a stand-alone application, we need to provide the profile as a value for the `spring.profiles.active` JVM argument, set it on the created context, add the configuration classes, and then refresh the context. This will ensure that only the beans matching the configured profile will be added to the context. Listing 4-41 shows the code to do this and test the results by printing the items returned by the `FoodProviderService.provideLunchSet()` call.

**Listing 4-41.** FoodProviderService Testing

```

package com.apress.prospring6.four.profile;
// import statements omitted

public class ProfileDemo {
    private static Logger logger = LoggerFactory.getLogger(ProfileDemo.class);

    public static void main(String... args) {
        var profile= System.getProperty("spring.profiles.active");

        var ctx = new AnnotationConfigApplicationContext();
        ctx.getEnvironment().setActiveProfiles(profile);
        ctx.register(HighSchoolConfig.class, KindergartenConfig.class);
        ctx.refresh();

        var foodProviderService = ctx.getBean("foodProviderService",
            FoodProviderService.class);
        var lunchSet = foodProviderService.provideLunchSet();
        lunchSet.forEach(food -> logger.info("Food: {}", food.getName()));
        ctx.close();
    }
}

```

To provide the `-Dspring.profiles.active="kindergarten"` JVM argument when running the `ProfileDemo` class in IntelliJ IDEA, you need to customize the launcher as shown in Figure 4-3.



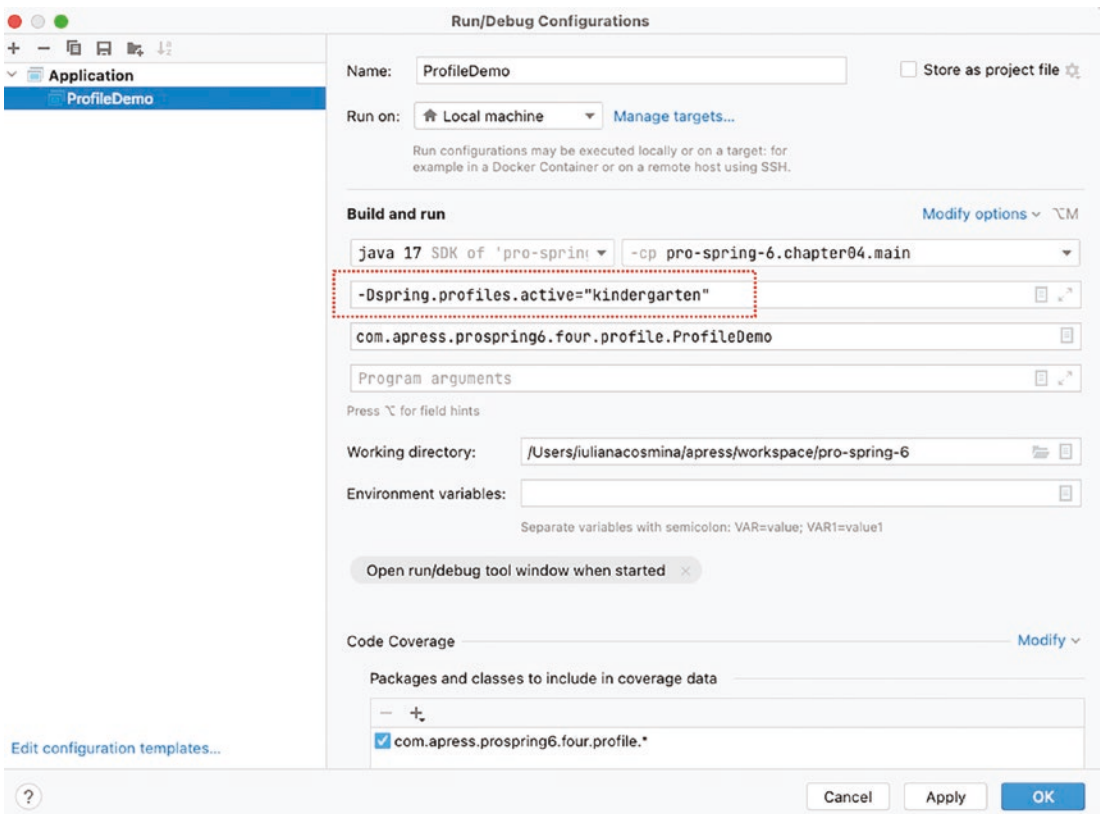


Figure 4-3. Spring Application Launcher with activated profile

You can provide the profile value in the same way when running a main class or executable jar in the command line.

Running the ProfileDemo class with the JVM `-Dspring.profiles.active="kindergarten"` argument produces the following output:

```
DEBUG: AbstractEnvironment - Activating profiles [kindergarten]
INFO : ProfileDemo - Food: Coke
INFO : ProfileDemo - Food: Hamburger
INFO : ProfileDemo - Food: Fries
```

This is exactly what the implementation of the kindergarten provider will produce for the lunch set. Now change the profile argument from the previous listing to high school (`-Dspring.profiles.active="highschool"`), and the output will change to the following:

```
DEBUG: AbstractEnvironment - Activating profiles [highschool]
INFO : ProfileDemo - Food: Coke
INFO : ProfileDemo - Food: Hamburger
INFO : ProfileDemo - Food: Fries
```

The active profile was set programmatically in Listing 4-41, by calling `ctx.getEnvironment().setActiveProfiles("..")`. The context is created empty and configuration is added after the profile is set. But the context can be created directly from all the configuration classes, and the profile is activated automatically, leading to only beans specific to it being added to the context. If no profile is specified, the application can still be functional by calling `ctx.getEnvironment().setDefaultProfiles("..")`, and providing an argument consisting of a list of profile names activated by default.

Listing 4-42 shows the other way of configuring an application context using profiled configurations.

**Listing 4-42.** FoodProviderService Testing (Second Version)

```
package com.apress.prospring6.four.profile;
// other import statements omitted

public class AnotherProfileDemo {
    private static Logger logger = LoggerFactory.getLogger(AnotherProfileDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(HighSchoolConfig.class,
            KindergartenConfig.class);

        var foodProviderService = ctx.getBean("foodProviderService",
            FoodProviderService.class);
        var lunchSet = foodProviderService.provideLunchSet();
        lunchSet.forEach(food -> logger.info("Food: {}", food.getName()));
        ctx.close();
    }
}
```

Additionally, you can enable profiles by using the `@ActiveProfiles` annotation, but for this we have to talk about testing first, because this annotation can only be used on testing classes.

## Considerations for Using Profiles

The profiles feature in Spring creates another way for developers to manage the application's running configuration, which used to be done in build tools (for example, Maven's profile support). Build tools rely on the arguments passed into the tool to pack the correct configuration/property files into the Java archive (JAR or WAR, depending on the application type) and then deploy to the target environment. Spring's profile feature lets you as an application developer define the profiles by yourself and activate them either programmatically or by passing in the JVM argument. By using Spring's profile support, you can now use the same application archive and deploy to all environments by passing in the correct profiles as an argument during JVM startup. For example, you can have applications with different profiles such as (dev, hibernate), (prd, jdbc), and so on, with each combination representing the running environment (development or production) and the data access library to use (Hibernate or JDBC). It brings application profile management into the programming side.

But this approach also has its drawbacks. For example, some may argue that putting all the configurations for different environments into application configuration files or Java classes and bundling them together will be error-prone if not handled carefully (for example, the administrator may forget to set the correct JVM argument in the application server environment). Packing files for all profiles together will also make the package a bit larger than usual. Again, let the application and configuration requirements drive you to select the approach that best fits your project.

## Environment and PropertySource Abstraction

To set the active profile, a call to `ctx.getEnvironment()` is necessary to provide access to Spring's Environment object. This is an abstraction layer that serves to encapsulate the environment of the running Spring application.

Besides the profile, other key pieces of information encapsulated by the Environment object are properties. Properties are used to store the application's underlying environment configuration, such as the location of the application folder, database connection information, and so on.

The Environment bean performs a search over a set of PropertySource objects to look for property values. PropertySource abstraction features in Spring assist developers in accessing various configuration information from the running platform. Under the abstraction, all system properties, environment variables, and application properties are served by the Environment interface, which Spring populates when bootstrapping ApplicationContext. Listing 4-43 shows a simple example.

**Listing 4-43.** Using the Environment Interface

```
package com.apress.prospring6.four;

import org.springframework.context.support.GenericApplicationContext;
import org.springframework.core.env.ConfigurableEnvironment;
import org.springframework.core.env.MapPropertySource;
import org.springframework.core.env.MutablePropertySources;
// other import statements omitted

public class EnvironmentTest {
    private static Logger logger = LoggerFactory.getLogger(EnvironmentTest.class);

    @Test
    void testPropertySourceOne(){
        var ctx = new GenericApplicationContext();

        ConfigurableEnvironment env = ctx.getEnvironment();
        MutablePropertySources propertySources = env.getPropertySources();

        Map<String, Object> appMap = new HashMap<>();
        appMap.put("user.home", "CUSTOM_USER_HOME");
        propertySources.addLast(new MapPropertySource("prospring6_MAP", appMap));

        logger.info("-- Env Variables from java.lang.System --");
        logger.info("user.home: " + System.getProperty("user.home"));
        logger.info("JAVA_HOME: " + System.getenv("JAVA_HOME"));

        logger.info("-- Env Variables from ConfigurableEnvironment --");
        logger.info("user.home: " + env.getProperty("user.home"));
        logger.info("JAVA_HOME: " + env.getProperty("JAVA_HOME"));

        ctx.close();
    }
}
```

In Listing 4-43, after the `ApplicationContext` initialization, we get a reference to the `ConfigurableEnvironment` interface, which extends `Environment`. Via this instance, a handle to `MutablePropertySources` (a default implementation of the `PropertySources` interface, which allows manipulation of the contained property sources) is obtained. Afterward, we construct a map, put the application properties into the map, and then construct a `MapPropertySource` class (a `PropertySource` subclass that reads keys and values from a `Map` instance) with the map. Finally, the `MapPropertySource` class is added to `MutablePropertySources` via the `addLast()` method. Running the program prints the output shown in Listing 4-44 in the console.

**Listing 4-44.** Values Extracted Using the Environment Interface

```
INFO : EnvironmentDemo - -- Env Variables from java.lang.System --
INFO : EnvironmentDemo - user.home: /Users/iulianacosmina
INFO : EnvironmentDemo - JAVA_HOME: /Users/iulianacosmina/.sdkman/candidates/java/current

INFO : EnvironmentDemo - -- Env Variables from ConfigurableEnvironment --
INFO : EnvironmentDemo - user.home: /Users/iulianacosmina
INFO : EnvironmentDemo - JAVA_HOME: /Users/iulianacosmina/.sdkman/candidates/java/current
```

For the first two lines, the JVM system property `user.home` and the environment variable `JAVA_HOME` are retrieved using the JVM's `System` class. However, for the last two lines, you can see that all the system properties, environment variables, and application properties can be accessed via the `Environment` interface. You can see how the `Environment` abstraction can help us manage and access all the various properties within the application's running environment.

The `Environment` instance performs a search over a set of `PropertySource` objects. Spring accesses the properties in the following default order:

- System properties for the running JVM
- Environment variables
- Application-defined properties

The output shows that when defining the same application property named `user.home`, and adding it to the `Environment` interface via the `MutablePropertySources` class, the `user.home` value is still retrieved from the JVM properties, and the `CUSTOM_USER_HOME` is nowhere to be found. However, Spring allows you to control the order in which `Environment` retrieves the properties. Listing 4-45 shows the revised version of the code in Listing 4-43.

**Listing 4-45.** Using the Environment Interface (Part 2)

```
package com.apress.prospring6.four;
// import statements omitted

public class EnvironmentTest {
    private static Logger logger = LoggerFactory.getLogger(EnvironmentTest.class);

    @Test
    void testPropertySourceTwo(){
        var ctx = new GenericApplicationContext();

        ConfigurableEnvironment env = ctx.getEnvironment();
        MutablePropertySources propertySources = env.getPropertySources();
```

```

Map<String, Object> appMap = new HashMap<>();
appMap.put("user.home", "CUSTOM_USER_HOME");
propertySources.addFirst(new MapPropertySource("prospring6_MAP", appMap));

logger.info("-- Env Variables from java.lang.System --");
logger.info("user.home: " + System.getProperty("user.home"));
logger.info("JAVA_HOME: " + System.getenv("JAVA_HOME"));

logger.info("-- Env Variables from ConfigurableEnvironment --");
logger.info("user.home: " + env.getProperty("user.home"));
logger.info("JAVA_HOME: " + env.getProperty("JAVA_HOME"));

ctx.close();
}
}

```

In the code sample in Listing 4-45, notice the line in bold. It declares an application property also called `user.home`, but this time is added as the first one to search for via the `addFirst()` method of the `MutablePropertySources` class. When you run the program, you will see the output shown in Listing 4-46.

**Listing 4-46.** Values Extracted Using the Environment Interface

```

INFO : EnvironmentTest - -- Env Variables from java.lang.System --
INFO : EnvironmentTest - user.home: /Users/iulianacosmina
INFO : EnvironmentTest - JAVA_HOME: /Users/iulianacosmina/.sdkman/candidates/java/current

INFO : EnvironmentDemo - -- Env Variables from ConfigurableEnvironment --
INFO : EnvironmentTest - user.home: CUSTOM_USER_HOME
INFO : EnvironmentTest - JAVA_HOME: /Users/iulianacosmina/.sdkman/candidates/java/current

```

The first two lines remain the same because we still use the `getProperty()` and `getenv()` methods of the JVM `System` class to retrieve them. However, when using the `Environment` interface, you will see that the `user.home` property we defined takes precedence since we defined it as the first one to search for property values.

In real life, you seldom need to interact directly with the `Environment` interface, but instead will use a property placeholder in the form of `${}` (for example, `${application.home}`) and inject the resolved value into Spring beans. Let's see this in action. Suppose we had a class to store all the application properties loaded from a property file. Listing 4-47 shows the `AppProperty` class and the contents of the application properties file.

**Listing 4-47.** The `AppProperty` Bean Type

```

package com.apress.prospring6.four;
// import statements omitted

class AppProperty {
    private String applicationHome;
    private String userHome;

    public String getApplicationHome() {
        return applicationHome;
    }
}

```

```

@Autowired
public void setApplicationHome(@Value("${application.home}") String applicationHome) {
    this.applicationHome = applicationHome;
}

public String getUserHome() {
    return userHome;
}

@Autowired
public void setUserHome(@Value("${user.home}") String userHome) {
    this.userHome = userHome;
}

@Override
public String toString() {
    return new ToStringBuilder(this)
        .append("applicationHome", applicationHome)
        .append("userHome", userHome)
        .toString();
}
}

// Contents of the application.properties file
application.home=application_home
user.home=/home/CUSTOM-USER-HOME

```

To add the contents of the `application.properties` file to Spring's application context, the `@PropertySource` annotation is required on the class annotated with `@Configuration`. This adds this file as a property source to the list of locations `Environment` is looking for properties in.

Listing 4-48 shows the configuration class, the test class, and the produced output of running the `main(..)` method.

**Listing 4-48.** Configuration Class for the `AppProperty` Bean, Test Class, and Console Output

```

package com.apress.prospring6.four;

import org.springframework.context.annotation.PropertySource;
// other import statements omitted

@Configuration
@PropertySource("classpath:application.properties")
class PropDemoConfig{

    @Bean
    AppProperty appProperty(){
        return new AppProperty();
    }
}

public class PropertySourceDemo {
    private static Logger logger = LoggerFactory.getLogger(PropertySourceDemo.class);

```

```

public static void main(String... args) {
    var ctx = new AnnotationConfigApplicationContext(PropDemoConfig.class);

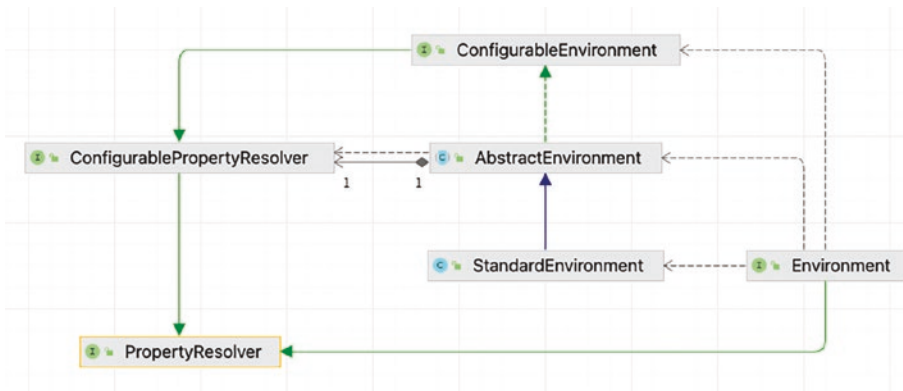
    var appProperty = ctx.getBean("appProperty", AppProperty.class);
    logger.info("Outcome: {}", appProperty);
}

// output
INFO : PropertySourceDemo - Outcome: com.apress.prospring6.four.AppProperty@624ea235[
  applicationHome=application_home,
  userHome=/Users/iulianacosmina
]

```

So, what is going on with that output? Well, the `application.home` placeholder is properly resolved, while the `user.home` property is still retrieved from the JVM properties, as expected, because system properties take precedence over custom property sources. So, how do we instruct Spring that we want to consider our property source (`application.properties`) as the one with the highest priority? Unless you use XML configuration (check out the previous edition of this book) or manual explicit configuration as shown in Listing 4-45, you cannot, because the order is defined as previously stated: system properties, environment properties, then application-defined properties. If you really want to use Java configuration for your application and override the order of property sources, there is a way to do it—it is not clean, but it is possible.

First thing, let's start with the Environment hierarchy, displayed in Figure 4-4.



**Figure 4-4.** IntelliJ IDEA Environment hierarchy

Figure 4-4 depicts the family of Environment classes. In its center notice the `StandardEnvironment` class that is the type of the object created within the Spring context. `StandardEnvironment` implements the `ConfigurableEnvironment` interface and this means we can manipulate this object and modify the priority of the locations where properties are read from.

Listing 4-49 shows the modified version of the `PropDemoConfig` class where the `StandardEnvironment` is autowired and an initialization method is declared to modify the property resource priority.

**Listing 4-49.** Configuration Class for the AppProperty Bean, with Customized Property Sources Locations

```

package com.apress.prospring6.four;

import org.springframework.context.annotation.PropertySource;
import org.springframework.core.env.StandardEnvironment;
import org.springframework.core.io.support.ResourcePropertySource;
// other import statements omitted

@Configuration
@PropertySource("classpath:application.properties")
class PropDemoConfig{

    @Autowired
    StandardEnvironment environment;

    @PostConstruct
    void configPriority() {
        ResourcePropertySource rps = (ResourcePropertySource) environment.
            getPropertySources()
                .stream().filter(ps -> ps instanceof ResourcePropertySource)
                .findAny().orElse(null);
        environment.getPropertySources().addFirst(rps);
    }

    @Bean
    AppProperty appProperty(){
        return new AppProperty();
    }
}

```

The ResourcePropertySource class loads a Properties object from a given Resource or resource (such as the classpath:application.properties used in this example). Since we know that a ConfigurableEnvironment interface exposes references to all its property sources in a MutablePropertySources object, all we have to do is access this object, identify the ResourcePropertySource, and add it back to the object by calling addFirst(..). It's the same thing we did in Listing 4-45, only instead of creating a new MapPropertySource we used the existing ResourcePropertySource.

In practice, you might never need to do this, but in case you ever need to do some Spring code acrobatics like this, now you have a working sample. And if you execute the PropertySourceDemo class with this funky configuration, you will notice the output in Listing 4-50 confirms that the properties in the application.properties file took precedence over anything else.

**Listing 4-50.** Output Produced by Running the PropertySourceDemo with a Reprioritized Property Sources Location Configuration

```

INFO : PropertySourceDemo - Outcome: com.apress.prospring6.four.AppProperty@5340477f[
    applicationHome=application_home,
    userHome=/home/CUSTOM-USER-HOME
]

```



# Testing Spring Applications

When developing applications for enterprise use, testing is an important way to ensure that the completed application performs as expected and fulfills all kinds of requirements (architectural, security, user requirements, and so on). Every time a change is made, you should ensure that the change doesn't impact the existing logic. Maintaining an ongoing build and test environment is critical for ensuring high-quality applications. Reproducible tests with high coverage for all your code allow you to deploy new applications, and changes to applications, with a high level of confidence. In an enterprise development environment, there are many kinds of testing that target each layer within an enterprise application, and each kind of testing has its own characteristics and requirements. In this section, we discuss the basic concepts involved in the testing of various application layers, especially in the testing of Spring-powered applications. We also cover the ways in which Spring makes implementing the test cases of various layers easier for developers.

This section introduces various kinds of testing and their purposes. It covers basic approaches to testing Spring applications, and in future chapters each code sample will be paired with a way to test it.

An *enterprise testing framework* refers to testing activities in the application's entire life cycle. In various phases, different testing activities are performed to verify that the functionalities of the application are working as expected, according to the defined business and technical requirements.

In each phase, different test cases are executed. Some are automated, while others are performed manually. In each case, the result is verified by the corresponding personnel (for example, business analysts, application users, and so on). Table 4-4 describes the characteristics and objectives of each type of testing, as well as common tools and libraries that are used for implementing the test cases.

**Table 4-4.** *Different Testing Categories Used in Practice*

Test Category	Description	Common Tools
Logic unit test	A logic unit test takes a single object and tests it by itself, without worrying about the role it plays in the surrounding system.	Unit test: JUnit, TestNG; Mock objects: Mockito, EasyMock
Integration unit test	An integration unit test focuses on testing the interaction between components in a “near real” environment. These tests exercise the interactions with the container (embedded database, web container, and so on).	Embedded database: H2; Database testing: DbUnit; In-memory web container: Jetty
Front-end unit test	A front-end unit test focuses on testing the user interface. The objective is to ensure that each user interface reacts to users' actions and produces output to users as expected.	Selenium, Cypress
Continuous build and code quality test	The application code base should be built on a regular basis to ensure that the code quality complies with the standard (for example, comments are all in place, no empty exception catch block, and so on). Also, test coverage should be as high as possible to ensure that all developed lines of codes are tested.	Code quality: PMD, Checkstyle, FindBugs, Sonar; Test coverage: Cobertura, EclEmma; Build tool: Gradle, Maven; Continuous build: Hudson, Jenkins
System integration test	A system integration test verifies the accuracy of communication among all programs in the new system and between the new system and all external interfaces. The integration test must also prove that the new system performs according to the functional specifications and functions effectively in the operating environment without adversely affecting other systems.	IBM Rational Functional Tester, HP Unified Functional Testing

(continued)

**Table 4-4.** (continued)

Test Category	Description	Common Tools
System quality test	A system quality test ensures that the developed application meets those nonfunctional requirements. Most of the time, this tests the performance of the application to ensure that the target requirements for concurrent users of the system and workload are met. Other nonfunctional requirements include security, high-availability features, and so on.	Apache JMeter, HP LoadRunner, Locust, K6
User acceptance test	A user acceptance test simulates the actual working conditions of the new system, including the user manuals and procedures. Extensive user involvement in this stage of testing provides the user with invaluable training in operating the new system. It also benefits the programmer or designer to see the user experience with the new programs. This joint involvement encourages the user and operations personnel to approve the system conversion.	IBM Rational TestManager, HP Quality Center

Now that the general testing academic details have been presented, let's get down to practice. Instead of presenting the full details and list of classes that the Spring Framework provides in the testing area, we cover the most commonly used patterns and the supporting interfaces and classes within the Spring TestContext Framework as we show how to implement the sample test cases in this chapter.

## Using Spring Test Annotations

Spring also provides testing-specific annotations in addition to the standard annotations (such as `@Autowired` and `@Resource`). These annotations can be used in your unit tests, providing various functionality such as simplified context file loading, profiles, test execution timing, and much more. Table 4-5 outlines the annotations and their uses.

**Table 4-5.** Spring specialized test annotations

Annotation	Description
<code>@BootstrapWith</code>	Class-level annotation used to determine how to bootstrap the Spring TestContext Framework.
<code>@ContextConfiguration</code>	Class-level annotation used to determine how to load and configure an <code>ApplicationContext</code> for integration tests. When using Junit 4, annotation test classes need to be annotated with <code>@RunWith(SpringRunner.class)</code> . When using Junit Jupiter, test classes need to be annotated with <code>@ExtendWith(SpringExtension.class)</code> .
<code>@WebAppConfiguration</code>	Class-level annotation used to indicate the <code>ApplicationContext</code> loaded should be a <code>WebApplicationContext</code> .
<code>@ContextHierarchy</code>	Class-level annotation used to define a hierarchy of <code>ApplicationContexts</code> for integration tests.

(continued)

**Table 4-5.** (continued)

Annotation	Description
@DirtiesContext	Class- and method-level annotation used to indicate that the context has been modified or corrupted in some way during the execution of the test and should be closed and rebuilt for subsequent tests.
@ActiveProfiles	Class-level annotation indicating which bean profile should be active.
@TestPropertySource	Class-level annotation used to configure locations of properties files and inlined properties to be added to the Environment's set of PropertySources for an ApplicationContext for integration tests.
@DynamicPropertySource	Method-level annotation for integration tests that need to add properties with dynamic values to the Environment's set of PropertySources.
@TestExecutionListeners	Class-level annotation for configuring TestExecutionListeners that should be registered with the TestContextManager.
@RecordApplicationEvents	Class-level annotation used to record all application events published in the ApplicationContext during the execution of a single test.
@Commit	Class- and method-level annotation that is used to indicate that a test-managed transaction should be committed after the test method has completed.
@Rollback	Class- and method-level annotation that is used to indicate whether a test-managed transaction should be rolled back after the test method has completed. As expected, @Rollback(false) is equivalent to @Commit.
@BeforeTransaction	Method-level annotation indicating that the annotated method should be called before a transaction is started for test methods marked with the @Transactional annotation.
@AfterTransaction	Method-level annotation indicating that the annotated method should be called after a transaction has ended for test methods marked with the @Transactional annotation.
@Sql	Class- and method-level annotation used to configure SQL scripts and statements to be executed against a given database during integration tests.
@SqlConfig	Class- and method-level annotation used to indicate how to parse and execute SQL scripts configured via the @Sql annotation.
@SqlMergeMode	Class- and method-level annotation used to indicate whether method-level @Sql declarations are merged with class-level @Sql declarations.
@SqlGroup	Container-level annotation that aggregates several @Sql annotations.

(continued)

**Table 4-5.** (continued)

Annotation	Description
@IfProfileValue	Class- and method-level annotation used to indicate that the test method should be enabled for a specific set of environmental conditions.
@ProfileValueSourceConfiguration	Class-level annotation used to specify the ProfileValueSource used by @IfProfileValue. If this annotation is not declared on the test, SystemProfileValueSource is used as the default.
@Timed	Method-level annotation used to indicate that the test must finish in the specified time period.
@Repeat	Method-level annotation used to indicate that the annotated test method should be repeated the specified number of times.

## Implementing Logic Unit Tests

As previously discussed, a logic unit test is the finest level of testing. The objective is to verify the behavior of an individual class, with all the class's dependencies being “mocked” with expected behavior. Considering the MessageRender and MessageProvider beans, testing the MessageRender bean in isolation, by injecting it with a mock MessageProvider bean, is a suitable example of unit testing. To help mock the behavior of the MessageProvider bean, we will show how to use Mockito<sup>4</sup>, which is a popular mocking framework.

The Spring Framework provides first-class support for integration testing in the spring-test module. To provide a test context for the integration tests that will be created for this section, you will use the spring-test.jar library. This library contains valuable classes for integration testing with a Spring container. For the tests in this section, the spring-test, mockito-all and junit-jupiter-engine are added to the configuration of the project.

Let's start small. Considering the MessageRender and MessageProvider beans, let's declare a test class that checks that the StandardOutMessageRenderer bean type works as intended, as in when render() is called, this invokes messageProvider.getMessage(). To perform this test, we do not need a Spring ApplicationContext nor a MessageProvider; we just need a mock, a simple replacement. Listing 4-51 depicts the test class and the test method that need to be run to execute the test.

**Listing 4-51.** Unit Test for StandardOutMessageRender Using Mockito

```
package com.apress.prospring6.four;

import static org.mockito.Mockito.mock;
import static org.mockito.Mockito.when;
import static org.mockito.Mockito.verify;
import static org.mockito.Mockito.times;

import org.junit.jupiter.api.Test;
// other import statements omitted

public class MessageRenderTest {
```

<sup>4</sup><https://site.mockito.org/>

```

@Test
void testStandardOutMessageRenderer(){
    MessageProvider mockProvider = mock(MessageProvider.class);
    when(mockProvider.getMessage()).thenReturn("test message");

    MessageRenderer messageRenderer = new StandardOutMessageRenderer();
    messageRenderer.setMessageProvider(mockProvider);

    messageRenderer.render();
    verify(mockProvider, times(1)).getMessage();
}
}

```

The test method is annotated with the Junit Jupiter `@Test` annotation, which marks it as a test method. The test method creates the context and checks the existence of the beans and the result of calling the `render()` method. Tests can be run in debug mode as well, and breakpoints can be used to pause execution to inspect objects for debugging purposes.

IntelliJ IDEA can run all the test methods within a test class, package, or module or a single method. Just right-click the component and there should be a Run option in the menu that is displayed. When you right-click the content of a test class, if you click outside any test method, the option will be to run all methods; when you right-click a method name or inside the method body, the Run option from the menu is specific to that method. Figure 4-5 shows the IntelliJ IDEA menu that appears when a test method name is right-clicked.



Figure 4-5. IntelliJ IDEA options for running tests

Figure 4-5 also shows two buttons to the left of the file. Clicking the button at the class level expands into a menu grouping options for running the test class. Clicking the button at the method level expands into a menu grouping options for running the test method. Feel free to experiment with those buttons and options a little to get used to them, then get back to reading the book.

The `testStandardOutMessageRenderer()` method verifies the behavior of the `StandardOutMessageRenderer` implementation in isolation. Its behavior cannot be influenced by anything else in the application; even its dependency on the `MessageProvider` instance is replaced with a mock implementation constructed by Mockito, with the perfect behavior configured by this line: `when(mockProvider.getMessage()).thenReturn("test message")`.

The Mockito utility methods are quite practical, because they also make the test code very readable. The `when(...)` line configures the `String` value to be returned when the `getMessage()` method is called on this mock. How does this work? Well, Mockito implements the `MessageProvider` interface to create a mock object, and then creates a proxy to intercept calls to it. When we invoke the `when(...)` method, we are in fact recalling the last registered method call from that context and `thenReturn()` saves the return value for it. Anyway, Mockito is really useful for isolating components for unit testing, or for reducing the number of levels in a integration test to focus only on the bits that present interest.



(Iuliana) In the company I've been working at for the last three years, we rarely write unit tests, because integration tests cover the behavior the unit tests cover anyway. Lately, I've found myself agreeing to this more and more, because setting up the test context requires effort, and using the same context for multiple tests makes that effort worthwhile.

---

In this book, we will mostly use integration testing, but some unit tests will be covered here and there, just enough to make you comfortable with them and recognize them in the future. There is more than one option for mocking dependencies. `JMock`<sup>5</sup> is an alternative library you can use. `EasyMock`<sup>6</sup> is another, and for writing assumption checks, take a look at `Hamcrest`<sup>7</sup>.

This being said, let's switch gears to integration testing.

## Implementing an Integration Test

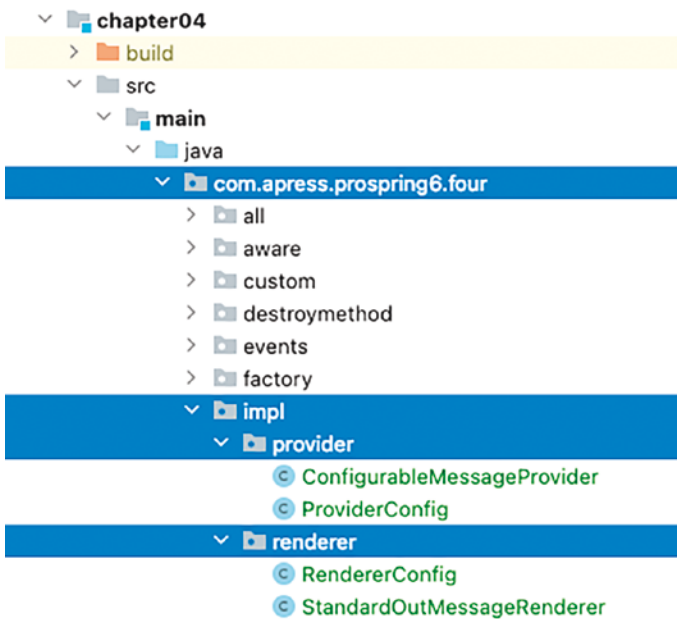
In this section, we will implement the integration test for the previous example. A configuration creating those beans and connecting them together is created, to prepare the test context. This configuration is used to create a test application context, and the test will check that the two beans are created correctly. To show how configurations can be aggregated for integration tests, the `MessageProvider` and the `MessageRenderer` bean types have been declared in their own package with their own configuration class, as shown in Figure 4-6.

---

<sup>5</sup><http://jmock.org>

<sup>6</sup><https://easymock.org>

<sup>7</sup><https://hamcrest.org>



**Figure 4-6.** Organizing beans with their own configuration

Before introducing tests to create the `ApplicationContext`, we would have created a class with a `main(..)` method, but now that we know how to write a test, let's give it a try. Listing 4-52 shows a test method that tests the proper creation of an `ApplicationContext` containing the two beans.

**Listing 4-52.** Integration Test for `StandardOutMessageRenderer`

```

package com.apress.prospring6.four;

import static org.junit.jupiter.api.Assertions.assertAll;
import static org.junit.jupiter.api.Assertions.assertEquals;
import static org.junit.jupiter.api.Assertions.assertNotNull;
// other import statements omitted

public class MessageRendererOneIT {

    @Test
    void testConfig(){
        var ctx = new AnnotationConfigApplicationContext(RendererConfig.class,
            ProviderConfig.class);

        var messageProvider = ctx.getBean(MessageProvider.class);
        var messageRenderer = ctx.getBean(MessageRenderer.class);

        assertAll( "messageTest" ,
            () -> assertNotNull(messageRenderer),
            () -> assertNotNull(messageProvider),
            () -> assertEquals(messageProvider, messageRenderer.getMessageProvider())
        );
    }
}

```

```

        messageRenderer.render();
    }
}

```

Compared to the initial approach of creating the `ApplicationContext` in a main method, there are three observations:

- In a test method, test utility methods can be used. Method `assertAll(..)` and other JUnit Jupiter utility methods are used to test our assumptions about the beans that were created as part of the context.
- The `render()` method cannot be tested since it returns `void`; we can only check the console and look for the *Text Sample* text being printed, just as we did using a `main(..)` method.
- Tests are run when the project is built, which means configuration problems will be identified quickly.

The previous test method is a very simple way to move the logic from the main module to the test module. Also, this is not the efficient way to do it, because if we write more test methods in the same class, the context must be built for each method. Reusing a test context is possible in more than one way. Listing 4-53 shows the JUnit way.

**Listing 4-53.** Integration Test for `StandardOutMessageRenderer` with Shared Test Context (the JUnit Way)

```

package com.apress.prospring6.four;

import org.junit.jupiter.api.BeforeAll;
// other import statements omitted

public class MessageRenderTwoIT {

    public static ApplicationContext ctx;

    @BeforeAll
    static void setUp() {
        ctx = new AnnotationConfigApplicationContext(RendererConfig.class,
            ProviderConfig.class);
    }

    @Test
    void testProvider(){
        var messageProvider = ctx.getBean(MessageProvider.class);
        assertNotNull(messageProvider);
    }

    @Test
    void testRenderer(){
        var messageRenderer = ctx.getBean(MessageRenderer.class);
        assertAll( "messageTest" ,
            () -> assertNotNull(messageRenderer),
            () -> assertNotNull(messageRenderer.getMessageProvider())
        );
    }
}

```



```

        messageRenderer.render();
    }
}

```

Sharing the test context among test methods the JUnit way is by declaring an `ApplicationContext` static reference and telling JUnit to call the `setUp(..)` method only once to initialize it by annotating it with `@BeforeAll`. This works for any other component that needs to be shared between the test methods.



The example in Listing 4-53 shows the test class written using annotations from JUnit Jupiter, also known as JUnit 5. An equivalent test can be written with JUnit 4. Check out the previous edition of this book if you are interested in using JUnit 4.

However, the best way is the Spring way. The `@ContextConfiguration` annotation introduced in Table 4-5 is used to configure the configuration classes used to build the `ApplicationContext`, but to integrate the Spring test context with the Jupiter 5 programming model, the `@ExtendWith` annotation is also required together with the `SpringExtension.class` argument, because this is how we configure the extension for Spring. Listing 4-54 shows the code of this class.

**Listing 4-54.** Integration Test for `StandardOutMessageRenderer` with Shared Test Context (the Spring Way)

```

package com.apress.prospring6.four;

import org.junit.jupiter.api.extension.ExtendWith;
import org.springframework.test.context.ContextConfiguration;
import org.springframework.test.context.junit.jupiter.SpringExtension;
// other import statements omitted

@ExtendWith(SpringExtension.class)
@ContextConfiguration(classes = {RendererConfig.class, ProviderConfig.class})
public class MessageRenderThreeIT {

    @Autowired
    MessageRenderer messageRenderer;

    @Autowired
    MessageProvider messageProvider;

    @Test
    void testProvider(){
        assertNotNull(messageProvider);
    }

    @Test
    void testRenderer(){
        assertAll( "messageTest" ,
            () -> assertNotNull(messageRenderer),
            () -> assertNotNull(messageRenderer.getMessageProvider())
        );
    }
}

```

```

        messageRenderer.render();
    }
}

```

Since the Spring `ApplicationContext` is integrated with the Jupiter programming model, we do not need to extract the beans from the context—we can just autowire them in the test class.

If you want to keep things simple, JUnit Jupiter also provides the `@SpringJUnit4Config` annotation in the package `org.springframework.test.context.junit4.jupiter` that replaces the `@ExtendWith + @ContextConfiguration` combination. Thus,

```

@ExtendWith(SpringExtension.class)
@ContextConfiguration(classes = {RendererConfig.class, ProviderConfig.class})

```

can be replaced with

```

@SpringJUnit4Config(classes = {RendererConfig.class, ProviderConfig.class})

```

## Configuring Profile for Integration Testing

The bean definition profiles feature introduced in Spring 3.1 is useful for implementing a test case with the appropriate configuration of the testing components. Profiles are useful for other things as well. For example, if you are working on an application that integrates with an Amazon DynamoDB instance, you might not want to use that instance during development or during continuous integration builds, to avoid costs. So, you could configure a development profile that includes a connection bean that connects to a local DynamoDB container instead of the remote Amazon DynamoDB instance.

Are you still wondering why we need profiles when we could just isolate beans specific to a purpose in their own configuration files and just import those? Profiles are useful when, for some reason, you cannot do that, because you can annotate certain bean definitions with the `@Profile(..)` annotations and leave the rest of the bean definitions untouched.

For example, take a look at the configuration class in Listing 4-55; it declares a `MessageRenderer` bean that is not associated with a profile and a `MessageProvider` bean that is associated to a profile named `dev`.

**Listing 4-55.** Configuration Class with a Bean Associated to a Profile

```

package com.apress.prospring6.four.impl;

import org.springframework.context.annotation.Profile;
// other import statement omitted

@Configuration
public class AllConfig {

    @Profile("dev")
    @Bean
    MessageProvider messageProvider(){
        return new ConfigurableMessageProvider("Text Sample");
    }
}

```

```

@Bean
MessageRenderer messageRenderer(){
    MessageRenderer messageRenderer = new StandardOutMessageRenderer();
    messageRenderer.setMessageProvider(messageProvider());
    return messageRenderer;
}
}

```

Not being associated to a profile, this means the `MessageRenderer` bean will be part of the context, regardless of the activated profile, which is what we are interested in, because this is the bean we are interested in testing.

To test this bean we need to provide a different `MessageProvider` dependency in the test context. We do this by declaring a new bean type named `TestMessageProvider` that implements `MessageProvider` but returns a different message. The implementation is basic, so it won't be shown here. Listing 4-56 shows the test configuration class declaring a bean definition associated to the test profile, the test class annotated with `@ActiveProfiles("test")` annotation to activate the test profile, and the test method that checks that the `MessageRenderer` was created as expected and the dependency injected is of type `TestMessageProvider`.

**Listing 4-56.** Test Configuration Class and Profiled Test Class

```

package com.apress.prospring6.four;

import org.springframework.context.annotation.Profile;
import org.springframework.test.context.ActiveProfiles;
import org.springframework.test.context.junit4.jupiter.SpringJUnitConfig;
// other import statements omitted

@Configuration
class TestConfig {

    @Profile("test")
    @Bean
    MessageProvider messageProvider(){
        return new TestMessageProvider("Test Message");
    }
}

@ActiveProfiles("test")
@SpringJUnitConfig(classes = {AllConfig.class, TestConfig.class})
public class MessageRenderFourIT {

    @Autowired
    MessageRenderer messageRenderer;

    @Autowired
    MessageProvider messageProvider;

    @Test
    void testConfig(){
        assertEquals( "messageTest" ,
            () -> assertNotNull(messageRenderer),

```

```

        () -> assertNotNull(messageProvider),
        () -> assertTrue(messageProvider instanceof TestMessageProvider),
        () -> assertEquals(messageProvider, messageRenderer.getMessageProvider())
    );

    messageRenderer.render();
}
}

```

This is all that can be said at the moment about integration tests. As this book progresses and more complex applications are built, the tests will increase in complexity, and thus almost all annotations in Table 4-5 are going to be introduced and explained when needed.

## Implementing a Front-End Unit Test

Another testing area of particular interest is testing the front-end behavior as a whole, upon the deployment of the web application to a web container like Apache Tomcat. The main reason is that even though we test every layer within the application, we still need to make sure that the views behave correctly with different actions from users. Automating front-end testing is important in saving time for developers and users when repeating the actions on the front end for a test case.

However, developing a test case for a front end is a challenging task, especially for those web applications with a lot of interactive, rich, and Ajax-based components. This is where Selenium and other web testing automation frameworks come to help.

## Introducing Selenium

Selenium is a powerful and comprehensive tool and framework target for automating web-based front-end testing. The main feature is that by using Selenium, we can “drive” the browsers, simulating user interactions with the application, and perform verification of the view status.

Selenium supports common browsers including Firefox, IE, and Chrome. In terms of languages, Selenium supports Java, C#, PHP, Perl, Ruby, and Python. Selenium is also designed with Ajax and rich Internet applications (RIAs) in mind, making automated testing of modern web applications possible.

If your application has a lot of front-end user interfaces and needs to run a large number of front-end tests, the `selenium-server` module provides built-in grid functionality that supports the execution of front-end tests among a group of computers.

The Selenium IDE is a Firefox plug-in that can help “record” user interactions with the web application. It also supports replay and exports the scripts into various formats that can help simplify the development of test cases.

Starting from version 2.0, Selenium integrates the WebDriver API, which addresses a number of limitations and provides an alternative, and simpler, programming interface. The result is a comprehensive object-oriented API that provides additional support for a larger number of browsers along with improved support for modern advanced web application testing problems.

Front-end web testing is a complex subject and beyond the scope of this book. From this brief overview, you can see how Selenium can help automate the user interaction with the web application front end with cross-browser compatibility. For more details, please refer to Selenium’s online documentation<sup>8</sup>.

Now that you have a basic idea of how to test Spring applications, let’s switch gears to one of the most loved and hated Spring projects: Groovy.

<sup>8</sup><https://www.selenium.dev>

## Configuration Using Groovy

Spring Framework 4.0 introduced the ability to configure bean definitions and `ApplicationContext` by using the Groovy language. This provides developers with another choice in configuration to either replace or supplement XML and/or annotation-based bean configuration. A Spring `ApplicationContext` can be created directly in a Groovy script or loaded from Java, both by way of the `GenericGroovyApplicationContext` class.

First let's dive into the details by showing how to create bean definitions from an external Groovy script and loading them from Java. In previous sections and chapters, we introduced various bean classes, and to promote some code reusability, we will use in this example the `Singer` class shown in Listing 4-57.

**Listing 4-57.** `Singer` Class to Be Used in Groovy Examples

```
package com.apress.prospring6.four.groovy;

import org.apache.commons.lang3.builder.ToStringBuilder;

public class Singer {
    private String name;
    private int age;

    @Override
    public String toString() {
        return new ToStringBuilder(this)
            .append("name", name)
            .append("age", age)
            .toString();
    }

    // setters and getters omitted
}
```

As you can see, this is just a Java class with a couple of properties describing a singer. We use this simple Java class here to show that just because you configure your beans in Groovy doesn't mean your entire code base needs to be rewritten in Groovy. Not only that, but Java classes can be imported from dependencies and used within Groovy scripts. Now, let's create the Groovy script (`beans.groovy`) that will be used to create the bean definition, as shown in Listing 4-58.

**Listing 4-58.** `Singer` Bean Groovy Definition

```
import com.apress.prospring6.four.groovy.Singer

beans {
    singer(Singer, name: 'John Mayer', age: 42)
}
```

This Groovy script starts with a top-level closure called `beans`, which provides bean definitions to Spring. First, we specify the bean name (`singer`), and then as arguments we provide the class type (`Singer`) followed by the property names and values that we would like to set. Next, let's create a simple test driver in Java, loading bean definitions from the Groovy script, as shown in Listing 4-59.

**Listing 4-59.** Test Class to Test Groovy Beans

```

package com.apress.prospring6.four.groovy;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.context.ApplicationContext;
import org.springframework.context.support.GenericGroovyApplicationContext;

public class GroovyBeansFromJavaDemo {
    private static Logger logger = LoggerFactory.getLogger(GroovyBeansFromJavaDemo.class);

    public static void main(String... args) {
        ApplicationContext context =
            new GenericGroovyApplicationContext("classpath:spring/beans.groovy");
        Singer singer = context.getBean("singer", Singer.class);

        logger.info("Singer bean: {}", singer);
    }
}

```

As you can see, the creation of `ApplicationContext` is carried out in typical fashion, but it's done by using the `GenericGroovyApplicationContext` class and providing your Groovy script that builds the bean definitions. Running `GroovyBeansFromJavaDemo` should print:

```

INFO : GroovyBeansFromJavaDemo - Singer bean: com.apress.prospring6.four.groovy.
Singer@272a179c[name=John Mayer,age=42]

```



The only thing you must keep in mind when using Groovy bean definitions is that the `groovy-all` library must be on the project classpath. So, whatever build tool you are using, whether Maven or Gradle, make sure you mention it in your configuration file.

---

Now that you have seen how to load bean definitions from Java via an external Groovy script, how can we go about creating the `ApplicationContext` and bean definitions from a Groovy script alone? There's not much to it, really, and the Groovy syntax is more simplistic than Java is, as shown in Listing 4-60.

**Listing 4-60.** Groovy Script to Declare Beans and Use Them

```

package com.apress.prospring6.four.groovy

import org.springframework.beans.factory.groovy.GroovyBeanDefinitionReader
import org.springframework.context.support.GenericApplicationContext

def ctx = new GenericApplicationContext()
def reader = new GroovyBeanDefinitionReader(ctx)

```

```

reader.beans {
    singer(Singer, name: 'John Mayer', age: 42)
}

ctx.refresh()
println ctx.getBean("singer")

```

When we run this sample, we get same output as before, only we don't get a log statement, since a logger is not used in this case, but a simple console output. This time we create an instance of a typical `GenericApplicationContext`, but use `GroovyBeanDefinitionReader`, which will be used to pass bean definitions to. Then, as in the previous example, we create a bean from our simple POJO, refresh `ApplicationContext`, and print the string representation of the `Singer` bean. It doesn't get any easier than that!

As you probably can tell, we are only scratching the surface of what can be done with the Groovy support in Spring. Since you have the full power of the Groovy language, you can do all sorts of interesting things when creating bean definitions. As you have full access to `ApplicationContext`, not only can you configure beans, but you can also work with profile support, property files, and so on. Just keep in mind, with great power comes great responsibility.

## Using Spring Boot

Following this book so far has taught you more than one way to declare beans that make up a Spring application. But what if we tell you there is something even cooler than all that?

The Spring Boot project aims to simplify the getting-started experience of building an application by using Spring. Spring Boot takes the guesswork out of manually gathering dependencies and provides some of the most common features needed by most applications, such as metrics and health checks.

Spring Boot takes an "opinionated" approach to achieve the goal of developer simplification by way of providing starter projects for various types of applications that already contain the proper dependencies and versions, which means less time spent to get started. For those who may be looking to get away from XML completely, Spring Boot does not require any configuration to be written in XML.

In this example, we will create the traditional Hello World web application with a twist. You may be surprised to see the minimal amount of code required to do so as compared to your typical Java web application setup. Typically, we have started off examples by defining the dependencies you need to add to your project. Part of Spring Boot's simplification model is to prepare all the dependencies for you, and when using Maven, for example, you as the developer utilize a parent POM to obtain this functionality. When using Gradle, things become even simpler. There is no parent needed, except a Gradle plug-in and a starter dependency. If your project is simple enough, you can generate the full configuration using Spring Initializr, accessible at <https://start.spring.io>; download the basic structure and configuration from there, and start customizing it according to your needs. **Chapter 2** mentioned how powerful Spring Boot is, and that the Maven setup of the project for this book uses Spring Boot dependency management to keep dependency versions compatible and the project stable. Spring Boot is powerful and practical, but it can become a tough-to-manage beast without the proper understanding of Spring. Thankfully, you are reading this book, so you'll be fine.

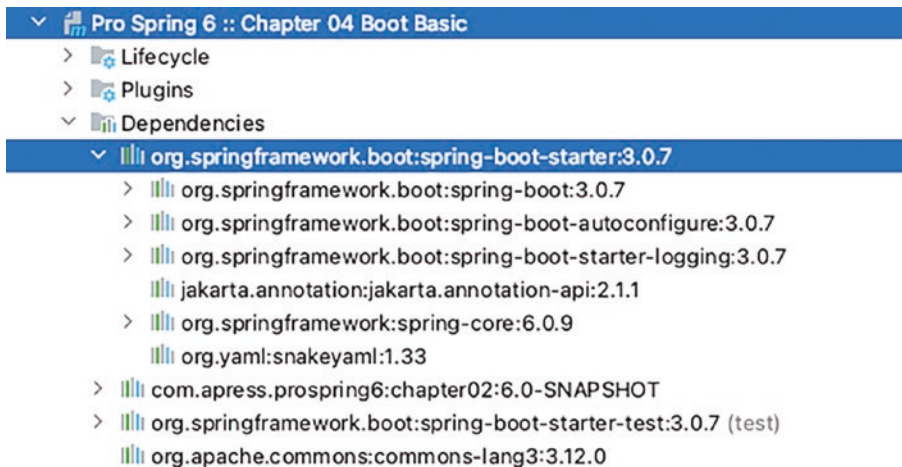
Without further ado, let's get down to using Spring Boot!

As of the time this chapter is being written, Spring Boot version 3.0.0 has not been released yet. This is the reason why the project is currently configured to use version 3.0.0-M2. By the time this book is released, the project will be updated with the official release version.

Each release of Spring Boot provides a curated list of dependencies it supports. The versions of the necessary libraries are selected so the API matches perfectly, and this is handled by Spring Boot. Therefore, the manual configuration of dependencies versions is not necessary. Upgrading Spring Boot will ensure that those dependencies are upgraded as well. With the previous configuration, a set of dependencies will be added to the project, each with the proper versions so that their API will be compatible. In a smart editor like IntelliJ IDEA, there is a Maven(or Gradle) Projects view, where you can expand each module and inspect the available tasks and dependencies, as shown in Figure 4-7.



The Spring Boot version in Figure 4-7 might be different in the project attached to the book, by the time the book is released. The reason behind this is that the code is written when Spring Boot 3 is still in development. So is Spring 6. The intention is to edit this book and update the image with the official version before publication, but in case we miss this image, just know that is all right as long as the code runs.



**Figure 4-7.** Spring Boot starter library and dependencies

The chapter04-boot project is very simple and declares a simple Spring boot starter dependency, the spring-boot-starter library. This dependency brings with it a set of Spring dependencies and their dependencies that make a strong foundation for building Spring application. The entry point of a Spring Boot project is the application class, the one annotated with `@SpringBootApplication`, in our case the `Chapter4application` class. When Spring Initializr is used to generate a Spring Boot project, this class is generated with an empty body for the `main(...)` method, but what we like to do is complete that body with a few lines of code that list all the beans in the application context, as shown in Listing 4-61.



**Listing 4-61.** Spring Boot Application Class Modified to Show All Beans in the Application Context

```

package com.apress.prospring6.four;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

import java.util.Arrays;

@SpringBootApplication
public class Chapter4Application {
    private static Logger logger = LoggerFactory.getLogger(Chapter4Application.class);

    public static void main(String... args) {
        var ctx = SpringApplication.run(Chapter4Application.class, args);
        assert (ctx != null);
        // listing all bean definition names
        Arrays.stream(ctx.getBeanDefinitionNames()).forEach(logger::info);
    }
}

```

That is all. Really. The extra lines to check that a context was created and to list all the bean names in the context is the bit we added. The only necessary statement to bootstrap a Spring application is `SpringApplication.run(Chapter4Application.class, args)`.

The novelty here is the `@SpringBootApplication` annotation. This annotation is a top-level annotation designed to be used only at the class level. It is a convenience annotation that is equivalent to declaring the following three:

- `@SpringBootConfiguration`: Indicates that this class provides configuration for a Spring Boot application. It is meta-annotated with `@Configuration`, which means this class can declare beans with `@Bean`.
- `@EnableAutoConfiguration`: This is a specific Spring Boot annotation from the package `org.springframework.boot.autoconfigure` that enables creating a default `SpringApplicationContext` with all the infrastructure beans needed based on the project dependencies. `@EnableAutoConfiguration` works well with Spring-provided starter dependencies, but it is not directly tied to them, so other dependencies outside the starters can be used. For example, if there is a specific embedded server on the classpath, it will be used, unless there is another `EmbeddedServletContainerFactory` configuration in the project. This is a core element of the practicality of Spring Boot; it configures stable default infrastructure beans, but it is easy to customize as well.
- `@ComponentScan`: This enables discovery of classes annotated with stereotype annotations. The attribute used to list the packages to scan used with `@SpringBootApplication` is `basePackages`. In version 1.3.0, another attribute was added to this annotation: `basePackageClasses`. This attribute provides a type-safe alternative to `basePackages` for specifying the packages to scan for annotated components. The package of each class specified will be scanned. By default `@SpringBootApplication` enables scanning for the package where the application class is declared and all packages under it.

If you ran the `Chapter4Application` call, you might have noticed that the number of infrastructure beans in the Spring Boot context is much higher than the number of beans in a simple Spring Classic application context. Being able to just declare your beans and run a Spring application comes with a cost: you avoid the work of setting up your context and allow Spring Boot to do it for you. The most basic Spring Boot application context is designed based on decisions of experienced developers who, after working with Spring for a long time, have identified the typical Spring components used in various Spring applications and baked that into default setups packed into the Spring Boot starter dependencies. There are multiple Spring Boot starter dependencies, and each of them is specific to the application being built: `spring-boot-starter` is used for the simplest Spring applications containing interoperating beans and writing logs; `spring-boot-starter-jpa` is used for simple Spring applications that manage data stored in a database; `spring-boot-starter-web` is used to create a basic Spring web application; and so on. All these starter dependencies will be covered and explained in more detail in the suitable chapters in the book.

For now let's modify this Spring Boot application to add the `MessageProvider` and `MessageRenderer` beans that we've played with so far. The only things we have to do are as follows:

- Modify the configuration files to add a Maven/Gradle dependency on the `chapter02` project where those two interfaces are declared.
- Copy the `ConfigurableMessageProvider` and `StandardOutMessageRenderer` classes into the `chapter04-boot` project and make sure they are annotated with `@Component` and `@Autowired` where necessary.
- Modify the `Chapter4Application` class to access the `MessageRenderer` and call `render()`.

Listing 4-62 shows all these changes together, and the bean definitions have been added to the `WithBeansApplication` file, to keep all things in the same context close to each other. (*You will thank us when navigating the project!*)

**Listing 4-62.** Spring Boot Application Class with Developer Beans

```
package com.apress.prospring6.four.beans;

import com.apress.prospring6.two.decoupled.MessageProvider;
import com.apress.prospring6.two.decoupled.MessageRenderer;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
// other import statements omitted

@Component("messageRenderer")
class StandardOutMessageRenderer implements MessageRenderer {
    private static Logger logger = LoggerFactory.getLogger(StandardOutMessageRender
er.class);

    private MessageProvider messageProvider;

    @Autowired
    @Override
    public void setMessageProvider(MessageProvider provider) {
        this.messageProvider = provider;
    }
}
```

```

@Override
public MessageProvider getMessageProvider() {
    return this.messageProvider;
}

@Override
public void render() {
    logger.info(messageProvider.getMessage());
}
}

@Component
class ConfigurableMessageProvider implements MessageProvider {

    private String message;

    public ConfigurableMessageProvider(@Value("Configurable message") String message) {
        this.message = message;
    }

    @Override
    public String getMessage() {
        return message;
    }
}

@SpringBootApplication
public class WithBeansApplication {
    private static Logger logger = LoggerFactory.getLogger(WithBeansApplication.class);

    public static void main(String... args) {
        var ctx = SpringApplication.run(WithBeansApplication.class, args);

        MessageRenderer mr = ctx.getBean("messageRenderer", MessageRenderer.class);
        mr.render();
    }
}

```

If you run the `WithBeansApplication` class and look at the console, you will also notice the `Configurable message` output being printed.

In this example we explicitly called the `render()` method on the `MessageRenderer` bean, but what if we did not have to? Spring Boot is the gift that keeps on giving, as you will discover reading this book, but we would like to introduce you right now to the `org.springframework.boot.CommandLineRunner` interface. This functional interface declares a single method named `run()` and is used to indicate that a bean should run—meaning the `run()` method is executed when it is contained within a Spring application. This means we can modify the `StandardOutMessageRenderer` class and make the `run()` method call `render`.

We can go even one step further. Since multiple `CommandLineRunner` beans can be defined within the same application context and can be ordered using the `Ordered` interface or `@Order` annotation, we can modify the `ConfigurableMessageProvider` as well to make it a `CommandLineRunner`, but in its `run()` method we make sure the `message` field is set with the command-line argument, thus making this implementation truly configurable.

Also, to make sure the two beans behave as expected, we use the `@Order` annotation on both, annotating `ConfigurableMessageProvider` with `@Order(1)` and `MessageRenderer` with `@Order(2)`, to make sure they are initialized and run correctly. The new runner beans and configuration class are shown in Listing 4-63.

**Listing 4-63.** Spring Boot Application Class with Runner Beans

```

package com.apress.prospring6.four.runners;

import org.springframework.boot.CommandLineRunner;
import org.springframework.core.annotation.Order;
// other import statements omitted

@Order(2)
@Component("messageRenderer")
class StandardOutMessageRenderer implements MessageRenderer, CommandLineRunner {
    // other methods omitted

    @Override
    public void run(String... args) throws Exception {
        render();
    }
}

@Order(1)
@Component
class ConfigurableMessageProvider implements MessageProvider, CommandLineRunner {

    private String message;

    public ConfigurableMessageProvider(@Value("Configurable message") String message) {
        this.message = message;
    }

    // getter omitted

    @Override
    public void run(String... args) throws Exception {
        if(args.length >=1) {
            message = args[0];
        }
    }
}

@SpringBootApplication
public class WithRunnersApplication {

    public static void main(String... args) {
        SpringApplication.run(WithRunnersApplication.class, args);
    }
}

```

When running the `WithRunnersApplication`, you will also notice the `Configurable` message output being printed. This happens because you probably ran it without providing any program arguments. To do that, open the launch configuration IntelliJ IDEA has created for this class and modify the `Build` and `run` section to include the `Program arguments` text box and introduce a value similar to the one shown in Figure 4-8.

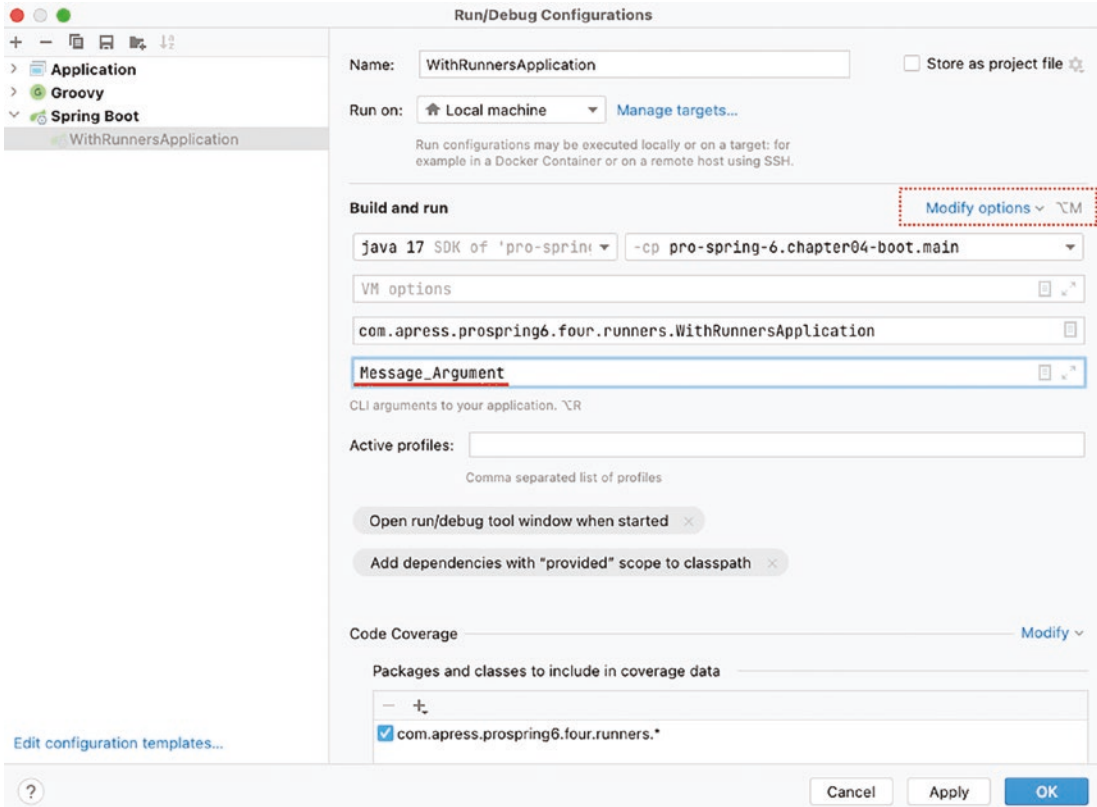


Figure 4-8. Spring Boot IntelliJ IDEA configuration window

If the `Program arguments` text box is not visible, add it from the `Modify options` menu (highlighted on right in Figure 4-8).

If you run the code using the launcher, you will see the program argument you provided appearing in the console log.

`org.springframework.boot.ApplicationRunner` provides similar functionality but exposes the arguments as an instance of `ApplicationArguments` that provides additional arguments operations such as: returning the raw, unprocessed arguments by invoking `getSourceArgs()`, or returning the names of all arguments by invoking `getOptionNames()`, which is useful if you want to print some command-line suggestions, and so forth.

The most useful Spring Boot starter library in our opinion is `spring-boot-starter-test`. When added to a project, it not only provides a cool set of classes for testing Spring Boot applications, but also brings in a rich set of testing libraries, so you don't have to add `JUnit`, `mock`, and so on, manually to your configuration.

Let's start with the basics. If the entry point of a Spring Boot application is the class annotated with `@SpringBootApplication`, the entry point of a Spring Boot test is the class annotated with `@SpringBootTest`. This annotation does the following things:

- Uses a default `SpringBootTestContextLoader` when no `ContextLoader` is defined, for example, via `@ContextConfiguration(loader=..)`
- Searches for a class annotated with `@SpringBootConfiguration` when nested `@Configuration` is not used
- Allows custom properties to be specified for a test context via its `properties` attribute
- Provides support for different `webEnvironment` modes, including the ability to start a fully running web server listening on a random port
- Registers a `TestRestTemplate` and/or `WebTestClient` for use in web tests that are using a fully running web server

Some capabilities of `@SpringBootTest` won't be obvious now, but they will be when you start writing more complex tests.

Another thing you should know about `@SpringBootTest` is that it is annotated with `@ExtendWith(SpringExtension.class)` and thus by default integrates the Spring TestContext Framework into JUnit 5's Jupiter programming model. This obviously means you won't be able to write JUnit 4 tests in a class annotated with `@SpringBootTest`, because the JUnit 4 annotations won't be recognized.

Listing 4-64 shows a Spring Boot test class that runs its test in the context defined by the `WithBeansApplication` Spring Boot class.

**Listing 4-64.** Spring Boot Test Class

```

package com.apress.prospring6.four.beans;

import org.springframework.boot.test.context.SpringBootTest;
// other import statements omitted

@SpringBootTest
public class BeansTest {

    @Autowired
    ApplicationContext context;

    @Autowired
    MessageRenderer messageRenderer;

    @Autowired
    MessageProvider messageProvider;

    @Test
    void contextLoaded(){
        assertNotNull(context);
    }

    @Test
    void rendererTest(){

```

```

    assertAll( "messageTest" ,
        () -> assertNotNull(messageRenderer),
        () -> assertNotNull(messageProvider),
        () -> assertEquals(messageProvider, messageRenderer.getMessageProvider())
    );

    messageRenderer.render();
}
}

```

Looking at the code in Listing 4-64, you might notice that the `WithBeansApplication` class is not mentioned anywhere, so you might be lifting an eyebrow sarcastically and asking, *How does Spring Boot know to use that class?* Well, remember that `@SpringBootTest` searches for a class annotated with `@SpringBootConfiguration`. The search starts in the package where the test class is defined. So if the test class is defined in package `com.apress.prospring6.four.beans`, then Spring Boot looks for a configuration class in this package and, if it is not found, continues searching in the packages within it.

However, if you want to make it really obvious which Spring Boot configuration class is being used, you can use the `classes` attribute:

```
@SpringBootTest(classes = {WithBeansApplication.class})
```

This attribute can be used to add additional test configuration classes, to override beans with scoped variants. Also, `@ActiveProfiles` is supported on `@SpringBootTest` annotated classes too, and it is particularly useful when testing applications that involve database access, as we'll see from **Chapter 6** onward.

A Spring Boot test class is nothing but a test class, so running it does not require anything else than just clicking right in your editor and selecting Run or Debug, depending on your overall intentions.



Since our technical reviewer insists, we will add this note: test classes and methods specifically can be run from the command line, using Maven or Gradle commands. This however is not relevant for this book, since the book is focused on the Spring Framework, so if you find yourself in need of doing that, the official documentation for the two build tools used to organize this project should suffice.

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## Summary

In this chapter, you saw a wide range of Spring-specific features that complement the core IoC capabilities. You saw how to hook into the life cycle of a bean and to make it aware of the Spring environment. We introduced `FactoryBeans` as a solution for IoC, enabling a wider set of classes. We also showed how you can use `PropertyEditors` to simplify application configuration and to remove the need for artificial String-typed properties. We showed you more than one way to define beans using annotations, Java configuration, and Groovy. Moreover, we finished with an in-depth look at some additional features offered by `ApplicationContext`, including i18n, event publication, and resource access.

We also covered features such as profiles support, and the environment and property source abstraction layer. Finally, we discussed various testing styles and testing Spring applications.

The icing on the cake was how to use Spring Boot to configure beans and boot up your application as soon as possible and with little effort.

So far, we have covered the main concepts of the Spring Framework and its features as a DI container, as well as other services that the core Spring Framework provides. In the next chapter and onward, we discuss using Spring in specific areas such as AOP, data access, transaction support, and web application support.



## CHAPTER 5



# Spring AOP

Besides dependency injection (DI), another core feature that the Spring Framework offers is support for aspect-oriented programming (AOP). AOP is often referred to as a tool for implementing crosscutting concerns. The term *crosscutting concerns* refers to logic in an application that cannot be decomposed from the rest of the application and may result in code duplication and tight coupling. By using AOP for modularizing individual pieces of logic, known as *concerns*, you can apply them to many parts of an application without duplicating the code or creating hard dependencies. Logging and security are typical examples of crosscutting concerns that are present in many applications. Consider an application that logs the start and end of every method for debugging purposes. You will probably refactor the logging code into a special class, but you still have to call methods on that class twice per method in your application in order to perform the logging. Using AOP, you can simply specify that you want the methods on your logging class to be invoked before and after each method call in your application.

It is important to understand that AOP complements object-oriented programming (OOP), rather than competing with it. OOP is very good at solving a wide variety of problems that we, as programmers, encounter. However, if you look at the logging example again, it is obvious to see where OOP is lacking when it comes to implementing crosscutting logic on a large scale. Using AOP on its own to develop an entire application is practically impossible, given that AOP functions on top of OOP. Likewise, although it is certainly possible to develop entire applications by using OOP, you can work smarter by employing AOP to solve certain problems that involve crosscutting logic.

The AOP framework is one of the core components of Spring, and important functionalities such as transactional data management and security would not be possible without it.

This chapter covers the following topics:

- *AOP basics*: Before discussing Spring's AOP implementation, we cover the basics of AOP as a technology. Most of the concepts covered in the "AOP Concepts" section are not specific to Spring and can be found in any AOP implementation. If you are already familiar with another AOP implementation, feel free to skip the "AOP Concepts" section.
- *Types of AOP*: There are two distinct types of AOP: static and dynamic. In static AOP, like that provided by AspectJ's<sup>1</sup> compile-time weaving mechanisms, the crosscutting logic is applied to your code at compile time, and you cannot change it without modifying the code and recompiling. With dynamic AOP, such as Spring AOP, crosscutting logic is applied dynamically at runtime. This allows you to make

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<sup>1</sup><https://www.eclipse.org/aspectj>

changes to the AOP configuration without having to recompile the application. These types of AOP are complementary, and, when used together, they form a powerful combination that you can use in your applications.

- *Spring AOP architecture*: Spring AOP is only a subset of the full AOP feature set found in other implementations such as AspectJ. In this chapter, we take a high-level look at which features are present in Spring, how they are implemented, and why some features are excluded from the Spring implementation.
- *Proxies in Spring AOP*: Proxies are a huge part of how Spring AOP works, and you must understand them to get the most out of Spring AOP. In this chapter, we look at the two kinds of proxy: the JDK dynamic proxy and the CGLIB proxy. We look at the different scenarios in which Spring uses each proxy, the performance of the two proxy types, and some simple guidelines to follow in your application to get the most from Spring AOP.
- *Using Spring AOP*: In this chapter, we present some practical examples of AOP usage. We start off with a simple example to ease you into Spring's AOP code, and we continue with a detailed description of the AOP features that are available in Spring, complete with examples.
- *Advanced use of pointcuts*: We explore the `ComposablePointcut` and `ControlFlowPointcut` classes, introductions, and appropriate techniques you should employ when using pointcuts in your application.
- *AOP framework services*: The Spring Framework fully supports configuring AOP transparently and declaratively. We look at two ways (the `ProxyFactoryBean` class, and `@AspectJ`-style annotations) to inject declaratively defined AOP proxies into your application objects as collaborators, thus making your application completely unaware that it is working with advised objects.
- *Integrating AspectJ*: AspectJ is a fully featured AOP implementation. The main difference between AspectJ and Spring AOP is that AspectJ applies advice to target objects via weaving (either compile-time or load-time weaving), while Spring AOP is based on proxies. The feature set of AspectJ is much greater than that of Spring AOP, but it is much more complicated to use than Spring. AspectJ is a good solution when you find that Spring AOP lacks a feature you need.

## AOP Concepts

As with most technologies, AOP comes with its own specific set of concepts and terms, and it's important to understand what they mean. The following are the core concepts of AOP:

- *Joinpoints*: A joinpoint is a well-defined point during the execution of your application. Typical examples of joinpoints include a call to a method, the method invocation itself, class initialization, and object instantiation. Joinpoints define the points in your application at which you can insert additional logic using AOP.
- *Advice*: The code that is executed at a particular joinpoint is the advice, defined by a method in your class. There are many types of advice, such as *before*, which executes before the joinpoint, and *after*, which executes after it.
- *Pointcuts*: A pointcut is a collection of joinpoints that you use to define when advice should be executed. By creating pointcuts, you gain fine-grained control over how

you apply advice to the components in your application. As mentioned previously, a typical joinpoint is a method invocation, or the collection of all method invocations in a particular class. Often you can compose pointcuts in complex relationships to further constrain when advice is executed.

- *Aspects*: An aspect is the combination of advice and pointcuts encapsulated in a class. This combination results in a definition of the logic that should be included in the application and where it should execute
- *Weaving*: This is the process of inserting aspects into the application code at the appropriate point. For compile-time AOP solutions, this weaving is generally done at build time. Likewise, for runtime AOP solutions, the weaving process is executed dynamically at runtime. AspectJ supports another weaving mechanism called *loadtime weaving (LTW)*, in which it intercepts the underlying JVM class loader and provides weaving to the bytecode when it is being loaded by the class loader.
- *Target*: An object whose execution flow is modified by an AOP process is referred to as the target object. Often you see the target object referred to as the *advised object*.
- *Introduction*: This is the process by which you can modify the structure of an object by introducing additional methods or fields to it. You can use introduction AOP to make any object implement a specific interface without needing the object's class to implement that interface explicitly.

Don't worry if you find these concepts confusing; this will all become clear when you see some examples. Also, be aware that you are shielded from many of these concepts in Spring AOP, and some are not relevant because of Spring's choice of implementation. We will discuss each of these features in the context of Spring as we progress through the chapter.

## Types of AOP

As we mentioned earlier, there are two distinct types of AOP: static and dynamic. The difference between them is really the point at which the weaving process occurs and how this process is achieved.

### Static AOP

In static AOP, the weaving process forms another step in the build process for an application. In Java terms, you achieve the weaving process in a static AOP implementation by modifying the actual bytecode of your application, changing and extending the application code as necessary. This is a well-performing way of achieving the weaving process because the end result is just Java bytecode, and you do not perform any special tricks at runtime to determine when advice should be executed. The drawback of this mechanism is that any modifications you make to the aspects, even if you simply want to add another joinpoint, require you to recompile the entire application. AspectJ's compile-time weaving is an excellent example of a static AOP implementation.

## Dynamic AOP

Dynamic AOP implementations, such as Spring AOP, differ from static AOP implementations in that the weaving process is performed dynamically at runtime. How this is achieved is implementation-dependent, but as you will see, Spring's approach is to create proxies for all advised objects, allowing for advice to be invoked as required. The drawback of dynamic AOP is that, typically, it does not perform as well as static AOP, but the performance is steadily increasing. The major benefit of dynamic AOP implementations is the ease with which you can modify the entire aspect set of an application without needing to recompile the main application code.

## Choosing an AOP Type

Choosing whether to use static or dynamic AOP is quite a hard decision. Both have their own benefits, and you are not restricted to using only one type. In general, static AOP implementations have been around longer and tend to have more feature-rich implementations, with a greater number of available joinpoints.

Typically, if performance is absolutely critical or you need an AOP feature that is not implemented in Spring, you will want to use AspectJ. In most other cases, Spring AOP is ideal. Keep in mind that many AOP-based solutions such as transaction management are already provided for you by Spring, so check the framework capabilities before rolling your own! As always, let the requirements of your application drive your choice of AOP implementation, and don't restrict yourself to a single implementation if a combination of technologies would better suit your application. In general, Spring AOP is less complex than AspectJ, so it tends to be an ideal first choice.

## AOP in Spring

Spring's AOP implementation can be viewed as two logical parts. The first part is the AOP core, which provides fully decoupled, purely programmatic AOP functionality (also known as the Spring AOP API). The second part of the AOP implementation is the set of framework services that make AOP easier to use in your applications. On top of this, other components of Spring, such as the transaction manager and EJB helper classes, provide AOP-based services to simplify the development of your application.

## The AOP Alliance

The AOP Alliance<sup>2</sup> is a joint effort among representatives of many open source AOP projects to define a standard set of interfaces for AOP implementations. Wherever applicable, Spring uses the AOP Alliance interfaces rather than defining its own. This allows you to reuse certain advice across multiple AOP implementations that support the AOP Alliance interfaces.

## Spring AOP Architecture

Spring AOP is implemented in pure Java. There is no need for a special compilation process. The core architecture of Spring AOP is based on *proxies*. An advised instance of a class is the result of a `ProxyFactory` creating a proxy instance of that class with all the aspects woven into the proxy. `ProxyFactory` can be used *manually* in a purely programmatic approach to creating AOP proxies. For the most part, you don't need to use this in your application; instead, you can rely on the declarative AOP configuration mechanisms

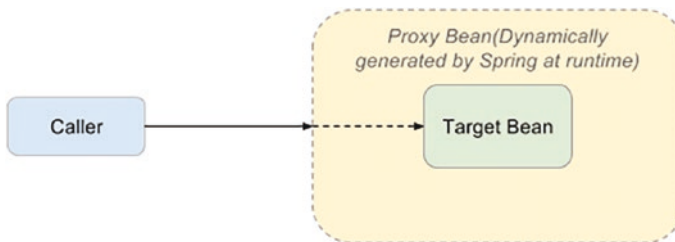
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<sup>2</sup><https://aopalliance.sourceforge.net>

provided by Spring (the `ProxyFactoryBean` class, the `aop` namespace [when using XML], and `@AspectJ`-style annotations) to take advantage of declarative proxy creation. However, it is important to understand how proxy creation works, so this chapter aims to provide a very solid knowledge base.

At runtime, Spring analyzes the crosscutting concerns defined for the beans in `ApplicationContext` and generates proxy beans (which wrap the underlying target bean) dynamically. Instead of calling the target bean directly, callers are injected with the proxied bean. The proxy bean then analyzes the running condition (that is, `joinpoint`, `pointcut`, or `advice`) and weaves in the appropriate advice accordingly.

Figure 5-1 shows a high-level view of a Spring AOP proxy in action.



**Figure 5-1.** Spring AOP proxy in action

Internally, Spring has two proxy implementations:

- JDK dynamic proxies
- CGLIB proxies

By default, when the target object to be advised implements an interface, Spring will use a JDK dynamic proxy to create proxy instances of the target. However, when the advised target object doesn't implement an interface (for example, it's a concrete class), CGLIB will be used for proxy instance creation. One major reason is that the JDK dynamic proxy supports only the proxying of interfaces. We discuss proxies in detail in the section "Understanding Proxies."

## Joinpoints in Spring

One of the more noticeable simplifications in Spring AOP is that it supports only one joinpoint type: **method invocation**. At first glance, this might seem like a severe limitation if you are familiar with other AOP implementations such as `AspectJ`, which supports many more joinpoints, but in fact this makes Spring more accessible.

The method invocation joinpoint is by far the most useful joinpoint available, and using it, you can achieve many of the tasks that make AOP useful in day-to-day programming. Remember that if you need to advise some code at a joinpoint other than a method invocation, you can always use Spring and `AspectJ` together.

## Aspects in Spring

In Spring AOP, an aspect is represented by an instance of a class that implements the `Advisor` interface. Spring provides convenience `Advisor` implementations that you can reuse in your applications, thus removing the need for you to create custom `Advisor` implementations. There are two subinterfaces of `org.springframework.aop.Advisor`:

- `org.springframework.aop.PointcutAdvisor`
- `org.springframework.aop.IntroductionAdvisor`

The `PointcutAdvisor` interface is implemented by all `Advisor` implementations that use pointcuts to control the advice applied to joinpoints. In Spring, introductions are treated as special kinds of advice, and by using the `IntroductionAdvisor` interface, you can control those classes to which an introduction applies.

We discuss `PointcutAdvisor` implementations in detail in the upcoming section “Advisors and Pointcuts in Spring.”

## The ProxyFactory Class

The `org.springframework.aop.framework.ProxyFactory` class controls the weaving and proxy creation process in Spring AOP. A proxy is created for an **advised** or **target object**, which can be set by calling the `setTarget(..)` method. Internally, `ProxyFactory` delegates the proxy creation process to an instance of `org.springframework.aop.framework.DefaultAopProxyFactory`, which in turn delegates to either `org.springframework.aop.framework.CglibAopProxy` or `org.springframework.aop.framework.JdkDynamicAopProxy`, depending on the settings of your application. We discuss proxy creation in more detail later in this chapter.



Starting with Spring 4, another implementation was added, `org.springframework.aop.framework.ObjenesisCglibAopProxy`, which extends `CglibAopProxy` to create proxy instances without invoking the constructor of the class. This is useful when a class has a constructor with arguments, a constructor with side effects, and constructors that throw exceptions.

---

The `ProxyFactory` class provides an implementation for the `addAdvice(Advice)` method (defined by the `org.springframework.aop.framework.Advised` interface) for cases where you want advice to apply to the invocation of all methods in a class, not just a selection. Internally, `addAdvice(..)` wraps the advice that you pass to it in an instance of `org.springframework.aop.support.DefaultPointcutAdvisor`, which is the standard implementation of `PointcutAdvisor`, and configures it with a pointcut that includes all methods by default. When you want more control over the `Advisor` that is created or when you want to add an introduction to the proxy, create the `org.springframework.aop.Advisor` yourself and use the `addAdvisor()` method of the `ProxyFactory`.

You can use the same `ProxyFactory` instance to create many proxies, each with different aspects. To help with this, `ProxyFactory` has `removeAdvice()` and `removeAdvisor()` methods, which allow you to remove any advice or advisors from the `ProxyFactory` that you previously passed to it. To check whether a `ProxyFactory` has particular advice attached to it, call `adviceIncluded()`, passing in the advice object for which you want to check.

## Creating Advice in Spring

Spring supports six flavors of advice, described in Table 5-1.

**Table 5-1.** Spring Advice Types

Advice Name	Interface	Description
<b>Before</b>	org.springframework.aop. BeforeAdvice	Using before advice, you can perform custom processing before a joinpoint executes. A joinpoint in Spring is always a method invocation, which essentially allows you to perform preprocessing before the method executes. The before advice has full access to the target of the method invocation as well as the arguments passed to the method, but it has no control over the execution of the method itself. If the before advice throws an exception, further execution of the interceptor chain (as well as the target method) will be aborted, and the exception will propagate back up the interceptor chain.
<b>After-returning</b>	org.springframework.aop. AfterReturningAdvice	After-returning advice is executed after the method invocation at the joinpoint has finished executing and has returned a value. The after-returning advice has access to the target of the method invocation, the arguments passed to the method, and the return value. Because the method has already executed when the after-returning advice is invoked, it has no control over the method invocation at all. If the target method throws an exception, the after-returning advice will not be run, and the exception will be propagated up to the call stack as usual.
<b>After(finally)</b>	org.springframework.aop. AfterAdvice	After(finally) advice is executed no matter the result of the advised method. The advice is executed even when the advised method fails and an exception is thrown.
<b>Throws</b>	org.springframework.aop. ThrowsAdvice	Throws advice is executed after a method invocation returns, but only if that invocation threw an exception. It is possible for throws advice to catch only specific exceptions, and if you choose to do so, you can access the method that threw the exception, the arguments passed into the invocation, and the target of the invocation.
<b>Around</b>	org.aopalliance.intercept. MethodInterceptor	In Spring, around advice is modeled using the AOP Alliance standard of a method interceptor. Your advice is allowed to execute before and after the method invocation, and you can control the point at which the method invocation is allowed to proceed. You can choose to bypass the method altogether if you want, providing your own implementation of the logic.
<b>Introduction</b>	org.springframework.aop. IntroductionInterceptor	Spring models introductions as special types of interceptors. Using an introduction interceptor, you can specify the implementation for methods that are being introduced by the advice.



## Interfaces for Advice

With regard to the `ProxyFactory` class, recall that advice is added to a proxy either directly, by using the `addAdvice(..)` method, or indirectly, by using an `Advisor` implementation with the `addAdvisor(..)` method. The main difference between advice and an advisor is that an advisor carries advice with the associated pointcut, which provides more fine-grained control on which joinpoints the advice will intercept.

With regard to advice, Spring has created a well-defined hierarchy for Advice interfaces. This hierarchy is based on the AOP Alliance interfaces and is shown in detail in Figure 5-2.

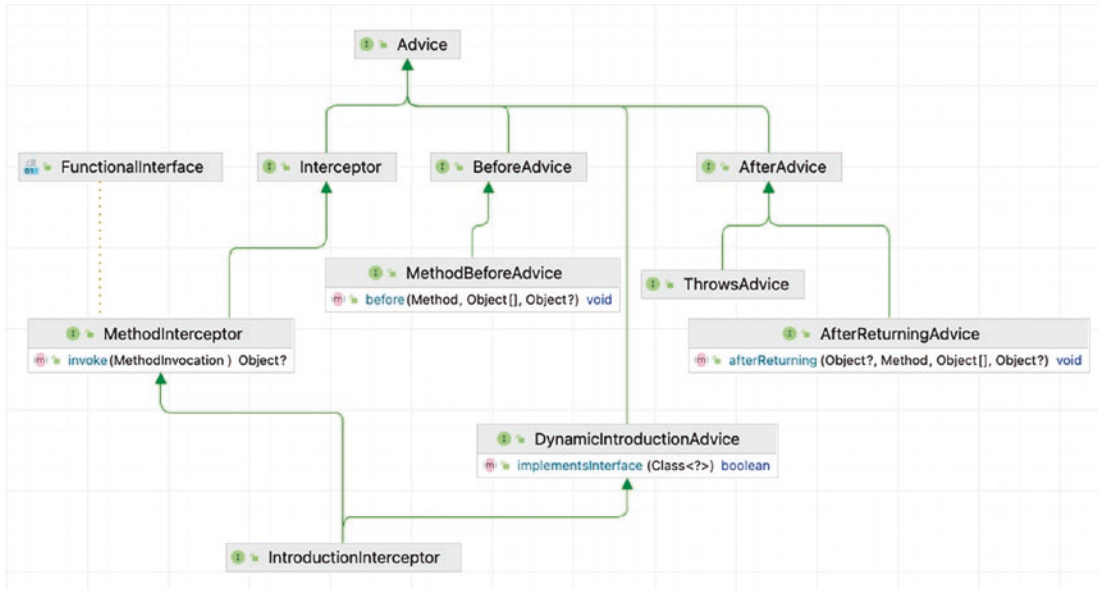


Figure 5-2. Interfaces for Spring advice types as depicted in IntelliJ IDEA

This kind of hierarchy has the benefit of not only being sound OO design but also enabling you to deal with advice types generically, such as by using a single `addAdvice(..)` method on the `ProxyFactory`, and you can add new advice types easily without having to modify the `ProxyFactory` class.

## Creating Advice Programmatically

It was mentioned in an earlier section that `ProxyFactory` can be used *manually* in a purely programmatic approach to creating AOP proxies. An example is in order before switching to the declarative Spring way of doing it. All interfaces listed in Table 5-1 can be implemented to define advices for a desired target. Listing 5-1 shows three such implementations: a before advice, an after advice, and an around advice, each of them implementing the appropriate interfaces.

Listing 5-1. Three Types of Custom Advice

```

package com.apress.prospring6.five.manual;

import org.aopalliance.intercept.MethodInterceptor;
import org.aopalliance.intercept.MethodInvocation;
import org.springframework.aop.AfterReturningAdvice;
    
```



```

import org.springframework.aop.MethodBeforeAdvice;
import org.springframework.util.StopWatch;
import java.lang.reflect.Method;
// other import statement omitted

class SimpleBeforeAdvice implements MethodBeforeAdvice {
    private static Logger logger = LoggerFactory.getLogger(SimpleBeforeAdvice.class);

    @Override
    public void before(Method method, Object[] args, Object target) throws Throwable {
        logger.info("Before: set up concert hall.");
    }
}

class SimpleAfterAdvice implements AfterReturningAdvice {
    private static Logger logger = LoggerFactory.getLogger(SimpleAfterAdvice.class);

    @Override
    public void afterReturning(Object returnValue, Method method, Object[] args, Object
target) throws Throwable {
        logger.info("After: offer standing ovation.");
    }
}

class SimpleAroundAdvice implements MethodInterceptor {
    private static Logger logger = LoggerFactory.getLogger(SimpleAroundAdvice.class);

    @Override
    public Object invoke(@Nonnull MethodInvocation invocation) throws Throwable {
        logger.info("Around: starting timer");
        StopWatch sw = new StopWatch();
        sw.start(invocation.getMethod().getName());
        Object returnValue = invocation.proceed();
        sw.stop();
        logger.info("Around: concert duration = {}", sw.getTotalTimeMillis());
        return returnValue;
    }
}

```

The `SimpleBeforeAdvice`, `SimpleAfterAdvice`, and `SimpleAroundAdvice` types are designed to be used on instances of type `Performance`. `SimpleBeforeAdvice` and `SimpleAfterAdvice` just print log messages, to confirm that the advice was applied. `SimpleAroundAdvice` is a little bit more complex and uses a `StopWatch` instance to time the performance. The intercepted method is being called using Java Reflection.

Listing 5-2 depicts the `Performance` interface and the `Concert` implementation.

**Listing 5-2.** Types of Objects to Apply Advice On

```
// Performance.java
package com.apress.prospring6.five.manual;

public interface Performance {
    void execute();
}

// Concert.java
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;

import static java.time.Duration.ofMillis;

public class Concert implements Performance{
    private static Logger LOGGER = LoggerFactory.getLogger(Concert.class);
    @Override
    public void execute() {
        LOGGER.info(" ... La la la la laaaa ...");
        try {
            Thread.sleep(ofMillis(2000).toMillis());
        } catch (InterruptedException e) {}
    }
}
```

Putting advice instances and the target together is easy; we just need to instantiate the ProxyFactory class and set the target and the advice instances as depicted in Listing 5-3.

**Listing 5-3.** Example Showing Programmatically Creating and Applying Advice on a Target

```
package com.apress.prospring6.five.manual;

import org.springframework.aop.framework.ProxyFactory;
// other import statements omitted

public class ManualAdviceDemo {

    public static void main(String... args) {
        Concert concert = new Concert();

        ProxyFactory pf = new ProxyFactory();
        pf.addAdvice(new SimpleBeforeAdvice());
        pf.addAdvice(new SimpleAroundAdvice());
        pf.addAdvice(new SimpleAfterAdvice());
        pf.setTarget(concert);

        Performance proxy = (Performance) pf.getProxy();

        proxy.execute();
    }
}
```



The order of execution of the advice is determined by the advice type, not the order in which they are added to the ProxyFactory instance.

The SimpleBeforeAdvice prints a message, making sure the concert hall is set up before the concert. The SimpleAroundAdvice intercepts the concert.execute() method to start the timer before the method execution, to stop it and print the duration after the execution. The SimpleAfterAdvice prints a message, making sure there is a standing ovation after the concert.

Running the class in Listing 5-3 prints the log shown in Listing 5-4.

**Listing 5-4.** Console Output Produced by Executing the ManualAdviceDemo Class

```
> Task :chapter05:ManualAdviceDemo.main()
INFO : SimpleBeforeAdvice - Before: set up concert hall.
INFO : SimpleAroundAdvice - Around: starting timer
INFO : Concert - ... La la la la laaaa ...
INFO : SimpleAroundAdvice - Around: concert duration = 2015
INFO : SimpleAfterAdvice - After: offer standing ovation.
```

The output from calling execute() on the proxy object is shown, and it includes the output of the before advice, the first message of the around advice, the actual message printed by the target object—the Concert object—the second message of the around advice, and the output of the after advice. The order of the messages demonstrates that the advices were applied where expected.

You can play around and write your own code samples implementing org.springframework.aop.AfterAdvice and org.springframework.aop.ThrowsAdvice or check out the examples in the project for this book. Because there is a lot of code duplication, they won't be covered here.

Applying advice this way is not really useful, the best way is to declare your bean, and your advice bean and tell Spring to do it, but before getting there some detailed conclusions about advice use are in order.

## A Few Conclusions

Before advice is one of the most useful advice types available in Spring. This advice can modify the arguments passed to a method and can prevent the method from executing by raising an exception. This is most useful for secure implementations, where a before advice checks user credentials before allowing the method invocation to proceed.

After-returning advice is executed after the method invocation at the joinpoint returns. Given that the method has already executed, you can't change the arguments that are passed to it. Although you can read these arguments, you can't change the execution path, and you can't prevent the method from executing. These restrictions are expected; what might not be expected, however, is that **you cannot modify the return value in the after-returning advice**. When using after-returning advice, you are limited to adding processing. Although after-returning advice cannot modify the return value of a method invocation, it can throw an exception that can be sent up the stack instead of the return value.

Throws advice is similar to after-returning advice in that it executes after the joinpoint, which is always a method invocation, but throws advice executes only if the method throws an exception. Throws advice is also similar to after-returning advice in that it has little control over program execution. If you are using throws advice, you can't choose to ignore the exception that was raised and return a value for the method instead. **The only modification you can make to the program flow is to change the type of exception that is thrown**. This is quite a powerful concept and can make application development much simpler. Consider a situation where you have an API that throws an array of poorly defined exceptions. Using

throws advice, you can advise all classes in that API and reclassify the exception hierarchy into something more manageable and descriptive. Of course, you can also use throws advice to provide centralized error logging across your application, thus reducing the amount of error-logging code that is spread across your application. After-throwing advice is useful in a variety of situations; it allows you to reclassify entire Exception hierarchies as well as build centralized exception logging for your application. We have found that after-throwing advice is particularly useful when we are debugging a live application because it allows us to add extra logging code without needing to modify the application's code.

Around advice functions like a combination of before and after advice, with two differences:

- You can modify the return value.
- You can prevent the method from executing.

This means that by using around advice, you can essentially replace the entire implementation of a method with new code. Around advice in Spring is modeled as an interceptor using the `MethodInterceptor` interface as shown in the example in this section. There are many uses for around advice, and you will find that many features of Spring are created by using method interceptors, such as the remote proxy support and the transaction management features. Method interception is also a good mechanism for profiling the execution of your application, and the example shown, by timing the execution of the target method, does exactly that—records the duration this method takes to execute, enabling you to study the values to make a decision if the method should be optimized or not.

## Choosing an Advice Type

In general, choosing an advice type is driven by the requirements of your application, but you should choose the most specific advice type for your need. That is to say, don't use around advice when before advice will do. In most cases, around advice can accomplish everything that the other three advice types can, but it may be overkill for what you are trying to achieve. By using the most specific type of advice, you are making the intention of your code clearer, and you are also reducing the possibility of errors. Consider advice that counts method calls. When you are using before advice, all you need to code is the counter, but with around advice, you need to remember to invoke the method and return the value to the caller. These small things can allow spurious errors to creep into your application. By keeping the advice type as focused as possible, you reduce the scope for errors.

## Advisors and Pointcuts in Spring

Thus far, all the examples you have seen have used the `ProxyFactory` class. This class provides a simple way of obtaining and configuring AOP proxy instances in custom user code. The `ProxyFactory.addAdvice()` method is used to configure advice for a proxy. This method delegates to `addAdvisor()` behind the scenes, creating an instance of `org.springframework.aop.support.DefaultPointcutAdvisor` and configuring it with a pointcut that points to all methods. In this way, the advice is deemed to apply to all methods on the target. In some cases, such as when you are using AOP for logging purposes, this may be desirable, but in other cases you may want to limit the methods to which the advice applies.

Of course, you could simply perform the checking in the advice itself that the method being advised is the correct one, but this approach has several drawbacks. First, hard-coding the list of acceptable methods into the advice reduces the advice's reusability. By using pointcuts, you can configure the methods to which an advice applies, without needing to put this code inside the advice; this clearly increases the reuse value of the advice. Other drawbacks with hard-coding the list of methods into the advice are performance related. To inspect the method being advised in the advice, you need to perform the check each time any method on the target is invoked. This clearly reduces the performance of your application. When you use pointcuts, the check is performed once for each method, and the results are cached for later use. The other

performance-related drawback of not using pointcuts to restrict the list-advised methods is that Spring can make optimizations for unadvised methods when creating a proxy, which results in faster invocations on unadvised methods. These optimizations are covered in greater detail when we discuss proxies later in the chapter.

We strongly recommend that you avoid the temptation to hard-code method checks into your advice and instead use pointcuts wherever possible to govern the applicability of advice to methods on the target. That said, in some cases it is necessary to hard-code the checks into your advice. Consider the earlier example of the after-returning advice designed to catch weak keys generated by the `KeyGenerator` class. This kind of advice is closely coupled to the class it is advising, and it is wise to check inside the advice to ensure that it is applied to the correct type. We refer to this coupling between advice and target as *target affinity*. In general, you should use pointcuts when your advice has little or no target affinity. That is, it can apply to any type or a wide range of types. When your advice has strong target affinity, try to check that the advice is being used correctly in the advice itself; this helps reduce head-scratching errors when advice is misused. We also recommend you avoid advising methods needlessly. As you will see, this results in a noticeable drop in invocation speed that can have a large impact on the overall performance of your application.

## The Pointcut Interface

Pointcuts in Spring are created by implementing the `org.springframework.aop.Pointcut` interface, which is shown in Listing 5-5 (full code is available on the GitHub Spring Framework repository<sup>3</sup>).

**Listing 5-5.** Spring Pointcut Interface

```
package org.springframework.aop;

public interface Pointcut {
    ClassFilter getClassFilter();

    MethodMatcher getMethodMatcher();

    // some non-relevant code missing
}
```

As you can see from this code, the `Pointcut` interface defines two methods, `getClassFilter()` and `getMethodMatcher()`, which return instances of `ClassFilter` and `MethodMatcher`, respectively. Obviously, if you choose to implement the `Pointcut` interface, you will need to implement these methods. Thankfully, as you will see in the next section, this is usually unnecessary because Spring provides a selection of `Pointcut` implementations that cover most, if not all, of your use cases.

When determining whether a pointcut applies to a particular method, Spring first checks to see whether the `Pointcut` interface applies to the method's class by using the `ClassFilter` instance returned by `Pointcut.getClassFilter()`. The `ClassFilter` functional interface is shown in Listing 5-6 (full code is available on the GitHub Spring Framework repository<sup>4</sup>).

<sup>3</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-aop/src/main/java/org/springframework/aop/Pointcut.java>

<sup>4</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-aop/src/main/java/org/springframework/aop/ClassFilter.java>

**Listing 5-6.** Spring ClassFilter Interface

```
org.springframework.aop;

@FunctionalInterface
public interface ClassFilter {
    boolean matches(Class<?> clazz);
    // some non-relevant code missing
}
```

As you can see, the `ClassFilter` functional interface defines a single abstract method, `matches()`, that is passed an instance of `Class` that represents the class to be checked. As you have no doubt determined, the `matches()` method returns `true` if the pointcut applies to the class and returns `false` otherwise.

The `MethodMatcher` interface is more complex than the `ClassFilter` interface, as shown Listing 5-7 (full code is available on the GitHub Spring Framework repository<sup>5</sup>).

**Listing 5-7.** Spring MethodMatcher Interface

```
package org.springframework.aop;

import java.lang.reflect.Method

public interface MethodMatcher {

    boolean matches(Method method, Class<?> targetClass);
    boolean isRuntime();
    boolean matches(Method method, Class<?> targetClass, Object... args);
    // some non-relevant code missing
}
```

Spring supports two types of `MethodMatcher`, static and dynamic, which are determined by the return value of `isRuntime()`. Before using `MethodMatcher`, Spring calls `isRuntime()` to determine whether `MethodMatcher` is static, indicated by a return value of `false`, or dynamic, indicated by a return value of `true`.

For a static pointcut, Spring calls the `matches(Method, Class<T>)` method of the `MethodMatcher` once for every method on the target, caching the return value for subsequent invocations of those methods. In this way, the check for method applicability is performed only once for each method, and subsequent invocations of a method do not result in an invocation of `matches()`.

With dynamic pointcuts, Spring still performs a static check by using `matches(Method, Class<T>)` the first time a method is invoked to determine the overall applicability of a method. However, in addition to this and provided that the static check returned `true`, Spring performs a further check for each invocation of a method by using the `matches(Method, Class<T>, Object[])` method. In this way, a dynamic `MethodMatcher` can determine whether a pointcut should apply based on a particular invocation of a method, not just on the method itself. For example, a pointcut needs to be applied only when the argument is an `Integer` with a value larger than 100. In this case, the `matches(Method, Class<T>, Object[])` method can be coded to perform further checking on the argument for each invocation.

Clearly, static pointcuts perform much better than dynamic pointcuts because they avoid the need for an additional check per invocation. Dynamic pointcuts provide a greater level of flexibility for deciding whether to apply advice. In general, we recommend you use static pointcuts wherever you can. However, in

<sup>5</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-aop/src/main/java/org/springframework/aop/MethodMatcher.java>

cases where your advice adds substantial overhead, it may be wise to avoid any unnecessary invocations of your advice by using a dynamic pointcut.

In general, you rarely create your own Pointcut implementations from scratch because Spring provides abstract base classes for both static and dynamic pointcuts. We will look at these base classes, along with other Pointcut implementations, over the next few sections.

## Available Pointcut Implementations

As of version 4.0, Spring provides eight main implementations of the Pointcut interface: two abstract classes intended as convenience classes for creating static and dynamic pointcuts, and six concrete classes, one for each of the following:

- Composing multiple pointcuts together
- Handling control flow pointcuts
- Performing simple name-based matching
- Defining pointcuts using regular expressions
- Defining pointcuts using AspectJ expressions
- Defining pointcuts that look for specific annotations at the class or method level

Table 5-2 summarizes the main eight Pointcut interface implementations.

**Table 5-2.** Summary of Spring Pointcut Implementations

Implementation Class	Description
<code>org.springframework.aop.support.annotation.AnnotationMatchingPointcut</code>	This implementation looks for a specific Java annotation on a class or method. This class requires JDK 5 or higher.
<code>org.springframework.aop.aspectj.AspectJExpressionPointcut</code>	This implementation uses an AspectJ weaver to evaluate a pointcut expression in AspectJ syntax.
<code>org.springframework.aop.support.ComposablePointcut</code>	The <code>ComposablePointcut</code> class is used to compose two or more pointcuts together with operations such as <code>union()</code> and <code>intersection()</code> .
<code>org.springframework.aop.support.ControlFlowPointcut</code>	<code>ControlFlowPointcut</code> is a special-case pointcut that matches all methods within the control flow of another method; that is, any method that is invoked either directly or indirectly as the result of another method being invoked.
<code>org.springframework.aop.support.DynamicMethodMatcherPointcut</code>	This implementation is intended as a base class for building dynamic pointcuts.
<code>org.springframework.aop.support.JdkRegexpMethodPointcut</code>	This implementation allows you to define pointcuts using JDK 1.4 regular expression support. This class requires JDK 1.4 or newer.
<code>org.springframework.aop.support.NameMatchMethodPointcut</code>	Using <code>NameMatchMethodPointcut</code> , you can create a pointcut that performs simple matching against a list of method names.
<code>org.springframework.aop.support.StaticMethodMatcherPointcut</code>	The <code>StaticMethodMatcherPointcut</code> class is intended as a base for building static pointcuts.

Figure 5-3 shows the Pointcut Spring hierarchy.

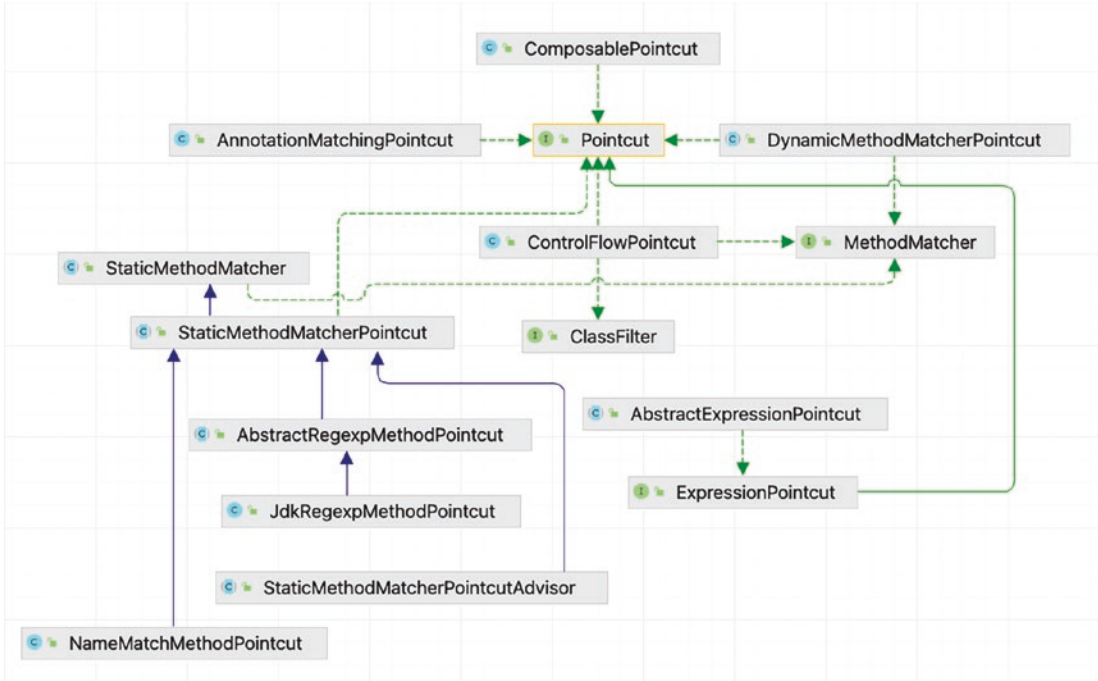


Figure 5-3. Pointcut implementation classes represented as a UML diagram in IntelliJ IDEA

## Using DefaultPointcutAdvisor

Before you can use any Pointcut implementation, you must first create an instance of the Advisor interface, or more specifically a PointcutAdvisor interface. Remember from our earlier discussions that Advisor is Spring’s representation of an aspect (see the previous section called “Aspects in Spring”), which is a coupling of advice and pointcuts that governs which methods should be advised and how they should be advised. Spring provides a number of implementations of PointcutAdvisor, but for now we will concern ourselves with just one, DefaultPointcutAdvisor. This is a simple PointcutAdvisor for associating a single Pointcut with a single Advice.

## Using StaticMethodMatcherPointcut

In this section, we will create a simple static pointcut by extending the abstract StaticMethodMatcherPointcut class. Since the StaticMethodMatcherPointcut class extends the StaticMethodMatcher class (an abstract class too), which implements the MethodMatcher interface, you are required to implement the method matches(Method, Class<?>). The rest of the Pointcut implementation is handled automatically. Although this is the only method you are required to implement (when extending the StaticMethodMatcherPointcut class), you may want to override the getClassFilter() method as shown in Listing 5-8 to ensure that only methods of the correct type get advised.



For this example, we have two classes, `GoodGuitarist` and `GreatGuitarist`, with identical methods defined in both, which are implementations of the method in interface `Singer`. They are depicted together with the `SimpleAroundAdvice` designed to wrap around instances of these types.

**Listing 5-8.** Classes `GoodGuitarist` and `GreatGuitarist` to Be Used for Showing `StaticMethodMatcherPointcut` Usage

```

package com.apress.prospring6.two.common;
// import statements omitted

public interface Singer {
    void sing();
}

public class GoodGuitarist implements Singer {
    private static Logger LOGGER = LoggerFactory.getLogger(GoodGuitarist.class);

    @Override public void sing() {
        LOGGER.info("Head on your heart, arms around me");
    }
}

public class GreatGuitarist implements Singer {
    private static Logger LOGGER = LoggerFactory.getLogger(GreatGuitarist.class);

    @Override public void sing() {
        LOGGER.info("You've got my soul in your hand");
    }
}

public class SimpleAroundAdvice implements MethodInterceptor {
    private static Logger LOGGER = LoggerFactory.getLogger(GoodGuitarist.class);

    @Override
    public Object invoke(MethodInvocation invocation) throws Throwable {
        LOGGER.debug(">> Invoking " + invocation.getMethod().getName());
        Object retVal = invocation.proceed();
        LOGGER.debug(">> Done");
        return retVal;
    }
}

```

With this example, we want to be able to create a proxy of both classes by using the same `DefaultPointcutAdvisor` but have the advice apply only to the `sing()` method of the `GoodGuitarist` class.

To do this, we created the `SimpleStaticPointcut` class as shown in Listing 5-9, together with the class used to test it.

**Listing 5-9.** StaticMethodMatcherPointcut Implementation

```

package com.apress.prospring6.five.pointcut;

import org.aopalliance.aop.Advice;
import org.springframework.aop.Advisor;
import org.springframework.aop.ClassFilter;
import org.springframework.aop.Pointcut;
import org.springframework.aop.framework.ProxyFactory;
import org.springframework.aop.support.DefaultPointcutAdvisor;
import org.springframework.aop.support.StaticMethodMatcherPointcut;
import java.lang.reflect.Method;
// other static imports omitted

class SimpleStaticPointcut extends StaticMethodMatcherPointcut {
    @Override
    public boolean matches(Method method, Class<?> cls) {
        return ("sing".equals(method.getName()));
    }

    @Override
    public ClassFilter getClassFilter() {
        return cls -> (cls == GoodGuitarist.class);
    }
}

public class StaticPointcutDemo {
    public static void main(String... args) {
        // targets
        GoodGuitarist johnMayer = new GoodGuitarist();
        GreatGuitarist ericClapton = new GreatGuitarist();

        Singer proxyOne;
        Singer proxyTwo;

        Pointcut pc = new SimpleStaticPointcut();
        Advice advice = new SimpleAroundAdvice();
        Advisor advisor = new DefaultPointcutAdvisor(pc, advice);

        ProxyFactory pf = new ProxyFactory();
        pf.addAdvisor(advisor);
        pf.setTarget(johnMayer);
        proxyOne = (Singer)pf.getProxy();

        pf = new ProxyFactory();
        pf.addAdvisor(advisor);
        pf.setTarget(ericClapton);
        proxyTwo = (Singer)pf.getProxy();

        proxyOne.sing();
        proxyTwo.sing();
    }
}

```

Notice that the `getClassFilter()` method was overridden to return a `ClassFilter` instance whose `matches()` method returns `true` only for the `GoodGuitarist` class. With this static pointcut, we are saying that only methods of the `GoodGuitarist` class will be matched, and furthermore, only the `sing()` method of that class is to be matched.

The `main(..)` method creates an instance of `DefaultPointcutAdvisor` by using the `SimpleAroundAdvice` and `SimpleStaticPointcut` classes. Also, because both classes (`GoodGuitarist` and `GreatGuitarist`) implement the same interface, you can see that the proxies can be created based on the interface, not on the concrete classes. Notice that the `DefaultPointcutAdvisor` instance is then used to create two proxies: one for an instance of `GoodGuitarist` and one for an instance of `EricClapton`. Finally, the `sing()` method is invoked on the two proxies. Running this example results in the output shown in Listing 5-10.

**Listing 5-10.** `StaticMethodMatcherPointcut` Example Output

```
DEBUG: SimpleAroundAdvice - >> Invoking sing
INFO : GoodGuitarist - Head on your heart, arms around me
DEBUG: SimpleAroundAdvice - >> Done

INFO : GreatGuitarist - You've got my soul in your hand
```

As you can see, the only method for which `SimpleAroundAdvice` was actually invoked was the `sing()` method for the `GoodGuitarist` class, exactly as expected. Restricting the methods to which advice applies is quite simple and, as you will see when we discuss proxy options, is key to getting the best performance out of your application.

## Using `DynamicMethodMatcherPointcut`

Creating a dynamic pointcut is not much different from creating a static one, so for this example we will create a dynamic pointcut for the same classes we did previously, but we also need a method with arguments, to use this type of pointcut. The easiest way to do this is to enrich the `Singer` interface with a default method, to not affect the other implementations. To match the context of this example, let's add a `sing(String key)` method that receives the value of the key for the singer to sing in. The implementation of the `Singer` interface is shown in Listing 5-11.

**Listing 5-11.** Enriched `Singer` Interface

```
package com.apress.prospring6.five.common;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;

public interface Singer {
    Logger logger = LoggerFactory.getLogger(Singer.class);

    void sing();

    default void sing(String key){
        logger.info("Singing in the key of {}", key);
    }
}
```

Listing 5-12 shows the `DynamicMethodMatcherPointcut` implementation.

**Listing 5-12.** `SimpleDynamicPointcut` Implementation

```

package com.apress.prospring6.five.pointcut;

import com.apress.prospring6.five.common.GoodGuitarist;
import org.springframework.aop.ClassFilter;
import org.springframework.aop.support.DynamicMethodMatcherPointcut;

import java.lang.reflect.Method;

class SimpleDynamicPointcut extends DynamicMethodMatcherPointcut {
    @Override
    public ClassFilter getClassFilter() {
        return cls -> (cls == GoodGuitarist.class);
    }

    @Override
    public boolean matches(Method method, Class<?> targetClass) {
        return ("sing".equals(method.getName()));
    }

    @Override
    public boolean matches(Method method, Class<?> targetClass, Object... args) {
        logger.debug("Dynamic check for " + method.getName());

        if(args.length == 0) {
            return false;
        }
        var key = (String) args[0];

        return key.equalsIgnoreCase("C");
    }
}

```

As you can see from Listing 5-12, we override the `getClassFilter()` method in a similar manner as in the previous section. This removes the need to check the class in the method-matching methods, which is something that is especially important for the dynamic check. Although only the dynamic check is required, we implement the static check as well. The reason for this is that you know the `sing()` method (the one without arguments) will not be advised. Indicating this by using the static check, Spring never has to perform a dynamic check for this method. This is because when the static check method is implemented, Spring will first check against it, and if the checking result is not a match, Spring will stop doing any further dynamic checking. Moreover, the result of the static check will be cached for better performance. If the static check is not implemented, Spring performs a dynamic check each time the `sing({key})` method is invoked.

As a recommended practice, perform the class checking in the `getClassFilter()` method, the method checking in the `matches(Method, Class<?>)` method, and the argument checking in the `matches(Method, Class<?>, Object[])` method. This will make your pointcut much easier to understand and maintain, and performance will be better too.

In the `matches(Method, Class<?>, Object[])` method, you can see that we return `false` if the value of the `String` argument passed to the `sing({key})` method is not equal to `"C"`; otherwise, we return `true`. Note that in the dynamic check, we know that we are dealing with a method named `sing` because no other method makes it past the static check. In the code in Listing 5-13, you can see the test class used to test this pointcut.

**Listing 5-13.** `DynamicPointcutDemo` Class to Test the Dynamic Pointcut

```
package com.apress.prospring6.five.pointcut;
import org.springframework.aop.Advisor;
import org.springframework.aop.framework.ProxyFactory;
import org.springframework.aop.support.DefaultPointcutAdvisor;
// other import statements omitted

public class DynamicPointcutDemo {
    public static void main(String... args) {
        GoodGuitarist target = new GoodGuitarist();
        Advisor advisor = new DefaultPointcutAdvisor(new SimpleDynamicPointcut(), new
        SimpleAroundAdvice());
        ProxyFactory pf = new ProxyFactory();
        pf.setTarget(target);
        pf.addAdvisor(advisor);

        Singer proxy = (Singer)pf.getProxy();

        proxy.sing("C");
        proxy.sing("c");
        proxy.sing("E");

        proxy.sing();
    }
}
```

Notice that we have used the same advice class as in the static pointcut example. However, in this example, only the first two calls to `sing({key})` should be advised. The dynamic check prevents the third call to `sing("E")` from being advised, and the static check prevents the `sing()` method from being advised. Running this example yields the output in Listing 5-14.

**Listing 5-14.** `DynamicPointcutDemo` Output

```
DEBUG: SimpleDynamicPointcut - Static check for sing
DEBUG: SimpleDynamicPointcut - Static check for toString
DEBUG: SimpleDynamicPointcut - Static check for clone
DEBUG: SimpleDynamicPointcut - Static check for sing
DEBUG: SimpleDynamicPointcut - Static check for sing
DEBUG: SimpleDynamicPointcut - Dynamic check for sing
DEBUG: SimpleAroundAdvice - >> Invoking sing
INFO : Singer - Singing in the key of C
DEBUG: SimpleAroundAdvice - >> Done
DEBUG: SimpleDynamicPointcut - Dynamic check for sing
INFO : Singer - Singing in the key of E
DEBUG: SimpleDynamicPointcut - Static check for sing
```

```
DEBUG: SimpleDynamicPointcut - Dynamic check for sing
INFO : GoodGuitarist - Head on your heart, arms around me
```

As we expected, only the first two invocations of the `sing({key})` method were advised. Notice that the `sing()` invocation is subject to a dynamic check, thanks to the static check that checks the method name. An interesting point to note here is that the `sing({key})` method is subject to two static checks: one during the initial phase when all methods are checked, and another when it is first invoked. This is why the log contains so many `Static check for sing` entries.



As you can see, dynamic pointcuts offer a greater degree of flexibility than static pointcuts, but because of the additional runtime overhead they require, you should use a dynamic pointcut only when absolutely necessary.

---

## Using Simple Name Matching

Often when creating a pointcut, we want to match based on just the name of the method, ignoring method signature and return type. In this case, you can avoid needing to create a subclass of `StaticMethodMatcherPointcut` and use `NameMatchMethodPointcut` (which is a subclass of `StaticMethodMatcherPointcut`) to match against a list of method names instead. When you are using `NameMatchMethodPointcut`, no consideration is given to the signature of the method, so if you have methods `sing()` and `sing({key})`, they are both matched for the name `sing()`.

In the code snippet in Listing 5-15, you can see the `GrammyGuitarist` class, which is yet another implementation of `Singer`, because this Grammy award singer sings using his voice, uses a guitar, and, being human, occasionally talks and rests during a performance.

**Listing 5-15.** GrammyGuitarist Implementation

```
package com.apress.prospring6.five.common;

public class GrammyGuitarist implements Singer {
    private static Logger LOGGER = LoggerFactory.getLogger(GrammyGuitarist.class);

    @Override
    public void sing() {
        LOGGER.info("sing: Gravity is working against me\n" +
            "And gravity wants to bring me down");
    }

    public void sing(Guitar guitar) {
        LOGGER.info("play: " + guitar.play());
    }

    public void talk(){
        LOGGER.info("talk");
    }
}
```

```

@Override
public void rest(){
    LOGGER.info("zzz");
}
}

public class Guitar {

    public String play(){
        return "G C G C Am D7";
    }
}

```

For this example, we want to match the `sing()`, `sing(Guitar)`, and `rest()` methods by using `NameMatchMethodPointcut`. This translates to matching the names `sing` and `rest`. This is shown in Listing 5-16.

**Listing 5-16.** `NamePointcutDemo` Class, Used to Test `NameMatchMethodPointcut`

```

package com.apress.prospring6.five.pointcut;

import org.springframework.aop.support.NameMatchMethodPointcut;
// other import statements omitted

public class NamePointcutDemo {

    public static void main(String... args) {
        GrammyGuitarist johnMayer = new GrammyGuitarist();

        NameMatchMethodPointcut pc = new NameMatchMethodPointcut();
        pc.addMethodName("sing");
        pc.addMethodName("rest");

        Advisor advisor = new DefaultPointcutAdvisor(pc, new SimpleAroundAdvice());
        ProxyFactory pf = new ProxyFactory();
        pf.setTarget(johnMayer);
        pf.addAdvisor(advisor);

        GrammyGuitarist proxy = (GrammyGuitarist) pf.getProxy();
        proxy.sing();
        proxy.sing(new Guitar());
        proxy.rest();
        proxy.talk();
    }
}

```

There is no need to extend `NameMatchMethodPointcut`; you can simply create an instance of `NameMatchMethodPointcut`, and you are on your way. Notice that we have added two method names to the pointcut, `sing` and `rest`, using the `addMethodName(..)` method. Running this example produces the output in Listing 5-17.

**Listing 5-17.** NamePointcutDemo Output

```

DEBUG: SimpleAroundAdvice - >> Invoking sing
INFO : GrammyGuitarist - sing: Gravity is working against me
And gravity wants to bring me down
DEBUG: SimpleAroundAdvice - >> Done

DEBUG: SimpleAroundAdvice - >> Invoking sing
INFO : GrammyGuitarist - play: G C G C Am D7
DEBUG: SimpleAroundAdvice - >> Done

DEBUG: SimpleAroundAdvice - >> Invoking rest
INFO : GrammyGuitarist - zzz
DEBUG: SimpleAroundAdvice - >> Done

INFO : GrammyGuitarist - talk

```

As expected, the `sing()`, `sing(Guitar)`, and `rest()` methods are advised, thanks to the pointcut, but the `talk()` method is left unadvised.

For many of the Pointcut implementations, Spring also provides a convenience Advisor implementation that acts as the pointcut. For instance, instead of using `NameMatchMethodPointcut` coupled with `DefaultPointcutAdvisor` in the previous example, we could simply have used `NameMatchMethodPointcutAdvisor`, as shown in Listing 5-18.

**Listing 5-18.** NameMatchMethodPointcutAdvisor Usage Example

```

package com.apress.prospring6.five;

import org.springframework.aop.support.NameMatchMethodPointcutAdvisor;
// other import statements omitted

public class NameMatchMethodPointcutAdvisorDemo {
    public static void main(String... args) {
        GrammyGuitarist johnMayer = new GrammyGuitarist();

        NameMatchMethodPointcutAdvisor advisor =
            new NameMatchMethodPointcutAdvisor(new SimpleAroundAdvice());
        advisor.setMappedNames("sing", "rest");

        ProxyFactory pf = new ProxyFactory();
        pf.setTarget(johnMayer);
        pf.addAdvisor(advisor);

        GrammyGuitarist proxy = (GrammyGuitarist) pf.getProxy();
        proxy.sing();
        proxy.sing(new Guitar());
        proxy.rest();
        proxy.talk();
    }
}

```



Notice that rather than creating an instance of `NameMatchMethodPointcut`, we configure the pointcut details on the instance of `NameMatchMethodPointcutAdvisor` by calling the `setMappedNames(..)` method and providing the method names as arguments. In this way, `NameMatchMethodPointcutAdvisor` is acting as both the advisor and the pointcut.

You can find full details of the different Advisor implementations by exploring the Javadoc for the `org.springframework.aop.support` package. There is no noticeable performance difference between the two approaches, and aside from there being slightly less code in the second example, there is very little difference in the actual coding approach. We prefer to stick with the first approach because we feel the intent is slightly clearer in the code. At the end of the day, the style you choose comes down to personal preference.

## Creating Pointcuts with Regular Expressions

In the previous section, we discussed how to perform simple matching against a predefined list of methods. But what if you don't know all the method names in advance, and instead you know the pattern that the names follow? For instance, what if you want to match all methods whose names start with `get`? In this case, you can use the regular expression pointcut `JdkRegexpMethodPointcut` to match a method name based on a regular expression. Listing 5-19 depicts another `Guitarist` class, which contains three methods.

**Listing 5-19.** Guitarist Implementation

```
package com.apress.prospring6.five.common;
// other imports omitted

public class Guitarist implements Singer{
    private static Logger LOGGER = LoggerFactory.getLogger(Guitarist.class);

    @Override
    public void sing() {
        LOGGER.info("Just keep me where the light is");
    }

    public void sing2() {
        LOGGER.info("And wrap me in your arms");
    }

    @Override
    public void rest() {
        LOGGER.info("zzz...");
    }
}
```

Using a regular expression-based pointcut, we can match all methods in this class whose name starts with `sing`. This is shown in Listing 5-20.

**Listing 5-20.** Regex Pointcut Test Class

```
package com.apress.prospring6.five.pointcut;

import org.springframework.aop.support.JdkRegexpMethodPointcut;
// other import statements omitted
```

```

public class RegexpPointcutDemo {
    public static void main(String... args) {
        Guitarist johnMayer = new Guitarist();

        var pc = new JdkRegexpMethodPointcut();
        pc.setPattern(".*sing.*");

        Advisor advisor = new DefaultPointcutAdvisor(pc, new SimpleAroundAdvice());
        ProxyFactory pf = new ProxyFactory();
        pf.setTarget(johnMayer);
        pf.addAdvisor(advisor);

        Guitarist proxy = (Guitarist) pf.getProxy();
        proxy.sing();
        proxy.sing2();
        proxy.rest();
    }
}

```

Notice we do not need to create a class for the pointcut; instead, we just create an instance of `JdkRegexpMethodPointcut` and specify the pattern to match, and we are finished. The interesting thing to note is the pattern. When matching method names, Spring matches the fully qualified name of the method, so for `sing1()`, Spring is matching against `com.apress.prospring6.five.common.Guitarist.sing1`, which is why there's the leading `.*` in the pattern. This is a powerful concept because it allows you to match all methods within a given package, without needing to know exactly which classes are in that package and what the names of the methods are. Running this example yields the output shown in Listing 5-21.

**Listing 5-21.** Regex Pointcut Test Class Output

```

DEBUG: SimpleAroundAdvice - >> Invoking sing
INFO : Guitarist - Just keep me where the light is
DEBUG: SimpleAroundAdvice - >> Done
DEBUG: SimpleAroundAdvice - >> Invoking sing2
INFO : Guitarist - And wrap me in your arms
DEBUG: SimpleAroundAdvice - >> Done
INFO : Guitarist - zzz...

```

As expected, only the `sing()` and `sing2()` methods have been advised because the `rest()` method does not match the regular expression pattern configured for the pointcut instance.

## Creating Pointcuts with AspectJ Pointcut Expression

Besides JDK regular expressions, you can use AspectJ's pointcut expression language for pointcut declaration. Later in this chapter, you will see that when we declare the pointcut in Java configuration, Spring defaults to using AspectJ's pointcut language. Moreover, when using Spring's `@AspectJ` annotation-style AOP support, you need to use AspectJ's pointcut language. So when declaring pointcuts by using expression language, using an AspectJ pointcut expression is the best way to go. Spring provides the class `AspectJExpressionPointcut` for defining pointcuts via AspectJ's expression language.



To use AspectJ pointcut expressions with Spring, you need to include two AspectJ library files, `aspectjrt.jar` and `aspectjweaver.jar`, in your project's classpath. Check out the `pom.xml` and `chapter05.gradle` files for the configuration for each build tool.

Considering the previous implementation of the `Guitarist` class, the same functionality implemented with JDK regular expressions can be implemented using an AspectJ expression. The code for that is shown in Listing 5-22.

**Listing 5-22.** AspectJ Regex Pointcut Test Class

```
package com.apress.prospring6.five.pointcut;
import org.springframework.aop.aspectj.AspectJExpressionPointcut;
// other import statements omitted

public class AspectjexpPointcutDemo {
    public static void main(String... args) {
        Guitarist johnMayer = new Guitarist();

        var pc = new AspectJExpressionPointcut();
        pc.setExpression("execution(* sing*(..))");

        var advisor = new DefaultPointcutAdvisor(pc, new SimpleAroundAdvice());

        ProxyFactory pf = new ProxyFactory();
        pf.setTarget(johnMayer);
        pf.addAdvisor(advisor);

        Guitarist proxy = (Guitarist) pf.getProxy();
        proxy.sing();
        proxy.sing2();
        proxy.rest();
    }
}
```

Note that we use the `AspectJExpressionPointcut` class' `setExpression()` method to set the matching criteria. The expression `execution(* sing*(..))` means that the advice should apply to the execution of any methods that start with `sing`, have any arguments, and return any types (yes, AspectJ is a lot more flexible and concise). Running the program will get the same result as the previous example using JDK regular expressions.

## Creating Annotation Matching Pointcuts

If your application is annotation-based, you may want to use your own specified annotations for defining pointcuts—that is, apply the advice logic to all methods or types with specific annotations. Spring provides the class `AnnotationMatchingPointcut` for defining pointcuts using annotations. Again, let's reuse the previous example and see how to do it when using an annotation as a pointcut.

First we define an annotation called `AdviceRequired`, which is an annotation that we will use for declaring a pointcut. Listing 5-23 shows the annotation class and the modified `AnnotatedGuitarist` class that has the `sing(Guitar)` method annotated with it.

**Listing 5-23.** Custom Annotation to Be Used with an `AnnotationMatchingPointcut` and the Class Using It

```

package com.apress.prospring6.five.common;

import java.lang.annotation.ElementType;
import java.lang.annotation.Retention;
import java.lang.annotation.RetentionPolicy;
import java.lang.annotation.Target;

@Retention(RetentionPolicy.RUNTIME)
@Target({ElementType.TYPE, ElementType.METHOD})
public @interface AdviceRequired { }

// AnnotatedGuitarist class
class AnnotatedGuitarist implements Singer {
    private static Logger LOGGER = LoggerFactory.getLogger(AnnotatedGuitarist.class);

    @Override
    public void sing() {}

    @AdviceRequired
    public void sing(Guitar guitar) {
        LOGGER.info("play: " + guitar.play());
    }
}

```

The interface `AdviceRequired` is declared as an annotation by using `@interface` as the type, and the `@Target` annotation defines that the annotation can apply at either the type or method level. The class `AnnotatedGuitarist` class implements the `Singer` interface and adds its own `sing(..)` method that takes a `Guitar` argument and is annotated with `@AdviceRequired`.

The testing program is no different from what was presented before and is depicted in Listing 5-24 together with its output.

**Listing 5-24.** Testing Program for the `AnnotationMatchingPointcut`

```

package com.apress.prospring6.five;

import com.apress.prospring6.five.common.AdviceRequired;
import org.springframework.aop.support.annotation.AnnotationMatchingPointcut;
// other import statements omitted

public class AnnotationPointcutDemo {
    public static void main(String... args) {
        var johnMayer = new AnnotatedGuitarist();
        var pc = AnnotationMatchingPointcut.forMethodAnnotation(AdviceRequired.class);
    }
}

```

```

    var advisor = new DefaultPointcutAdvisor(pc, new SimpleAroundAdvice());
    ProxyFactory pf = new ProxyFactory();
    pf.setTarget(johnMayer);
    pf.addAdvisor(advisor);

    AnnotatedGuitarist proxy = (AnnotatedGuitarist) pf.getProxy();
    proxy.sing(new Guitar());
    proxy.rest();
}
}

```

```

// output
DEBUG: SimpleAroundAdvice - >> Invoking sing
INFO : AnnotatedGuitarist - play: G C G C Am D7
DEBUG: SimpleAroundAdvice - >> Done

```

An instance of `AnnotationMatchingPointcut` is acquired by calling its static method `forMethodAnnotation()` and passing in the annotation type. This indicates that we want to apply the advice to all the methods annotated with the given annotation. It's also possible to specify annotations applied at the type level by calling the `forClassAnnotation()` method.

As you can see, since we annotated the `sing(Guitar)` method, only that method was advised.

## Understanding Proxies

So far, we have taken only a cursory look at the proxies generated by `ProxyFactory`. We mentioned that two types of proxy are available in Spring: JDK proxies created by using the `JDK Proxy` class and CGLIB-based proxies created by using the `CGLIB Enhancer` class. You may be wondering exactly what the difference between the two proxies is and why Spring needs two types of proxy. In this section, we take a detailed look at the differences between the proxies.

The core goal of a proxy is to intercept method invocations and, where necessary, execute chains of advice that apply to a particular method. The management and invocation of advice is largely proxy independent and is managed by the Spring AOP framework. However, the proxy is responsible for intercepting calls to all methods and passing them as necessary to the AOP framework for the advice to be applied.

In addition to this core functionality, the proxy must support a set of additional features. It is possible to configure the proxy to expose itself via the `AopContext` class (which is an abstract class) so that you can retrieve the proxy and invoke advised methods on the proxy from the target object. The proxy is responsible for ensuring that when this option is enabled via `ProxyFactory.setExposeProxy()`, the proxy class is appropriately exposed. In addition, all proxy classes implement the `Advised` interface by default, which allows for, among other things, the advice chain to be changed after the proxy has been created. A proxy must also ensure that any methods that return this (that is, return the proxied target) do return the proxy and not the target.

As you can see, a typical proxy has quite a lot of work to perform, and all of this logic is implemented in both the `JDK` and `CGLIB` proxies.

## Using JDK Dynamic Proxies

**JDK proxies** are the most basic type of proxy available in Spring. Unlike the `CGLIB` proxy, the `JDK` proxy can generate proxies only of interfaces, not classes. In this way, any object you want to proxy must implement at least one interface, and the resulting proxy will be an object that implements that interface. Figure 5-4 shows an abstract schema of such a proxy.

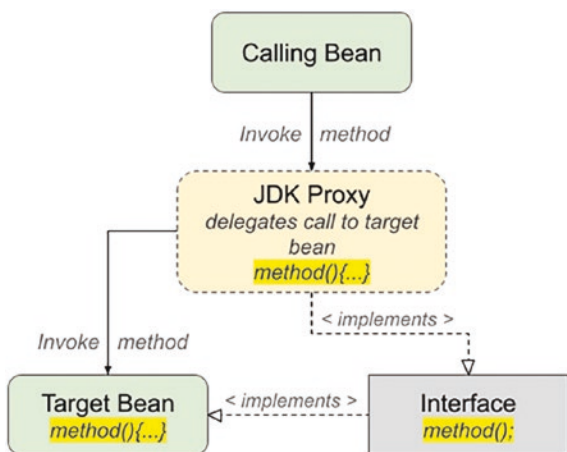


Figure 5-4. JDK proxy abstract schema

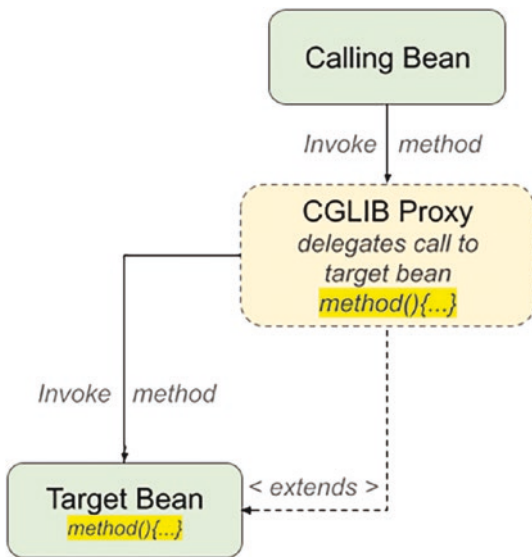
In general, it is good design to use interfaces for your classes, but it is not always possible, especially when you are working with third-party or legacy code. In this case, you must use the CGLIB proxy. When you are using the JDK proxy, all method calls are intercepted by the JVM and routed to the `invoke()` method of the proxy. This method then determines whether the method in question is advised (by the rules defined by the pointcut), and if so, it invokes the advice chain and then the method itself by using reflection. In addition to this, the `invoke()` method performs all the logic discussed in the previous section.

The JDK proxy makes no determination between methods that are advised and unadvised until it is in the `invoke()` method. This means that for unadvised methods on the proxy, the `invoke()` method is still called, all the checks are still performed, and the method is still invoked by using reflection. Obviously, this incurs runtime overhead each time the method is invoked, even though the proxy often performs no additional processing other than to invoke the unadvised method via reflection.

You can instruct `ProxyFactory` to use a JDK proxy by specifying the list of interfaces to proxy by using `setInterfaces()` (in the `AdvisedSupport` class that the `ProxyFactory` class extends indirectly).

## Using CGLIB Proxies

With the JDK proxy, all decisions about how to handle a particular method invocation are handled at runtime each time the method is invoked. When you use CGLIB, CGLIB dynamically generates the bytecode for a new class on-the-fly for each proxy, reusing already generated classes wherever possible. The resulting proxy type in this case will be a subclass of the target object class. Figure 5-5 shows an abstract schema of such a proxy.



**Figure 5-5.** CGLIB proxy abstract schema

When a CGLIB proxy is first created, CGLIB asks Spring how it wants to handle each method. This means that many of the decisions that are performed in each call to `invoke()` on the JDK proxy are performed just once for the CGLIB proxy. Because CGLIB generates actual bytecode, there is also a lot more flexibility in the way you can handle methods. For instance, the CGLIB proxy generates the appropriate bytecode to invoke any unadvised methods directly, reducing the overhead introduced by the proxy. In addition, the CGLIB proxy determines whether it is possible for a method to return this; if not, it allows the method call to be invoked directly, again reducing the runtime overhead.

The CGLIB proxy also handles fixed-advice chains differently than the JDK proxy. A *fixed-advice chain* is one that you guarantee will not change after the proxy has been generated. By default, you are able to change the advisors and advice on a proxy even after it is created, although this is rarely a requirement. The CGLIB proxy handles fixed-advice chains in a particular way, reducing the runtime overhead for executing an advice chain.



There are some limitations when working with CGLIB proxies:

1. For obvious reasons, GLIB proxies cannot be created for final classes (since they cannot be subclassed).
  2. Since static members belong to a class, not to an instance, they cannot be proxied.
  3. Private methods cannot be proxied either, since a subclass cannot access them.
-

## Comparing Proxy Performance

So far, we've discussed only in loose terms the differences in implementation between the proxy types. In this section, we are going to run a simple test to compare the performance of the CGLIB proxy with the JDK proxy. For this purpose we need the simplest bean and its interface, with no-op methods and a no-op before advice.

The bean is named `DefaultSimpleBean` and implements the `SimpleBean` interface. It implements the two methods declared by the interface, aptly named `advised` and `unadvised`, which are shown in Listing 5-25.

**Listing 5-25.** `SimpleBean` and Its Implementation

```
package com.apress.prospring6.five.performance;

public interface SimpleBean {
    void advised();
    void unadvised();
}

// DefaultSimpleBean.java in the same package
public class DefaultSimpleBean implements SimpleBean {

    @Override
    public void advised() {
        System.currentTimeMillis();
    }

    @Override
    public void unadvised() {
        System.currentTimeMillis();
    }
}
```

Listing 5-26 depicts the `NoOpBeforeAdvice` class, which is just simple before advice without any operation; this is needed to avoid polluting the output.

**Listing 5-26.** `NoOpBeforeAdvice` Implementation

```
package com.apress.prospring6.five.performance;
// import statements omitted

class NoOpBeforeAdvice implements MethodBeforeAdvice {
    @Override
    public void before(Method method, Object[] args, Object target) throws Throwable {
        // no-op
    }
}
```



Listing 5-27 shows the code used to test various types of proxies.

**Listing 5-27.** NoOpBeforeAdvice Implementation test class

```

package com.apress.prospring6.five.performance
public class ProxyPerfTestDemo {
    private static Logger LOGGER = LoggerFactory.getLogger(ProxyPerfTestDemo.class);

    public static void main(String... args) {
        SimpleBean target = new DefaultSimpleBean();

        NameMatchMethodPointcutAdvisor advisor = new NameMatchMethodPointcutAdvisor(new
        NoOpBeforeAdvice());
        advisor.setMappedName("advised");

        LOGGER.info("Starting tests ...");
        runCglibTests(advisor, target);
        runCglibFrozenTests(advisor, target);
        runJdkTests(advisor, target);
    }

    private static void runCglibTests(Advisor advisor, SimpleBean target) {
        ProxyFactory pf = new ProxyFactory();
        pf.setProxyTargetClass(true);
        pf.setTarget(target);
        pf.addAdvisor(advisor);
        SimpleBean proxy = (SimpleBean)pf.getProxy();
        var testResults = test(proxy);
        LOGGER.info(" --- CGLIB (Standard) Test results ---\n {} ", testResults);
    }

    private static void runCglibFrozenTests(Advisor advisor, SimpleBean target) {
        ProxyFactory pf = new ProxyFactory();
        pf.setProxyTargetClass(true);
        pf.setTarget(target);
        pf.addAdvisor(advisor);
        pf.setFrozen(true);
        SimpleBean proxy = (SimpleBean) pf.getProxy();
        var testResults = test(proxy);
        LOGGER.info(" --- CGLIB (Frozen) Test results ---\n {} ", testResults);
    }

    private static void runJdkTests(Advisor advisor, SimpleBean target) {
        ProxyFactory pf = new ProxyFactory();
        pf.setTarget(target);
        pf.addAdvisor(advisor);
        pf.setInterfaces(SimpleBean.class);
        SimpleBean proxy = (SimpleBean)pf.getProxy();
        var testResults = test(proxy);
        LOGGER.info(" --- JDK Test results ---\n {} ", testResults);
    }
}

```

```

private static TestResults test(SimpleBean bean) {
    TestResults testResults = new TestResults();
    long before = System.currentTimeMillis();
    for(int x = 0; x < 500000; x++) {
        bean.advised();
    }
    long after = System.currentTimeMillis();
    testResults.advisedMethodTime = after - before;
    //-----
    before = System.currentTimeMillis();
    for(int x = 0; x < 500000; x++) {
        bean.unadvised();
    }
    after = System.currentTimeMillis();
    testResults.unadvisedMethodTime = after - before;
    //-----

    before = System.currentTimeMillis();
    for(int x = 0; x < 500000; x++) {
        bean.equals(bean);
    }
    after = System.currentTimeMillis();
    testResults.equalsTime = after - before;
    // ----

    before = System.currentTimeMillis();
    for(int x = 0; x < 500000; x++) {
        bean.hashCode();
    }
    after = System.currentTimeMillis();
    testResults.hashCodeTime = after - before;
    // -----

    Advised advised = (Advised)bean;
    before = System.currentTimeMillis();
    for(int x = 0; x < 500000; x++) {
        advised.getTargetClass();
    }
    after = System.currentTimeMillis();
    testResults.proxyTargetTime = after - before;
    return testResults;
}
}

```

In this code, you can see that you are testing three kinds of proxies:

- A standard CGLIB proxy
- A CGLIB proxy with a frozen advice chain (that is, when a proxy is frozen by calling the `setFrozen()` method in the `ProxyConfig` class that `ProxyFactory` extends indirectly, CGLIB will perform further optimization; however, further advice change will not be allowed)
- A JDK proxy

For each proxy type, you run the following five test cases:

- *Advised method (test 1)*: This is a method that is advised. The advice type used in the test is before advice that performs no processing, so it reduces the effects of the advice on the performance tests.
- *Unadvised method (test 2)*: This is a method on the proxy that is unadvised. Often your proxy has many methods that are not advised. This test looks at how well unadvised methods perform for the different proxies.
- *The equals() method (test 3)*: This test looks at the overhead of invoking the equals() method. This is especially important when you use proxies as keys in a HashMap<K,V> or similar collection.
- *The hashCode() method (test 4)*: As with the equals() method, the hashCode() method is important when you are using HashMaps or similar collections.
- *Executing methods on the Advised interface (test 5)*: As we mentioned earlier, a proxy implements the Advised interface by default, allowing you to modify the proxy after creation and to query information about the proxy. This test looks at how fast methods on the Advised interface can be accessed using the different proxy types.

Table 5-3 shows the results of these tests.

**Table 5-3.** Proxy Performance Test Results (in Milliseconds)

Methods being tested	CGLIB (Standard)	CGLIB (Frozen)	JDK
advised()	126	73	159
unadvised()	127	28	96
equals()	20	16	122
hashCode()	28	20	33
Advised.getProxyTargetClass()	13	8	81

As you can see, the performance between standard CGLIB and JDK dynamic proxy for both advised() and unadvised() methods doesn't differ much. As always, these numbers will vary based on hardware and the JDK being used.

However, there is a noticeable difference when you are using a CGLIB proxy with a frozen advice chain. Similar figures apply to the equals() and hashCode() methods, which are noticeably faster when you are using the CGLIB proxy. For methods on the Advised interface, you will notice that they are also faster on the CGLIB frozen proxy. The reason for this is that Advised methods are handled early on in the intercept() method, so they avoid much of the logic that is required for other methods.

The TestResults class is a simple utility class with four properties, named after the method being tested. Saving the test results for each proxy type in an instance of this type is done for practical reasons, in an attempt to keep the code concise and readable. You can see this class in Listing 5-28.

**Listing 5-28.** TestResults Implementation

```
package com.apress.prospring6.five.performance;
// import statements omitted

public class TestResults {
    private static Logger LOGGER = LoggerFactory.getLogger(TestResults.class);
```

```

    long advisedMethodTime;
    long unadvisedMethodTime;
    long equalsTime;
    long hashCodeTime;
    long proxyTargetTime;

    @Override
    public String toString() {
        return new ToStringBuilder(this)
            .append("advised", advisedMethodTime)
            .append("unadvised", unadvisedMethodTime)
            .append("equals ", equalsTime)
            .append("hashCode", hashCodeTime)
            .append("getProxyTargetClass ", proxyTargetTime)
            .toString();
    }
}

```

## Choosing a Proxy to Use

Deciding which proxy to use is typically easy. The CGLIB proxy can proxy both classes and interfaces, whereas JDK proxies can proxy only interfaces. In terms of performance, there is no significant difference between JDK and CGLIB standard mode (at least in running both advised and unadvised methods), unless you use CGLIB in frozen mode, in which case the advice chain can't be changed and CGLIB performs further optimization when in frozen mode. When proxying a class, the CGLIB proxy is the default choice because it is the only proxy capable of generating a proxy of a class. To use the CGLIB proxy when proxying an interface, you must set the value of the `optimize` flag in `ProxyFactory` to `true` by using the `setOptimize()` method.

## Advanced Use of Pointcuts

Earlier in the chapter, we looked at the six basic Pointcut implementations Spring provides; for the most part, we have found that these meet the needs of our applications. However, sometimes you might need more flexibility when defining pointcuts. Spring provides two additional Pointcut implementations, `ComposablePointcut` and `ControlFlowPointcut`, which provide exactly the flexibility you need.

### Using Control Flow Pointcuts

Spring control flow pointcuts, implemented by the `ControlFlowPointcut` class, are similar to the `cflow` construct available in many other AOP implementations, although they are not quite as powerful. Essentially, a control flow pointcut in Spring applies to all method calls below a given method or below all methods in a class. This is quite hard to visualize and is better explained using an example.

Listing 5-29 shows a `SimpleBeforeAdvice` class that writes out a message describing the method it is advising.

**Listing 5-29.** SimpleBeforeAdvice Implementation

```

package com.apress.prospring6.five.advanced;

import org.springframework.aop.MethodBeforeAdvice;
import java.lang.reflect.Method;
//other import statements omitted

public class SimpleBeforeAdvice implements MethodBeforeAdvice {
    private static Logger LOGGER = LoggerFactory.getLogger(SimpleBeforeAdvice.class);

    @Override
    public void before(Method method, Object[] args, Object target) throws Throwable {
        LOGGER.info("Before method: {}", method);
    }
}

```

This advice class allows us to see which methods the `ControlFlowPointcut` applies to. The `TestBean` class is shown in Listing 5-30.

**Listing 5-30.** TestBean Implementation

```

package com.apress.prospring6.five.advanced;
// import statements omitted

public class TestBean {
    private static Logger LOGGER = LoggerFactory.getLogger(TestBean.class);

    public void foo() {
        LOGGER.info("foo()");
    }
}

```

You can see the simple `foo()` method that we want to advise. We have, however, a special requirement: we want to advise this method only when it is called from another, specific method. Listing 5-31 shows a simple driver program for this example.

**Listing 5-31.** ControlFlowDemo Implementation

```

package com.apress.prospring6.five.advanced;

import org.springframework.aop.support.ControlFlowPointcut;
// other import statements omitted

public class ControlFlowDemo {
    private static Logger LOGGER = LoggerFactory.getLogger(ControlFlowDemo.class);

    public static void main(String... args) {
        ControlFlowDemo ex = new ControlFlowDemo();
        ex.run();
    }
}

```

```

public void run() {
    TestBean target = new TestBean();
    Pointcut pc = new ControlFlowPointcut(ControlFlowDemo.class, "test");
    Advisor advisor = new DefaultPointcutAdvisor(pc, new SimpleBeforeAdvice());

    ProxyFactory pf = new ProxyFactory();
    pf.setTarget(target);
    pf.addAdvisor(advisor);

    TestBean proxy = (TestBean) pf.getProxy();
    LOGGER.info("\tTrying normal invoke");
    proxy.foo();
    LOGGER.info("\tTrying under ControlFlowDemo.test()");
    test(proxy);
}

private void test(TestBean bean) {
    bean.foo();
}
}

```

Notice that the advised proxy is assembled with `ControlFlowPointcut`, and then the `foo()` method is invoked twice, once directly from the `run()` method and once from the `test()` method.

Here is the line of particular interest:

```
Pointcut pc = new ControlFlowPointcut(ControlFlowDemo.class, "test");
```

In this line, we are creating a `ControlFlowPointcut` instance for the `test()` method of the `ControlFlowDemo` class. Essentially, this says, “Pointcut all methods that are called from the `ControlFlowExample.test()` method.” Note that “Pointcut all methods” in fact means “Pointcut all methods on the proxy object that is advised using the `Advisor` corresponding to this instance of `ControlFlowPointcut`.” Running the code yields in the console the output shown in Listing 5-32.

### **Listing 5-32.** `ControlFlowDemo` Console Output

```

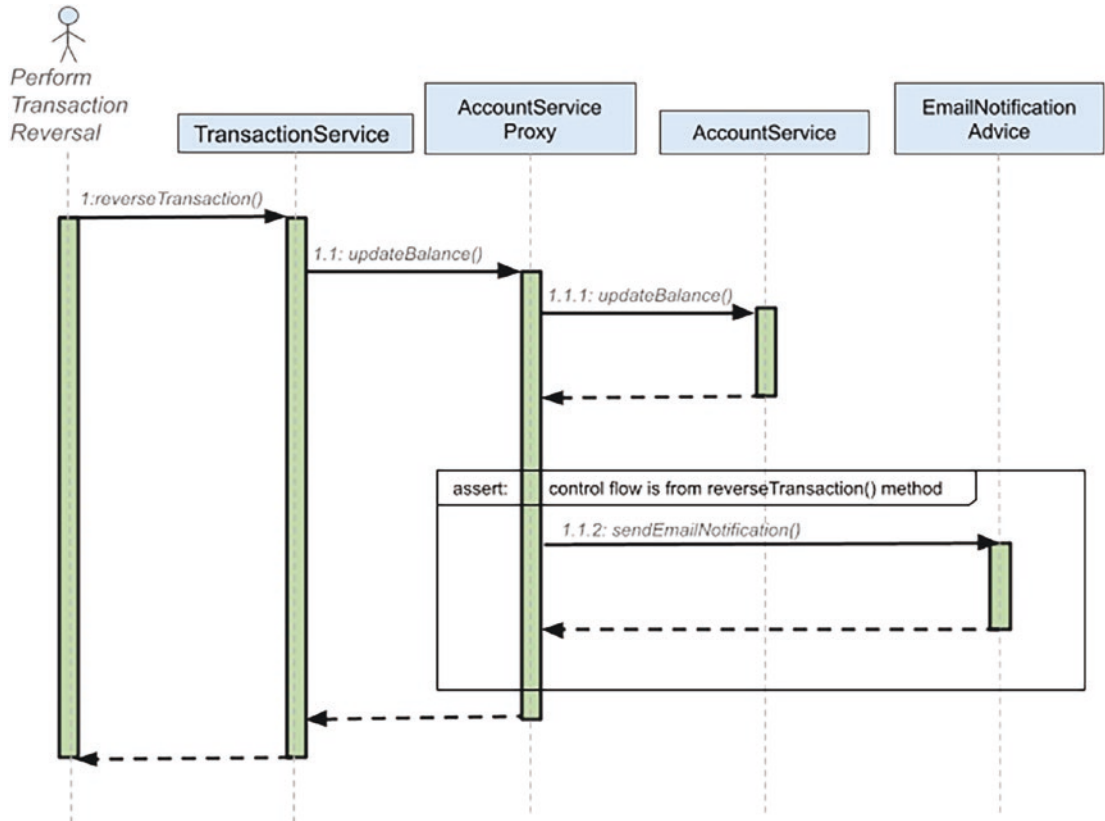
INFO : ControlFlowDemo - Trying normal invoke
INFO : TestBean - foo()
INFO : ControlFlowDemo - Trying under ControlFlowDemo.test()
INFO : SimpleBeforeAdvice - Before method: public void com.apress.prospring6.five.advanced.
    TestBean.foo()
INFO : TestBean - foo()

```

As you can see, when the `foo()` method is first invoked outside of the control flow of the `test()` method, it is unadvised. When it executes for a second time, this time inside the control flow of the `test()` method, the `ControlFlowPointcut` indicates that its associated advice applies to the method, and thus the method is advised. Note that if we had called another method from within the `test()` method, one that was not on the advised proxy, it would not have been advised.

Control flow pointcuts can be extremely useful, allowing you to advise an object selectively only when it is executed in the context of another. However, be aware that you take a substantial performance hit for using control flow pointcuts over other pointcuts.

Let's consider an example. Suppose we have a transaction processing system, which contains a `TransactionService` interface as well as an `AccountService` interface. We would like to apply after advice so that when the `AccountService.updateBalance()` method is called by `TransactionService.reverseTransaction()`, an e-mail notification is sent to the customer, after the account balance is updated. However, an e-mail will not be sent under any other circumstances. In this case, the control flow pointcut will be useful. Figure 5-6 shows the UML sequence diagram for this scenario.



**Figure 5-6.** UML sequence diagram for a control flow pointcut

## Using a Composable Pointcut

In previous pointcut examples, we used just a single pointcut for each advisor. In most cases, this is usually enough, but in some cases, you may need to compose two or more pointcuts together to achieve the desired goal. Say you want to pointcut all getter and setter methods on a bean. You have a pointcut for getters and a pointcut for setters, but you don't have one for both. Of course, you could just create another pointcut with the new logic, but a better approach is to combine the two pointcuts into a single pointcut by using `ComposablePointcut`.

`ComposablePointcut` supports two methods: `union()` and `intersection()`. By default, `ComposablePointcut` is created with a `ClassFilter` that matches all classes and a `MethodMatcher` that matches all methods, although you can supply your own initial `ClassFilter` and `MethodMatcher` during construction. The `union()` and `intersection()` methods are both overloaded to accept `ClassFilter` and `MethodMatcher` arguments.

The `ComposablePointcut.union()` method can be called by passing in an instance of either the `ClassFilter`, `MethodMatcher`, or `Pointcut` interface. The result of a union operation is that `ComposablePointcut` will add an “or” condition into its call chain for matching with the joinpoints. It’s the same for the `ComposablePointcut.intersection()` method, but this time an “and” condition will be added instead, which means that all `ClassFilter`, `MethodMatcher`, and `Pointcut` definitions within `ComposablePointcut` should be matched for applying an advice. You can imagine it as the `WHERE` clause in a SQL query, with the `union()` method like the “or” operator and the `intersection()` method like the “and” operator.

As with control flow pointcuts, this is quite difficult to visualize, and it is much easier to understand with an example. Listing 5-33 shows the `GrammyGuitarist` class used in a previous example with its four methods.

**Listing 5-33.** GrammyGuitarist Implementation

```
package com.apress.prospring6.five.common;
// other import statements omitted

public class GrammyGuitarist implements Singer {
    private static Logger LOGGER = LoggerFactory.getLogger(GrammyGuitarist.class);

    @Override
    public void sing() {
        LOGGER.info("sing: Gravity is working against me\n" +
            "And gravity wants to bring me down");
    }

    public void sing(Guitar guitar) {
        LOGGER.info("play: " + guitar.play());
    }

    public void talk(){
        LOGGER.info("talk");
    }

    @Override
    public void rest(){
        LOGGER.info("zzz");
    }
}
```

With this example, we are going to generate three proxies by using the same `ComposablePointcut` instance, but each time, we are going to modify `ComposablePointcut` by using either the `union()` or `intersection()` method. Following this, we will invoke all three methods on the target bean proxy and look at which ones have been advised. Listing 5-34 depicts this.

**Listing 5-34.** Testing ComposablePointcut

```
package com.apress.prospring6.five;

import org.springframework.aop.support.ComposablePointcut;
import org.springframework.aop.support.StaticMethodMatcher;
// other import statement omitted
```



```

public class ComposablePointcutDemo {
    private static Logger LOGGER = LoggerFactory.getLogger(ComposablePointcutDemo.class);

    public static void main(String... args) {
        GrammyGuitarist johnMayer = new GrammyGuitarist();
        ComposablePointcut pc = new ComposablePointcut(ClassFilter.TRUE, new
SingMethodMatcher());

        LOGGER.info("Test 1 >> ");
        GrammyGuitarist proxy = getProxy(pc, johnMayer);
        testInvoke(proxy);

        LOGGER.info("Test 2 >> ");
        pc.union(new TalkMethodMatcher());
        proxy = getProxy(pc, johnMayer);
        testInvoke(proxy);

        LOGGER.info("Test 3 >> ");
        pc.intersection(new RestMethodMatcher());
        proxy = getProxy(pc, johnMayer);
        testInvoke(proxy);
    }

    private static GrammyGuitarist getProxy(ComposablePointcut pc, GrammyGuitarist target) {
        Advisor advisor = new DefaultPointcutAdvisor(pc, new SimpleBeforeAdvice());

        ProxyFactory pf = new ProxyFactory();
        pf.setTarget(target);
        pf.addAdvisor(advisor);
        return (GrammyGuitarist) pf.getProxy();
    }

    private static void testInvoke(GrammyGuitarist proxy) {
        proxy.sing();
        proxy.sing(new Guitar());
        proxy.talk();
        proxy.rest();
    }
}

class SingMethodMatcher extends StaticMethodMatcher {
    @Override
    public boolean matches(Method method, Class<?> cls) {
        return (method.getName().startsWith("si"));
    }
}

class TalkMethodMatcher extends StaticMethodMatcher {
    @Override
    public boolean matches(Method method, Class<?> cls) {
        return "talk".equals(method.getName());
    }
}

```

```

class RestMethodMatcher extends StaticMethodMatcher {
    @Override
    public boolean matches(Method method, Class<?> cls) {
        return (method.getName().endsWith("st"));
    }
}

```

The first thing to notice in this example is the set of three private `MethodMatcher` implementations. `SingMethodMatcher` matches all methods that start with 'get'. This is the default `MethodMatcher` that we use to assemble `ComposablePointcut`. Because of this, we expect that the first round of invocations on the `GrammyGuitarist` methods will result in only the `sing()` methods being advised.

`TalkMethodMatcher` matches all methods named `talk`, and it is combined with `ComposablePointcut` by using `union()` for the second round of invocations. At this point, we have a union of two `MethodMatchers`: one that matches all methods starting with `si` and one that matches all methods named `talk`. We now expect that all invocations during the second round will be advised. `TalkMethodMatcher` is very specific and matches only the `talk()` method. This `MethodMatcher` is combined with `ComposablePointcut` by using `intersection()` for the third round for invocations.

Because `RestMethodMatcher` is being composed by using `intersection()`, we expect none of the methods to be advised in the third round because there is no method that matches all the composed `MethodMatchers`.

Running the code in Listing 5-34 yields the console output shown in Listing 5-35.

**Listing 5-35.** `ComposablePointcutDemo` Output

```

INFO : ComposablePointcutDemo - Test 1 >>
INFO : SimpleBeforeAdvice - Before method: public void com.apress.prospring6.five.common.
    GrammyGuitarist.sing()
INFO : GrammyGuitarist - sing: Gravity is working against me
And gravity wants to bring me down
INFO : SimpleBeforeAdvice - Before method: public void com.apress.prospring6.five.common.
    GrammyGuitarist.sing(com.apress.prospring6.five.common.Guitar)
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : GrammyGuitarist - talk
INFO : GrammyGuitarist - zzz
INFO : ComposablePointcutDemo - Test 2 >>
INFO : SimpleBeforeAdvice - Before method: public void com.apress.prospring6.five.common.
    GrammyGuitarist.sing()
INFO : GrammyGuitarist - sing: Gravity is working against me
And gravity wants to bring me down
INFO : SimpleBeforeAdvice - Before method: public void com.apress.prospring6.five.common.
    GrammyGuitarist.sing(com.apress.prospring6.five.common.Guitar)
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : SimpleBeforeAdvice - Before method: public void com.apress.prospring6.five.common.
    GrammyGuitarist.talk()
INFO : GrammyGuitarist - talk
INFO : GrammyGuitarist - zzz
INFO : ComposablePointcutDemo - Test 3 >>
INFO : GrammyGuitarist - sing: Gravity is working against me
And gravity wants to bring me down
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : GrammyGuitarist - talk
INFO : GrammyGuitarist - zzz

```

Although this example demonstrated the use of `MethodMatchers` only in the composition process, it is just as simple to use `ClassFilter` when you are building the pointcut. Indeed, you can use a combination of `MethodMatchers` and `ClassFilters` when building your composite pointcut.

## Composition and the Pointcut Interface

In the previous section, you saw how to create a composite pointcut by using multiple `MethodMatchers` and `ClassFilters`. You can also create composite pointcuts by using other objects that implement the `Pointcut` interface.

Another way to construct a composite pointcut is to use the `org.springframework.aop.support.Pointcuts` class. The class provides three static methods. The `intersection()` and `union()` methods both take two pointcuts as arguments to construct a composite pointcut. On the other hand, a `matches(Pointcut, Method, Class, Object[])` method is provided for performing a quick check on whether a pointcut matches with the provided method, class, and method arguments.

The `Pointcuts` class supports operations on only two pointcuts. So, if you need to combine `MethodMatcher` and `ClassFilter` with `Pointcut`, you need to use the `ComposablePointcut` class. However, when you need to combine just two pointcuts, the `Pointcuts` class will be more convenient.

## Pointcut Summary

Spring offers a powerful set of `Pointcut` implementations that should meet most, if not all, of your application's requirements. Remember that if you can't find a pointcut to suit your needs, you can create your own implementation from scratch by implementing `Pointcut`, `MethodMatcher`, and `ClassFilter`.

You can use two patterns to combine pointcuts and advisors. The first pattern, the one we have used so far, involves having the `Pointcut` implementation decoupled from the advisor. In the code we have seen up to this point, we created instances of `Pointcut` implementations and then used the `DefaultPointcutAdvisor` implementation to add advice along with the `Pointcut` to the proxy.

The second option, one that is adopted by many of the examples in the Spring documentation, is to encapsulate the `Pointcut` inside your own `Advisor` implementation. This way, you have a class that implements both `Pointcut` and `PointcutAdvisor`, with the `PointcutAdvisor.getPointcut()` method simply returning this. This is an approach many classes, such as `StaticMethodMatcherPointcutAdvisor`, use in Spring. We find that the first approach is the most flexible, allowing you to use different `Pointcut` implementations with different `Advisor` implementations. However, the second approach is useful in situations where you are going to be using the same combination of `Pointcut` and `Advisor` in different parts of your application or, indeed, across many applications.

The second approach is useful when each `Advisor` bean must have a separate instance of a `Pointcut`; by making the `Advisor` responsible for creating the `Pointcut`, you can ensure that this is the case. If you recall the discussion on proxy performance from the previous section, you will remember that unadvised methods perform much better than methods that are advised. For this reason, you should ensure that, by using `Pointcuts`, you advise only the methods that are absolutely necessary. This way, you reduce the amount of unnecessary overhead added to your application by using AOP.

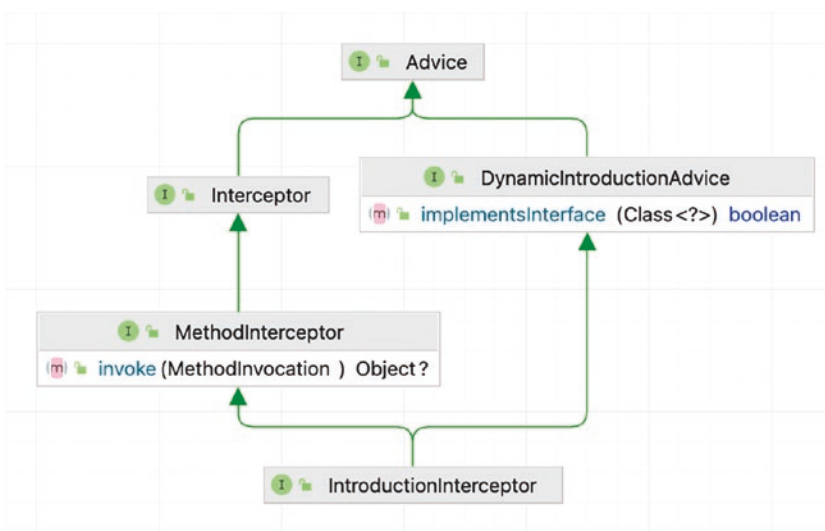
## Getting Started with Introductions

Introductions are an important part of the AOP feature set available in Spring. By using introductions, you can introduce new functionality to an existing object dynamically. In Spring, you can introduce an implementation of any interface to an existing object. You may well be wondering exactly why this is useful. Why would you want to add functionality dynamically at runtime when you can simply add that functionality at development time? The answer to this question is easy: you add functionality dynamically when the functionality is crosscutting and is not easily implemented using traditional advice.

## Introduction Basics

Spring treats introductions as a special type of advice, more specifically, as a special type of around advice. Because introductions apply solely at the class level, you cannot use pointcuts with introductions; semantically, the two don't match. An introduction adds new interface implementations to a class, and a pointcut defines which methods the advice applies to. You create an introduction by implementing the `IntroductionInterceptor` interface, which extends the `MethodInterceptor` and `DynamicIntroductionAdvice` interfaces.

Figure 5-7 shows this structure along with the methods of both interfaces, as depicted by the IntelliJ IDEA UML plug-in.



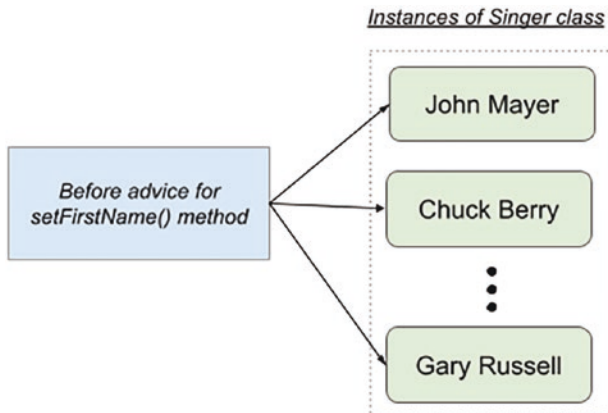
**Figure 5-7.** *IntroductionInterceptor interface hierarchy*

As you can see, the `MethodInterceptor` interface defines an `invoke()` method. Using this method, you provide the implementation for the interfaces that you are introducing and perform interception for any additional methods as required. Implementing all methods for an interface inside a single method can prove troublesome, and it is likely to result in an awful lot of code that you will have to wade through just to decide which method to invoke. Thankfully, Spring provides a default implementation of `IntroductionInterceptor`, called `DelegatingIntroductionInterceptor`, which makes creating introductions much simpler. To build an introduction by using `DelegatingIntroductionInterceptor`, you create a class that both inherits from `DelegatingIntroductionInterceptor` and implements the interfaces you want to introduce. The `DelegatingIntroductionInterceptor` implementation then simply delegates all calls to introduced methods to the corresponding method on itself. Don't worry if this seems a little unclear; you will see an example of it in the next section.

Just as you need to use `PointcutAdvisor` when you are working with pointcut advice, you need to use `IntroductionAdvisor` to add introductions to a proxy. The default implementation of `IntroductionAdvisor` is `DefaultIntroductionAdvisor`, which should suffice for most, if not all, of your introduction needs. You should be aware that adding an introduction by using `ProxyFactory.addAdvice()` is not permitted and results in `AopConfigException` being thrown. Instead, you should use the `addAdvisor()` method and pass an instance of the `IntroductionAdvisor` interface.

When using standard advice—that is, not introductions—it is possible for the same advice instance to be used for many objects. The Spring documentation refers to this as the *per-class life cycle*, although you can use a single advice instance for many classes. For introductions, the introduction advice forms part of the

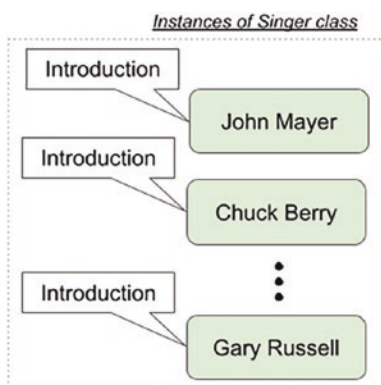
state of the advised object, and as a result, you must have a distinct advice instance for every advised object. This is called the *per-instance life cycle*. Because you must ensure that each advised object has a distinct instance of the introduction, it is often preferable to create a subclass of `DefaultIntroductionAdvisor` that is responsible for creating the introduction advice. This way, you need to ensure only that a new instance of your advisor class is created for each object because it will automatically create a new instance of the introduction. For example, say you want to apply before advice to the `setFirstName()` method on all instances of the `Contact` class. Figure 5-8 shows the same advice that applies to all objects of the `Contact` type.



**Figure 5-8.** Per-class life cycle of advice

Now let's say you want to mix an introduction into all instances of the `Contact` class, and the introduction will carry information for each `Contact` instance (for example, an attribute `isModified` that indicates whether the specific instance was modified). In this case, the introduction will be created for each instance of `Contact` and tied to that specific instance, as shown in Figure 5-9.

That covers the basics of introduction creation. We will now discuss how you can use introductions to solve the problem of object modification detection.



**Figure 5-9.** Per-instance introduction

## Object Modification Detection with Introductions

*Object modification detection* is a useful technique for many reasons. Typically, you apply modification detection to prevent unnecessary database access when you are persisting object data. If an object is passed to a method for modification but it comes back unmodified, there is little point in issuing an update statement to the database. Using a modification check in this way can really increase application throughput, especially when the database is already under a substantial load or is located on a remote network, making communication an expensive operation.

Unfortunately, this kind of functionality is difficult to implement by hand because it requires you to add to every method that can modify object state to check whether the object state is actually being modified. When you consider all the null checks that have to be made and the checks to see whether the value is actually changing, you are looking at around eight lines of code per method. You could refactor this into a single method, but you still have to call this method every time you need to perform the check. Spread this across a typical application with many classes that require modification checks, and you have a disaster waiting to happen.

This is clearly a place where introductions will help. We don't want to have each class that requires modification checks inherit from some base implementation, losing its only chance for inheritance as a result, nor do we really want to be adding checking code to each and every state-changing method. Using introductions, we can provide a flexible solution to the modification detection problem without having to write a bunch of repetitive, error-prone code.

In this example, we are going to build a full modification check framework using introduction. The modification check logic is encapsulated by the `IsModified` interface, an implementation of which will be introduced into the appropriate objects, along with interception logic to perform modification checks automatically. For the purposes of this example, we use JavaBeans conventions, in that we consider a modification to be any call to a setter method. Of course, we don't just treat all calls to a setter method as a modification; we check to see whether the value being passed to the setter is different from the one currently stored in the object. The only flaw with this solution is that setting an object back to its original state will still reflect a modification if any one of the values on the object has changed. For example, you have a `Contact` object with the `firstName` attribute. Let's say that during processing, the `firstName` attribute was changed from Peter to John. As a result, the object was marked as modified. However, it will still be marked as modified, even if the value is then changed back from John to its original value Peter in later processing.

One way to keep track of such changes is to store the full history of changes in the object's entire life cycle. However, the implementation here is trivial and suffices for most requirements. Implementing the more complete solution would result in an overly complex example.

### Using the `IsModified` Interface

Central to the modification check solution is the `IsModified` interface, which the fictional application uses to make intelligent decisions about object persistence. We do not cover how the application would use `IsModified`; instead, we will focus on the implementation of the introduction. Listing 5-36 shows the `IsModified` interface.

**Listing 5-36.** The `IsModified` Interface

```
package com.apress.prospring6.five.introduction;

public interface IsModified {
    boolean isModified();
}
```

There's nothing special here—just a single method, `isModified()`, indicating whether an object has been modified.

## Creating a Mixin

The next step is to create the code that implements `IsModified` and that is introduced to the objects; this is referred to as a *mix-in*. As we mentioned earlier, it is much simpler to create mixins by subclassing `DelegatingIntroductionInterceptor` than to create one by directly implementing the `IntroductionInterceptor` interface. The mixin class, `IsModifiedMixin`, subclasses `DelegatingIntroductionInterceptor` and also implements the `IsModified` interface. This implementation is shown in Listing 5-37.

**Listing 5-37.** The `IsModifiedMixin` Class

```
package com.apress.prospring6.five.introduction;

import java.lang.reflect.Method;
import java.util.HashMap;
import java.util.Map;
import java.util.function.Predicate;
import org.aopalliance.intercept.MethodInvocation;
import org.springframework.aop.support.DelegatingIntroductionInterceptor;

public class IsModifiedMixin extends DelegatingIntroductionInterceptor implements
IsModified {
    private boolean isModified = false;
    private final Map<Method, Method> methodCache = new HashMap<>();
    private final Predicate<MethodInvocation> isSetter = invocation ->
        invocation.getMethod().getName().startsWith("set") && (invocation.
            getArguments().length == 1);

    @Override
    public boolean isModified() {
        return isModified;
    }

    @Override
    public Object invoke(MethodInvocation invocation) throws Throwable {
        if (!isModified) {
            if (isSetter.test(invocation)) {
                Method getter = getGetter(invocation.getMethod());
                if (getter != null) {
                    Object newVal = invocation.getArguments()[0];
                    Object oldVal = getter.invoke(invocation.getThis(), null);
                    if (newVal == null && oldVal == null) {
                        isModified = false;
                    } else if ((newVal == null && oldVal != null) || (newVal != null &&
                        oldVal == null)) {
                        isModified = true;
                    } else {
                        isModified = !newVal.equals(oldVal);
                    }
                }
            }
        }
    }
}
```

```

        return super.invoke(invocation);
    }

    private Method getGetter(Method setter) {
        Method getter = methodCache.get(setter);
        if (getter != null) {
            return getter;
        }
        String getterName = setter.getName().replaceFirst("set", "get");
        try {
            getter = setter.getDeclaringClass().getMethod(getterName, null);
            synchronized (methodCache) {
                methodCache.put(setter, getter);
            }
            return getter;
        } catch (NoSuchMethodException ex) {
            return null;
        }
    }
}

```

The first thing to notice here is the implementation of `IsModified`, which consists of the private modified field and the `isModified()` method. This example highlights why you must have one mixin instance per advised object—the mixin introduces not only methods to the object but also state. If you share a single instance of this mixin across many objects, then you are also sharing the state, which means all objects show as modified the first time a single object becomes modified.

You do not actually have to implement the `invoke()` method for a mixin, but in this case, doing so allows us to detect automatically when a modification occurs. We start by performing the check only if the object is still unmodified; we do not need to check for modifications once we know that the object has been modified. Next, we check to see whether the method is a setter, and if it is, we retrieve the corresponding getter method. Note that we cache the getter/setter pairs for quicker future retrieval. Finally, we compare the value returned by the getter with that passed to the setter to determine whether a modification has occurred. Notice that we check for the different possible combinations of null and set the modifications appropriately. It is important to remember that when you are using `DelegatingIntroductionInterceptor`, you must call `super.invoke()` when overriding `invoke()` because it is `DelegatingIntroductionInterceptor` that dispatches the invocation to the correct location, either the advised object or the mixin itself.

You can implement as many interfaces as you like in your mixin, each of which is automatically introduced into the advised object.

## Creating an Advisor

The next step is to create an `Advisor` class to wrap the creation of the mixin class. This step is optional, but it does help to ensure that a new instance of the mixin is being used for each advised object. Listing 5-38 shows the `IsModifiedAdvisor` class.



**Listing 5-38.** The IsModifiedAdvisor Class

```

package com.apress.prospring6.five.introduction;

import org.springframework.aop.support.DefaultIntroductionAdvisor;

public class IsModifiedAdvisor extends DefaultIntroductionAdvisor {
    public IsModifiedAdvisor() {
        super(new IsModifiedMixin());
    }
}

```

Notice that we have extended `DefaultIntroductionAdvisor` to create our `IsModifiedAdvisor`. The implementation of this advisor is trivial and self-explanatory.

## Putting It All Together

Now that we have a mixin class and an Advisor class, we can test the modification check framework. The class that we are going to use is the `Contact` class that was mentioned earlier, which is part of a common package. This class is often used as a dependency for projects in this book for reasons of reusability. The contents of this class are shown in Listing 5-39.

**Listing 5-39.** The Contact Class

```

package com.apress.prospring6.five.introduction;

public class Contact {
    private String name;
    private String phoneNumber;
    private String email;

    // getters, setters and toString omitted
}

```

This bean has a set of properties, but only the name property for testing the modification check mixin. Listing 5-40 shows how to assemble the advised proxy and then tests the modification check code.

**Listing 5-40.** The IntroductionDemo Class

```

package com.apress.prospring6.five.introduction;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.aop.IntroductionAdvisor;
import org.springframework.aop.framework.ProxyFactory;

public class IntroductionDemo {
    private static Logger LOGGER = LoggerFactory.getLogger(IntroductionDemo.class);

    public static void main(String... args) {
        Contact target = new Contact();
        target.setName("John Mayer");
    }
}

```

```

IntroductionAdvisor advisor = new IsModifiedAdvisor();
ProxyFactory pf = new ProxyFactory();
pf.setTarget(target);
pf.addAdvisor(advisor);
pf.setOptimize(true);

Contact proxy = (Contact) pf.getProxy();
IsModified proxyInterface = (IsModified)proxy;
LOGGER.info("Is Contact? => {} " , (proxy instanceof Contact));
LOGGER.info("Is IsModified? => {} " , (proxy instanceof IsModified));
LOGGER.info("Has been modified? => {} " , proxyInterface.isModified());

proxy.setName("John Mayer");
LOGGER.info("Has been modified? => {} " , proxyInterface.isModified());

proxy.setName("Ben Barnes");
LOGGER.info("Has been modified? => {} " , proxyInterface.isModified());
}
}

```

Notice that when we are creating the proxy, we set the `optimize` flag to `true` to force the use of the CGLIB proxy. The reason for this is that when you are using the JDK proxy to introduce a mixin, the resulting proxy will not be an instance of the object class (in this case `Contact`); the proxy implements only the mixin interfaces, it does not extend the original class. With the CGLIB proxy, the original class is extended by the proxy along with the mixin interfaces.

Notice in Listing 5-40 that we test first to see whether the proxy is an instance of `Contact` and then to see whether it is an instance of `IsModified`. Both tests return `true` when you are using the CGLIB proxy, but only the `IsModified` test returns `true` for the JDK proxy. Finally, we test the modification check code by first setting the name property to its current value and then to a new value, checking the value of the `isModified` flag each time. Running the example results in the output shown in Listing 5-41.

**Listing 5-41.** The `IntroductionDemo` Execution Output

```

INFO : IntroductionDemo - Is Contact? => true
INFO : IntroductionDemo - Is IsModified? => true
INFO : IntroductionDemo - Has been modified? => false
INFO : IntroductionDemo - Has been modified? => false
INFO : IntroductionDemo - Has been modified? => true

```

As expected, both `instanceof` tests return `true`. Notice that the first call to `isModified()`, before any modification occurred, returns `false`. The next call, after we set the value of `name` to the same value, also returns `false`. For the final call, however, after we set the value of `name` to a new value, the `isModified()` method returns `true`, indicating that the object has in fact been modified.

## Introduction Summary

Introductions are one of the most powerful features of Spring AOP; they allow you not only to extend the functionality of existing methods but to extend the set of interfaces and object implementations dynamically. Using introductions is the perfect way to implement crosscutting logic that your application interacts with through well-defined interfaces. In general, this is the kind of logic that you want to apply

declaratively rather than programmatically. By using `IsModifiedMixin` defined in this example and the framework services discussed in the next section, we can declaratively define which objects are capable of modification checks, without needing to modify the implementations of those objects.

Obviously, because introductions work via proxies, they add a certain amount of overhead. All methods on the proxy are considered advised since pointcuts cannot be used in conjunction with introductions. However, in the case of many of the services that you can implement by using introductions, such as the object modification check, this performance overhead is a small price to pay for the reduction in code required to implement the service, as well as the increase in stability and maintainability that comes from fully centralizing the service logic.

## Framework Services for AOP

Up to now, we have had to write a lot of code to advise objects and generate the proxies for them. Although this in itself is not a huge problem, it does mean that all advice configuration is hard-coded into your application, removing some benefits of being able to advise a method implementation transparently. Thankfully, Spring provides additional framework services that allow you to create an advised proxy in your application configuration and then inject this proxy into a target bean just like any other dependencies.

Using the declarative approach to AOP configuration is preferable to the manual, programmatic mechanism. When you use the declarative mechanism, not only do you externalize the configuration of advice, but you also reduce the chance of coding errors. You can also take advantage of DI and AOP combined to enable AOP so that it can be used in a completely transparent environment.

## Configuring AOP Declaratively

When using declarative configuration of Spring AOP, three options exist.

- *Using ProxyFactoryBean:* In Spring AOP, `ProxyFactoryBean` provides a declarative way to configure Spring's `ApplicationContext` (and hence the underlying `BeanFactory`) when creating AOP proxies based on defined Spring beans.
- *Using the Spring aop namespace:* Introduced in Spring 2.0, the `aop` namespace provides a simplified way (when compared to `ProxyFactoryBean`) to define aspects and their DI requirements in Spring applications. However, the `aop` namespace also uses `ProxyFactoryBean` behind the scenes. We do not show this option in this book since the focus is on using Java configuration.
- *Using @AspectJ-style annotations:* The practical way for configuring Spring AOP is to use `@AspectJ`-style annotations within your classes. Although the syntax it uses is based on `AspectJ` and you need to include some `AspectJ` libraries when using this option, Spring still uses the proxy mechanism (that is, creates proxied objects for the targets) when bootstrapping `ApplicationContext`.

## Using ProxyFactoryBean

The `ProxyFactoryBean` class is an implementation of `FactoryBean` that allows you to specify a bean to target, and it provides a set of advice and advisors for that bean that are eventually merged into an AOP proxy. `ProxyFactoryBean` is used to apply interceptor logic to an existing target bean in such a way that when methods on that bean are invoked, the interceptors are executed before and after that method call. Because you can use both advisor and advice with `ProxyFactoryBean`, you can configure not only the advice declaratively but the pointcuts as well.

ProxyFactoryBean shares a common interface (the `org.springframework.aop.framework.Advised` interface) with ProxyFactory (both classes extend the `org.springframework.aop.framework.AdvisedSupport` class indirectly, which implements the `Advised` interface), and as a result, it exposes many of the same flags such as `frozen`, `optimize`, and `exposeProxy`. The values for these flags are passed directly to the underlying ProxyFactory, which allows you to configure the factory declaratively as well.

Using ProxyFactoryBean is simple. You define a bean that will be the target bean, and then using ProxyFactoryBean, you define the bean that your application will access, using the target bean as the proxy target. Where possible, define the target bean as an anonymous bean inside the proxy bean declaration. This prevents your application from accidentally accessing the unadvised bean. However, in some cases, such as the sample we are about to show you, you may want to create more than one proxy for the same bean, so you should use a normal top-level bean for this case.

For the following example, imagine this scenario: you have a singer working together with a documentarist to produce a documentary of a tour. In this case, Documentarist has a dependency on the Singer implementation. The Singer implementation that we will use here is the previously introduced GrammyGuitarist that has been shown twice before in this chapter, the last time in Listing 5-33. The Documentarist class that will basically tell the singer what to do while filming the documentary is shown in Listing 5-42.

**Listing 5-42.** The Documentarist Class

```
package com.apress.prospring6.five.common;

public class Documentarist {

    private GrammyGuitarist guitarist;
    public void execute() {
        guitarist.sing();
        guitarist.talk();
    }

    public void setDep(GrammyGuitarist guitarist) {
        this.guitarist = guitarist;
    }
}
```

For this example, we are going to create two proxies for a single GrammySinger instance, both with the same basic advice shown in Listing 5-43.

**Listing 5-43.** The AuditAdvice Class

```
package com.apress.prospring6.five.common;

import org.aspectj.lang.JoinPoint;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;

public class AuditAdvice implements MethodBeforeAdvice {
    private static Logger LOGGER = LoggerFactory.getLogger(AuditAdvice.class);
```

```

@Override
public void before(Method method, Object[] args, Object target) throws Throwable {
    LOGGER.info("Executing {}" , method );
}
}

```

The first proxy will just advise the target by using the advice directly; thus, all methods will be advised.

For the second proxy, we will configure AspectJExpressionPointcut and DefaultPointcutAdvisor so that only the `sing()` method of the `GrammySinger` class is advised. To test the advice, we will create two bean definitions of type `Documentarist`, each of which will be injected with a different proxy. Then we will invoke the `execute()` method on each of these beans and observe what happens when the advised methods on the dependency are invoked. Figure 5-10 shows the configuration for this example represented by the `AopConfig` class.

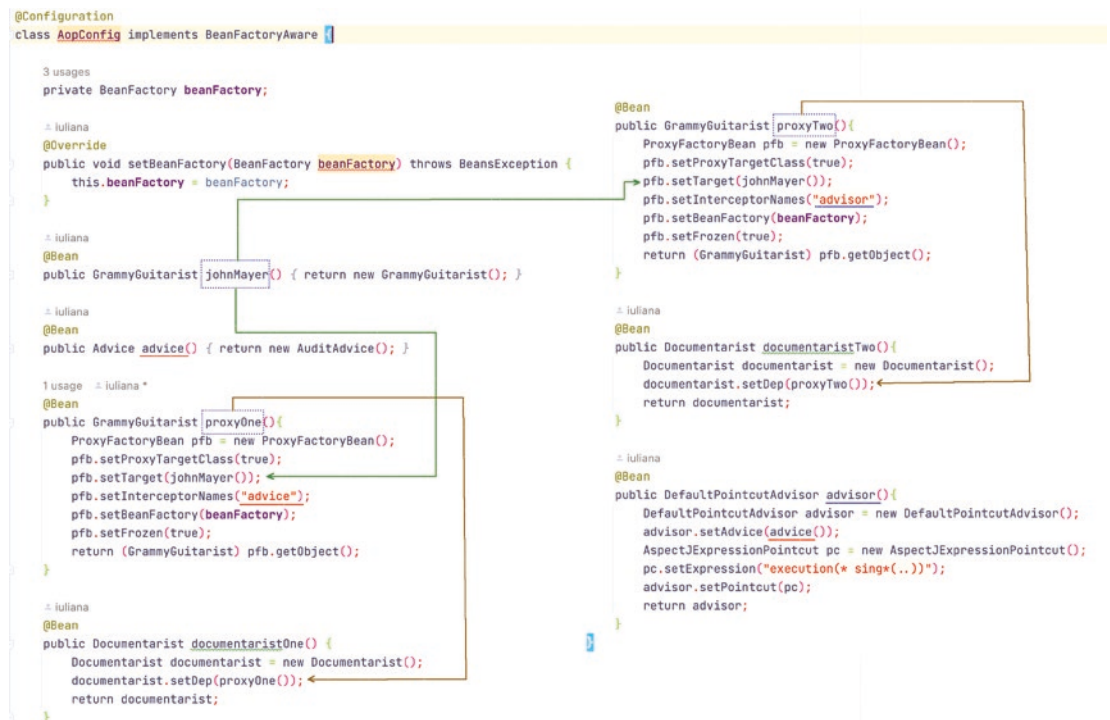


Figure 5-10. Declarative AOP configuration

Since the image might be unclear in print, Listing 5-44 shows the `AopConfig` class.

#### Listing 5-44. The `AopConfig` Configuration Class

```

package com.apress.prospring6.five;
// import statements omitted

@Configuration
class AopConfig implements BeanFactoryAware {

    private BeanFactory beanFactory;

```

```

@Override
public void setBeanFactory(BeanFactory beanFactory) throws BeansException {
    this.beanFactory = beanFactory;
}

@Bean
public GrammyGuitarist johnMayer(){
    return new GrammyGuitarist();
}

@Bean
public Advice advice(){
    return new AuditAdvice();
}

@Bean
public GrammyGuitarist proxyOne(){
    ProxyFactoryBean pfb = new ProxyFactoryBean();
    pfb.setProxyTargetClass(true);
    pfb.setTarget(johnMayer());
    pfb.setInterceptorNames("advice");
    pfb.setBeanFactory(beanFactory);
    pfb.setFrozen(true);
    return (GrammyGuitarist) pfb.getObject();
}

@Bean
public Documentarist documentaristOne() {
    Documentarist documentarist = new Documentarist();
    documentarist.setDep(proxyOne());
    return documentarist;
}

@Bean
public GrammyGuitarist proxyTwo(){
    ProxyFactoryBean pfb = new ProxyFactoryBean();
    pfb.setProxyTargetClass(true);
    pfb.setTarget(johnMayer());
    pfb.setInterceptorNames("advisor");
    pfb.setBeanFactory(beanFactory);
    pfb.setFrozen(true);
    return (GrammyGuitarist) pfb.getObject();
}

@Bean
public Documentarist documentaristTwo(){
    Documentarist documentarist = new Documentarist();
    documentarist.setDep(proxyTwo());
    return documentarist;
}

```

```

@Bean
public DefaultPointcutAdvisor advisor(){
    DefaultPointcutAdvisor advisor = new DefaultPointcutAdvisor();
    advisor.setAdvice(advice());
    AspectJExpressionPointcut pc = new AspectJExpressionPointcut();
    pc.setExpression("execution(* sing*(..))");
    advisor.setPointcut(pc);
    return advisor;
}
}

```

We used an image to depict this configuration because it might look a little confusing and we wanted to make sure it is easy to see where each bean is injected. In the example, we are simply setting the properties that we set in code using Spring's DI capabilities. The only points of interest are that the pointcut is not declared as a bean, but as a simple pojo set on the advisor bean, since this is not meant to be shared, and we use the ProxyFactoryBean class to create proxies. The important point to realize when you are using ProxyFactoryBean is that the ProxyFactoryBean declaration is the one to expose to your application and the one to use when you are fulfilling dependencies. The underlying target bean declaration is not advised, so you should use this bean only when you want to bypass the AOP framework, although in general, your application should not be aware of the AOP framework and thus should not want to bypass it. For this reason, you should use anonymous beans wherever possible to avoid accidental access from the application.

Listing 5-45 shows a simple class that obtains the two Documentarist instances from ApplicationContext and then runs the execute() method for each one. In the same listing you can also see its output.

**Listing 5-45.** The Class Testing the ProxyFactoryBean Configuration

```

package com.apress.prospring6.five;
// import statements omitted

public class ProxyFactoryBeanDemo {
    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(AopConfig.class);

        Documentarist documentaristOne = ctx.getBean("documentaristOne",
            Documentarist.class);
        Documentarist documentaristTwo = ctx.getBean("documentaristTwo",
            Documentarist.class);

        System.out.println("Documentarist One >>");
        documentaristOne.execute();

        System.out.println("\nDocumentarist Two >> ");
        documentaristTwo.execute();
    }
}

// output
Documentarist One >>
INFO : AuditAdvice - Executing public void com.apress.prospring6.five.common.
    GrammyGuitarist.sing()
INFO : GrammyGuitarist - sing: Gravity is working against me

```

```
And gravity wants to bring me down
INFO : AuditAdvice - Executing public void com.apress.prospring6.five.common.
    GrammyGuitarist.talk()
INFO : GrammyGuitarist - talk
```

```
Documentarist Two >>
INFO : AuditAdvice - Executing public void com.apress.prospring6.five.common.
    GrammyGuitarist.sing()
INFO : GrammyGuitarist - sing: Gravity is working against me
And gravity wants to bring me down
INFO : GrammyGuitarist - talk
```

As expected, both the `sing()` and `talk()` methods in the first proxy are advised because no pointcut was used in its configuration. For the second proxy, however, only the `sing()` method was advised because of the pointcut used in the configuration.

## Using ProxyFactoryBean for Introductions

You are not limited in using the `ProxyFactoryBean` class for just advising an object but also for introducing mixins to your objects. Remember from the earlier discussion on introductions that you must use an `IntroductionAdvisor` to add an introduction; you cannot add an introduction directly. The same rule applies when you are using `ProxyFactoryBean` with introductions. When you are using `ProxyFactoryBean`, it becomes much easier to configure your proxies if you created a custom `Advisor` for your mixin. Listing 5-46 shows a configuration snippet for the `IsModifiedMixin` introduction from earlier in the chapter.

**Listing 5-46.** The Class Testing the `ProxyFactoryBean` Configuration

```
package com.apress.prospring6.five;

import org.springframework.aop.framework.ProxyFactoryBean;
// other import statements omitted

@Configuration
class IntroductionAopConfig {

    @Bean
    public Contact guitarist(){
        var contact = new Contact();
        contact.setName("John Mayer");
        return contact;
    }

    @Bean
    public IsModifiedAdvisor advisor() {
        return new IsModifiedAdvisor();
    }

    @Bean
    public Contact proxy(){
        ProxyFactoryBean pfb = new ProxyFactoryBean();
        pfb.setProxyTargetClass(true);
```



```

        pfb.setTarget(guitarist());
        pfb.addAdvisor(advisor());
        pfb.setFrozen(true);
        return (Contact) pfb.getObject();
    }
}

```

Running this example yields exactly the same output as the previous introduction example, covered at the beginning of the “Getting Started with Introductions” section, but this time the proxy is obtained from `ApplicationContext` and no configuration is present in the application code.

Notice that there is no need to refer to the advisor bean by name to provide it as an argument to `ProxyFactoryBean` because `addAdvisor(..)` can be called directly and the advisor bean can be provided as the argument. This obviously simplifies the configuration.

## ProxyFactoryBean Summary

When you use `ProxyFactoryBean`, you can configure AOP proxies that provide all the flexibility of the programmatic method without needing to couple your application to the AOP configuration. Unless you need to perform decisions at runtime as to how your proxies should be created, it is best to use the declarative method of proxy configuration over the programmatic method. Let’s move on, so you can see the most practical way for using declarative Spring AOP.

## Using @AspectJ-Style Annotations

When using Spring AOP with JDK 5 or newer, you can also use the `@AspectJ`-style annotations to declare your advice. However, as stated before, Spring still uses its own proxying mechanism for advising the target methods, not AspectJ’s weaving mechanism.

In this section, we will go through how to implement the same aspects as the ones introduced at the beginning of the chapter by using `@AspectJ`-style annotations. AspectJ is a general-purpose aspect-oriented extension to Java born out of need to solve issues or concerns that are not well captured by traditional programming methodologies—in other words, crosscutting concerns. For the examples in this section, we will use annotations for other Spring beans as well, and we will use Java configuration classes.

Listing 5-47 depicts the `GrammyGuitarist` class with the bean being declared using annotations.

**Listing 5-47.** GrammyGuitarist Bean Declared Using the `@Component` Annotation

```

package com.apress.prospring6.five.annotated;

import org.springframework.stereotype.Component;
// other import statements missing

@Component("johnMayer") //
public class GrammyGuitarist implements Singer {
    private static Logger LOGGER = LoggerFactory.getLogger(GrammyGuitarist.class);

    @Override
    public void sing() {
        LOGGER.info("sing: Gravity is working against me\n" +
            "And gravity wants to bring me down");
    }
}

```

```

public void sing(Guitar guitar) {
    LOGGER.info("play: " + guitar.play());
}

public void talk(){
    LOGGER.info("talk");
}

@Override
public void rest(){
    LOGGER.info("zzz");
}
}

```

To make things more interesting, a `NewDocumentarist` class is introduced that calls `sing(Guitar)` as well. This class is shown in Listing 5-48.

**Listing 5-48.** `NewDocumentarist` Bean Declared Using the `@Component` Annotation

```

package com.apress.prospring6.five.annotated;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.beans.factory.annotation.Qualifier;
// other import statements omitted

@Component("documentarist")
public class NewDocumentarist {

    protected GrammyGuitarist guitarist;

    public void execute() {
        guitarist.sing();
        Guitar guitar = new Guitar();
        guitar.setBrand("Gibson");
        guitarist.sing(guitar);
        guitarist.talk();
    }
    @Autowired
    @Qualifier("johnMayer")
    public void setGuitarist(GrammyGuitarist guitarist) {
        this.guitarist = guitarist;
    }
}

```

Both classes are annotated with `@Component` to declare beans of these types. The annotation is also used to name the beans. In the `NewDocumentarist` class, the setter method of the property `guitarist` was annotated with `@Autowired` for automatic injection by Spring and with `@Qualifier` to configure the name of the bean that Spring should inject.

Now that we have the beans, let's start with a very simple before advice.

## Declarative Before Advice with AspectJ Annotations

Using annotations, we don't always need to explicitly declare a `Pointcut`, since the `AspectJ@Before` annotation's default attribute can be configured with a pointcut expression representing where to bind the advice. Listing 5-49 shows the `BeforeAdviceV1` class that declares the annotated advice.

**Listing 5-49.** `BeforeAdviceV1` Class, Declaring an Aspect Bean with a Single Before Advice

```
package com.apress.prospring6.five.advice;

import org.aspectj.lang.JoinPoint;
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Before;
// other import annotations omitted

@Component
@Aspect
public class BeforeAdviceV1 {
    private static Logger LOGGER = LoggerFactory.getLogger(BeforeAdviceV1.class);

    @Before("execution(* com.apress.prospring6.five..sing*(com.apress.prospring6.five.common.Guitar))")
    public void simpleBeforeAdvice(JoinPoint joinPoint) {
        var signature = (MethodSignature) joinPoint.getSignature();
        LOGGER.info("> Executing: {} from {}", signature.getName(), signature.getDeclaringTypeName());
    }
}
```



Why the V1 suffix? Because there is more than one way to declare this advice and pointcut. In this section all classes declaring the same before advice in different ways are suffixed with a number that is also used as a suffix for the method testing the advice.

---

Notice how the advice class does not need to implement the `MethodBeforeAdvice`. Another thing to notice is the `@Aspect` annotation is used to declare that it's an aspect class. An aspect class groups together advice declarations, pointcuts, and other utility methods for declaring these.

The `@Before` annotation marks the `simpleBeforeAdvice(..)` method as a before advice and the expression provided as the value for its default attribute is a pointcut expression that means we want to advise all methods with the name starting with `sing`, and the classes are defined under the package `com.apress.prospring6.five` (including all the subpackages, which is what the `..` means). Also, the `sing*` method should receive one argument with the `com.apress.prospring6.five.common.Guitar` type.

The before advice method accepts the `joinpoint` as an argument but not the method, object, and arguments. Actually, for the advice class, this argument is optional, so you can leave the method with no argument. However, if in the advice you need to access the information of the `joinpoint` being advised (in this case, we want to dump the information of the calling type and method name), then you need to define the acceptance of the argument. When the argument is defined for the method, Spring will automatically pass the `joinpoint` into the method for your processing. In this example, we use the `JoinPoint` to print the `joinpoint` details.

To test this advice we must design a Spring configuration class that discovers the `GrammyGuitarist` and `NewDocumentarist` beans and enables support for handling components marked with AspectJ's `@Aspect` annotation and others. To keep the code simple and the advices isolated for each scenario in this section, the aspect bean will be registered together with the configuration class in Listing 5-50 in an empty `ApplicationContext`. This allows us to reuse this configuration class, and keeps the testing snippets identical, the only difference being the aspect class added to the context.

The configuration class is shown in Listing 5-50.

**Listing 5-50.** AspectJ Spring Configuration Class

```
package com.apress.prospring6.five.annotated;

import org.springframework.context.annotation.ComponentScan;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.EnableAspectJAutoProxy;

@ComponentScan
@Configuration
@EnableAspectJAutoProxy(proxyTargetClass = true)
public class AspectJAopConfig {
}
```

Notice the `@EnableAspectJAutoProxy` annotation. This annotation enables support for handling components marked with AspectJ's `@Aspect` annotation and is designed to be used on classes annotated with `@Configuration`. It also has an attribute called `proxyTargetClass`. When set to `true` it indicates that subclass-based (CGLIB) proxies are to be created as opposed to standard Java interface-based proxies. In this example, CGLIB proxies are needed because even if `GrammyGuitarist` implements the `Singer` interface, and by default interface-based JDK dynamic proxies should be suitable, `NewDocumentarist` strictly requires the dependency to be of type `GrammyGuitarist` or an extension of it. So we need a proxy that extends `GrammyGuitarist`. Without the `proxyTargetClass = true` attribute when attempting to start a Spring application with this configuration the following exception will be thrown:

```
Error creating bean with name 'documentarist': Unsatisfied dependency expressed through method 'setGuitarist' parameter 0; nested exception is org.springframework.beans.factory.BeanNotOfRequiredTypeException: Bean named 'johnMayer' is expected to be of type 'com.apress.prospring6.five.annotated.GrammyGuitarist' but was actually of type 'jdk.proxy3.$Proxy26'
```



A rule of thumb if at least one class in the configuration needs to be proxied through subclassing the `proxyTargetClass=true` is mandatory, otherwise the application context won't be created correctly.

---

The class is also annotated with `@ComponentScan` that enables discovery of beans in the class where this class is (`com.apress.prospring6.five.annotated`) and its subpackages.

To test each type of advice introduced in this section, test methods are used and grouped in the `AnnotatedAdviceTest` class shown in Listing 5-51.

**Listing 5-51.** AnnotatedAdviceTest Class, Grouping All Annotated Aspect Tests and a Test Method Verifying the Before Advice Declared in Class BeforeAdviceV1

```

package com.apress.prospring6.five.annotated;

import org.junit.jupiter.api.Test;
import com.apress.prospring6.five.advice.BeforeAdviceV1;
import org.springframework.context.annotation.AnnotationConfigApplicationContext;

public class AnnotatedAdviceTest {

    @Test
    void testBeforeAdviceV1(){
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(AspectJAopConfig.class, BeforeAdviceV1.class);
        ctx.refresh();
        assertTrue(Arrays.asList(ctx.getBeanDefinitionNames()).contains("beforeAdviceV1"));

        NewDocumentarist documentarist = ctx.getBean("documentarist",
            NewDocumentarist.class);
        documentarist.execute();
        ctx.close();
    }
}

```

The `testBeforeAdviceV1()` method creates an `ApplicationContext` based on the `AspectJAopConfig` configuration class and adds the aspect bean declared by the `BeforeAdviceV1` class to it. If the context can be created and the bean is found to be present, then the `documentarist` bean is retrieved and its `execute()` method is invoked. This will cause the `proxy.sing()` method to be called that includes the `simpleBeforeAdvice`. When all goes well, the test should pass and the produced console output should be as shown in Listing 5-52.

**Listing 5-52.** Console Output Produced by Running the `testBeforeAdviceV1()` Method

```

DEBUG: AbstractApplicationContext - Refreshing org.springframework.context.annotation
      .AnnotationConfigApplicationContext@1046d517
...
DEBUG: ReflectiveAspectJAdvisorFactory - Found AspectJ method: public void com.apress.
      prospring6.five.advice.BeforeAdviceV1.simpleBeforeAdvice(org.aspectj.lang.JoinPoint)
...
INFO : GrammyGuitarist - sing: Wild blue, deeper than I ever knew
INFO : BeforeAdviceV1 - > Executing: sing from com.apress.prospring6.five.annotated.
      GrammyGuitarist
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : GrammyGuitarist - talk
DEBUG: AbstractApplicationContext - Closing org.springframework.context.annotation
      .AnnotationConfigApplicationContext@1046d517, started on ...

```

A few things were mentioned so far:

- In our example, we have a pointcut expression, but a pointcut can be declared separately from the advice, which is quite cool, since this means it can be reused.
- The before advice method accepts the joinpoint as an argument, but not the method, object, and arguments. However, the signature of this method is flexible, so we can add the argument value.

Listing 5-53 shows `BeforeAdviceV2`, an equivalent advice to `BeforeAdviceV1`, but the pointcut is separated from the advice declaration.

**Listing 5-53.** `BeforeAdviceV2` Class, Declaring an Aspect Bean with a Single Before Advice and a Pointcut

```

package com.apress.prospring6.five.advice;

import org.aspectj.lang.annotation.Pointcut;
// other import statements omitted

@Component
@Aspect
public class BeforeAdviceV2 {
    private static Logger LOGGER = LoggerFactory.getLogger(BeforeAdviceV2.class);

    @Pointcut("execution(* com.apress.prospring6.five..sing*(com.apress.prospring6.five.
common.Guitar))")
    public void singExecution() {
    }

    @Before("singExecution()")
    public void simpleBeforeAdvice(JoinPoint joinPoint) {
        var signature = (MethodSignature) joinPoint.getSignature();
        LOGGER.info(" > Executing: {} from {}", signature.getName(), signature.
getDeclaringTypeName() );
    }
}

```

Notice how the expression is provided as a value for the `@Pointcut` default attribute and this annotation is used to decorate a different method than the advice. A call to this method is then used as an expression for the `@Before` annotation. The method annotated with `@Pointcut` must return `void` and can also have arguments, as shown a little bit later in this section.

The test method is 99% identical to the one shown in Listing 5-50, with the exception that the `BeforeAdviceV1` gets replaced with the `BeforeAdviceV2` type. The output is identical to that of the execution of `testBeforeAdviceV1()`.

As previously mentioned, now that we have a pointcut, we can add another pointcut and compose them. The AspectJ pointcut expressions semantics are quite rich, and if you are interested you can check out the official documentation<sup>6</sup>. The second pointcut introduced in class `BeforeAdviceV3` is used to declare that the bean used as a target should have a name that starts with `john`. This pointcut is composed with the `singExecution()` pointcut using an AND (`&&`) operation. This obviously ensures that all methods with

<sup>6</sup><https://www.eclipse.org/aspectj/doc/released/progguide/semantics-pointcuts.html>

the name starting with `sing` and the classes are defined under the package `com.apress.prospring6.five` (including all the subpackages, indicated by `..`). Also, the `sing*` method should receive one argument with the `com.apress.prospring6.five.common.Guitar` type **AND** only the beans with names starting with `john` should be advised.

Listing 5-54 shows `BeforeAdviceV3`, a before advice declaration that applies to a composed pointcut.

**Listing 5-54.** `BeforeAdviceV3` Class, Declaring an Aspect Bean with a Single Before Advice and Two Pointcuts That Are Composed

```

package com.apress.prospring6.five.advice;
// import statements omitted

@Component
@Aspect
public class BeforeAdviceV3{
    private static Logger LOGGER = LoggerFactory.getLogger(BeforeAdviceV3.class);

    @Pointcut("execution(* com.apress.prospring6.five..sing*(com.apress.prospring6.five.
common.Guitar))")
    public void singExecution() {
    }

    @Pointcut("bean(john*)")
    public void isJohn() {
    }

    @Before("singExecution() && isJohn()")
    public void simpleBeforeAdvice(JoinPoint joinPoint) {
        var signature = (MethodSignature) joinPoint.getSignature();
        LOGGER.info(" > Executing: {} from {}", signature.getName(), signature.
getDeclaringTypeName() );
    }
}

```

The test method is 99% identical to the one shown in Listing 5-50, with the exception that the `BeforeAdviceV1` gets replaced with the `BeforeAdviceV3` type. The output is identical to that of the execution of `testBeforeAdviceV1()`, since we only have one bean named `johnMayer` in the configuration.

As for the arguments, we can modify the advice to do some checks on the arguments of the method being advised, but this will require the modification of the pointcut identifying the method and the method it decorates, and also the signature of the advice. This version of this advice is depicted in Listing 5-55.

**Listing 5-55.** `BeforeAdviceV4` Class, Declaring an Aspect Bean with a Single Before Advice That Checks the Argument Value

```

package com.apress.prospring6.five.advice;
// import statements omitted

@Component
@Aspect
public class BeforeAdviceV4 {
    private static Logger LOGGER = LoggerFactory.getLogger(BeforeAdviceV4.class);

```

```

@Pointcut("execution(* com.apress.prospring6.five..sing*(com.apress.prospring6.five.
common.Guitar)) && args(value)")
public void singExecution(Guitar value) {
}

@Pointcut("bean(john*)")
public void isJohn() {
}

@Before(value = "singExecution(guitar) && isJohn()", argNames = "joinPoint,guitar")
public void simpleBeforeAdvice(JoinPoint joinPoint, Guitar guitar) {
    if(guitar.getBrand().equals("Gibson")) {
        var signature = (MethodSignature) joinPoint.getSignature();
        LOGGER.info(" > Executing: {} from {}", signature.getName(), signature.
            getDeclaringTypeName());
    }
}
}

```



Notice that the pointcut expression includes the argument names: `joinPoint` and `guitar`. The advice method must have arguments with the names as the expression and the must appear in the same order.

---

The test method is 99% identical to the one shown in Listing 5-50, with the exception that the `BeforeAdviceV1` gets replaced with the `BeforeAdviceV4` type. The output is identical to that of the execution of `testBeforeAdviceV1()`, since we only have one bean named `johnMayer` in the configuration and this bean had a `Guitar` property with the brand set to `Gibson`. Feel free to modify the advice code and replace the guitar brand name and check how the advice output is no longer shown in the console when you run the test.

## Declarative Around Advice with AspectJ Annotations

Declaring an around advice is pretty similar, but there are a few differences. As expected, the annotation to declare the advice is `@Around` and the method signature includes a `ProceedingJoinPoint` since this type of advice has to have the possibility to call the target method.

Listing 5-56 depicts the class `AroundAdviceV1` that declares a pointcut and an around advice. This version does not take parameters into account.

**Listing 5-56.** `AroundAdviceV1` Class, Declaring an Aspect Bean with a Single Around Advice That Wraps Around the Target Method

```

package com.apress.prospring6.five.advice;

import org.aspectj.lang.ProceedingJoinPoint;
import org.aspectj.lang.annotation.Around;
// other import statements omitted

```



```

@Component
@Aspect
public class AroundAdviceV1 {
    private static Logger LOGGER = LoggerFactory.getLogger(AroundAdviceV1.class);

    @Pointcut("execution(* com.apress.prospring6.five..sing*(com.apress.prospring6.five.
common.Guitar))")
    public void singExecution() {
    }

    @Around("singExecution()")
    public Object simpleAroundAdvice(ProceedingJoinPoint pjp) throws Throwable {
        var signature = (MethodSignature) pjp.getSignature();

        LOGGER.info("> Before Executing: {} from {}", signature.getName(), signature.
getDeclaringTypeName() );
        Object retVal = pjp.proceed();
        LOGGER.info("> After Executing: {} from {}", signature.getName(), signature.
getDeclaringTypeName() );

        return retVal;
    }
}

```

This advice does nothing else than print a message before and after invoking the target method. If a configuration is created from the AspectJAopConfig class and the AroundAdviceV1 and tested as shown previously in the section (Listing 5-51), the resulted output proves without a doubt that the advice method has executed as expected, since the message printed by the target method `sing(Guitar)` is wrapped between the messages printed by the `simpleAfterAdvice` as shown in Listing 5-57.

**Listing 5-57.** Console Output Produced by Testing the AroundAdviceV1 Aspect Class

```

INFO : GrammyGuitarist - sing: Wild blue, deeper than I ever knew
INFO : AroundAdviceV1 - > Before Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : AroundAdviceV1 - > After Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist
INFO : GrammyGuitarist - talk

```

Let's make things more interesting and introduce AroundAdviceV2, which also uses the argument of the target method; in this case, the `Guitar.brand` property value is added to the advice messages, as shown in Listing 5-58.

**Listing 5-58.** AroundAdviceV2 Class, Declaring an Aspect Bean with a Single Around Advice That Wraps Around the Target Method

```

package com.apress.prospring6.five.advice;
// other import statements omitted

```

```

@Component
@Aspect

```

```

public class AroundAdviceV2 {
    private static Logger LOGGER = LoggerFactory.getLogger(AroundAdviceV2.class);

    @Pointcut("execution(* com.apress.prospring6.five..sing*(com.apress.prospring6.five.
common.Guitar)) && args(value)")
    public void singExecution(Guitar value) {
    }

    @Around(value = "singExecution(guitar)", argNames = "pjp,guitar")
    public Object simpleAroundAdvice(ProceedingJoinPoint pjp, Guitar guitar) throws
Throwable {
        var signature = (MethodSignature) pjp.getSignature();

        LOGGER.info(" > Before Executing: {} from {} with argument {}", signature.getName(),
signature.getDeclaringTypeName(), guitar.getBrand());
        Object retVal = pjp.proceed();
        LOGGER.info(" > After Executing: {} from {} with argument {}", signature.getName(),
signature.getDeclaringTypeName(), guitar.getBrand());

        return retVal;
    }
}

```

To underline how advice is being applied to all invocation, let's also extend the `NewDocumentarist` and change the brand of guitar our singer is playing. The new implementation is depicted in Listing 5-59.

**Listing 5-59.** `CommandingDocumentarist` Class

```

package com.apress.prospring6.five.annotated;
// import statements omitted

@Component("commandingDocumentarist")
public class CommandingDocumentarist extends NewDocumentarist {

    @Override
    public void execute() {
        guitarist.sing();
        Guitar guitar = new Guitar();
        guitar.setBrand("Gibson");
        guitarist.sing(guitar);
        guitarist.sing(new Guitar());
        guitarist.talk();
    }
}

```

When testing the new `CommandingDocumentarist` bean from a context created using the `AspectJAopConfig`, `CommandingDocumentarist`, and `AroundAdviceV2` classes using a test method similar to what was shown so far, the output is as shown in Listing 5-60.

**Listing 5-60.** Output for Testing an AroundAdviceV2

```
INFO : GrammyGuitarist - sing: Wild blue, deeper than I ever knew

INFO : AroundAdviceV2 - > Before Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist with argument Gibson
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : AroundAdviceV2 - > After Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist with argument Gibson

INFO : AroundAdviceV2 - > Before Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist with argument Martin
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : AroundAdviceV2 - > After Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist with argument Martin

INFO : GrammyGuitarist - talk
```

You see that the around advice was applied to both invocations of the `sing(Guitar)` method, since applying the advice does not depend on the argument value.

## Declarative After Advice with AspectJ Annotations

There are three AspectJ annotations for declaring after advice:

- `@After` (finally) declares advice that gets executed after the target method, regardless if it returned normally or by an exception being thrown. This type of advice is typically used for releasing resources or sending notifications. Since the advice gets executed regardless of mode of return, its behavior is similar to a `try-finally` statement.
- `@AfterReturning` declares advice that gets executed after the target method only if it returned normally.
- `@AfterThrowing` declares advice that gets executed after the target method, only if the method returned by an exception being thrown.

To demonstrate how to configure each type of after advice, a new `Singer` implementation is needed. This implementation is named `PretentiosGuitarist` and it implements the `sing(Guitar)` method to throw an exception when the brand of the `Guitar` instance is *'Musicman'*. This class and the bean declaration is shown in Listing 5-61.

**Listing 5-61.** PretentiosGuitarist Class

```
package com.apress.prospring6.five.annotated;
// import statements omitted

@Component("agustin")
public class PretentiosGuitarist implements Singer {

    private static Logger LOGGER = LoggerFactory.getLogger(PretentiosGuitarist.class);
```

```

public void sing(Guitar guitar) {
    if (guitar.getBrand().equalsIgnoreCase("Musicman")) {
        throw new IllegalArgumentException("Unacceptable guitar!");
    }
    LOGGER.info("play: " + guitar.play());
}

@Override
public void sing() {
    LOGGER.info("sing: solo tu puedes calmar el hambre de ti");
}
}

```

Let's start with the `@After` advice. The `AfterAdviceV1` class, the class that declares the `@After` advice that intercepts the `sing(Guitar)` method, is shown in Listing 5-62.

**Listing 5-62.** `AfterAdviceV1` Class Declaring an Aspect Bean with a Single `After`(finally) Advice That Is Called After the Target Method

```

package com.apress.prospring6.five.advice;

import org.aspectj.lang.annotation.After;
// other import statements omitted

@Component
@Aspect
public class AfterAdviceV1 {
    private static Logger LOGGER = LoggerFactory.getLogger(AfterAdviceV1.class);

    @Pointcut("execution(* com.apress.prospring6.five..PretentiousGuitarist.sing*(com.apress.
    prospring6.five.common.Guitar)) && args(value)")
    public void singExecution(Guitar value) {
    }

    @After(value = "singExecution(guitar) ", argNames = "joinPoint,guitar")
    public void simpleAfterAdvice(JoinPoint joinPoint, Guitar guitar) {
        var signature = (MethodSignature) joinPoint.getSignature();
        LOGGER.info(" > Executed: {} from {} with guitar {}", signature.getName(),
        signature.getDeclaringTypeName(), guitar.getBrand() );
    }
}

```

Notice that the `@After` advice has access to the argument of the target method and can make use of it, but it does not have access to the exception being thrown. Testing this advice requires a different approach; in the test method, the proxy bean is accessed directly and the `sing(..)` method is invoked twice, once with a default `Guitar` instance and once with the same instance after the `brand` property was set to the name that causes the `IllegalArgumentException` to be thrown. The test method is shown in Listing 5-63.

**Listing 5-63.** Test Method for the AfterAdviceV1 Aspect

```

package com.apress.prospring6.five.annotated;

import com.apress.prospring6.five.advice.AfterAdviceV1;
import static org.junit.jupiter.api.Assertions.assertThrows;
//other import statements omitted

public class AnnotatedAdviceTest {
    private static Logger LOGGER = LoggerFactory.getLogger(AnnotatedAdviceTest.class);

    @Test
    void testAfterAdviceV1(){
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(AspectJAopConfig.class, AfterAdviceV1.class);
        ctx.refresh();
        assertTrue(Arrays.asList(ctx.getBeanDefinitionNames()).contains("afterAdviceV1"));

        var guitar = new Guitar();
        var guitarist = ctx.getBean("agustin", PretentiousGuitarist.class);
        guitarist.sing(guitar);
        LOGGER.info("-----");
        guitar.setBrand("Musicman");

        assertThrows(IllegalArgumentException.class, () -> guitarist.sing(guitar),
"Unacceptable guitar!");
        ctx.close();
    }
}

```

JUnit Jupiter provides a method named `assertThrows(..)` to test the assumption that the exception is thrown when calling `sing(Guitar)` the second time. Running the code generates in the console the output shown in Listing 5-64.

**Listing 5-64.** Output When Testing AfterAdviceV1

```

INFO : PretentiousGuitarist - play: G C G C Am D7
INFO : AfterAdviceV1 - > Executed: sing from com.apress.prospring6.five.annotated.
      PretentiousGuitarist with guitar Martin
INFO : AnnotatedAdviceTest - -----
INFO : AfterAdviceV1 - > Executed: sing from com.apress.prospring6.five.annotated.
      PretentiousGuitarist with guitar Musicman

```

Notice that the advice is executed twice, but the stacktrace is nowhere to be seen. The reason for this is the `assertThrows(..)` method, but since the test passed we are sure the exception was thrown. If you have doubts, just comment the `assertThrows(..)` line, replace it with a call to `sing(guitar)`, and rerun the test.

For the `@AfterReturning` advice, the code stays mostly the same, with the exception that the advice is annotated with `@AfterReturning` instead of `@After` and testing it will only cause `> Executed: sing from com.apress.prospring6.five.annotated.PretentiousGuitarist with guitar Martin` to be printed.

For the `@AfterThrowing` advice the code stays mostly the same, with the exception that the advice is annotated with `@AfterThrowing` instead of `@After` and testing it will only cause `> Executed: sing from com.apress.prospring6.five.annotated.PretentiousGuitarist with guitar Musicman` to be printed.

One extra thing an `@AfterThrowing` advice can do what the other two types of advice can't: intercept the exception thrown by the target method and replace it with a different exception type.

The `AfterThrowingAdviceV2` aspect replaces the `IllegalArgumentException` thrown by the target method with an instance of `RejectedInstrumentException`, a very simple custom `RuntimeException` implementation. An `@AfterThrowing` advice cannot prevent an exception being thrown by the target method, but it can replace the exception thrown by it. The `AfterThrowingAdviceV2` code is shown in Listing 5-65.

**Listing 5-65.** `AfterThrowingAdviceV2` Class Declaring an Aspect Bean with a Single After-Throwing Advice That Replaces the Target Method Exception

```
package com.apress.prospring6.five.advice;

import com.apress.prospring6.five.common.RejectedInstrumentException;
import org.aspectj.lang.annotation.AfterThrowing;
// other import statements omitted

@Component
@Aspect
public class AfterThrowingAdviceV2 {
    private static Logger LOGGER = LoggerFactory.getLogger(AfterThrowingAdviceV2.class);

    @Pointcut("execution(* com.apress.prospring6.five..PretentiosGuitarist.sing*(com.apress.
    prospring6.five.common.Guitar)) && args(value)")
    public void singExecution(Guitar value) {
    }

    @AfterThrowing(value = "singExecution(guitar) ", argNames = "joinPoint,guitar, ex",
    throwing = "ex")
    public void simpleAfterAdvice(JoinPoint joinPoint, Guitar guitar,
    IllegalArgumentException ex) {
        var signature = (MethodSignature) joinPoint.getSignature();
        LOGGER.info(" > Executed: {} from {} with guitar {}", signature.getName(),
        signature.getDeclaringTypeName(), guitar.getBrand());
        if(ex.getMessage().contains("Unacceptable guitar!")) {
            throw new RejectedInstrumentException(ex.getMessage(), ex);
        }
    }
}
```

The introduction of the new exception type requires an updated test method that tests the assumption that the `RejectedInstrumentException` is thrown when invoking the `sing(Guitar)` method on the `agustin` bean. This test method is depicted in Listing 5-66.

**Listing 5-66.** Test Method for the `AfterThrowingAdviceV2` Aspect

```
package com.apress.prospring6.five.annotated;

import com.apress.prospring6.five.advice.AfterThrowingAdviceV2;
// other import statements omitted

public class AnnotatedAdviceTest {
    private static Logger LOGGER = LoggerFactory.getLogger(AnnotatedAdviceTest.class);
```

```

@Test
void testAfterThrowingAdviceV2(){
    var ctx = new AnnotationConfigApplicationContext();
    ctx.register(AspectJAopConfig.class, AfterThrowingAdviceV2.class);
    ctx.refresh();
    assertTrue(Arrays.asList(ctx.getBeanDefinitionNames()).contains("afterThrowing
AdviceV2"));

    var guitar = new Guitar();
    var guitarist = ctx.getBean("agustin", PretentiosGuitarist.class);
    guitarist.sing(guitar);
    LOGGER.info("-----");
    guitar.setBrand("Musicman");

    assertThrows(RejectedInstrumentException.class, () -> guitarist.sing(guitar),
    "Unacceptable guitar!");
    ctx.close();
}
}

```

The `testAfterThrowingAdviceV2()` test should pass and produce the output shown in Listing 5-67 in the console.

**Listing 5-67.** Output When Testing `AfterThrowingAdviceV2`

```

INFO : PretentiosGuitarist - play: G C G C Am D7
INFO : AfterAdviceV1 - > Executed: sing from com.apress.prospring6.five.annotated.
    PretentiosGuitarist with guitar Martin
INFO : AnnotatedAdviceTest - -----
INFO : AfterAdviceV1 - > Executed: sing from com.apress.prospring6.five.annotated.
    PretentiosGuitarist with guitar Musicman

```

## Declarative Introductions with AspectJ Annotations

Introductions were mentioned briefly when discussing proxies. The earlier “Getting Started with Introductions” section showed how to write an aspect that decorates a target object with an interface, and provided an implementation for that interface. Putting all of this together in an application was done using a `ProxyFactory` instance and `ProxyFactoryBean`. All was done programmatically at the time, but a declarative configuration is possible as well by using the AspectJ `@DeclareParents` annotation.

To demonstrate this, Listing 5-68 introduces a new interface named `Performer` and its implementation named `Dancer`.

**Listing 5-68.** `Performer` and `Dancer` Implementations

```

package com.apress.prospring6.five.common;

public interface Performer {
    void perform();
}

```

```
// import statements omitted
public class Dancer implements Performer {
    private static Logger LOGGER = LoggerFactory.getLogger(Dancer.class);

    @Override
    public void perform() {
        LOGGER.info(" Shake it to the left, shake it to the right!");
    }
}
```

The `@DeclareParents` annotation is used to introduce the `Performer` interface for any bean of a type that implements `Singer`. Listing 5-69 shows the configuration of the `AnnotatedIntroduction` aspect.

**Listing 5-69.** `AnnotatedIntroduction` Class and Aspect Definition for Introduction

```
package com.apress.prospring6.five.annotated;

import com.apress.prospring6.five.common.Dancer;
import com.apress.prospring6.five.common.Performer;
import org.aspectj.lang.annotation.DeclareParents;
// other import statements omitted

@Component
@Aspect
public class AnnotatedIntroduction {

    @DeclareParents(value="com.apress.prospring6.five.common.Singer+",
    defaultImpl=Dancer.class)
    public static Performer performer;

}
```

The interface to be implemented is determined by the type of the annotated field, in this case `Performer`. The `value` attribute of `@DeclareParents` is used to tell Spring for what types the introduction must happen. Any bean of a matching type is wrapped in a proxy that implements the `Performer` interface and introduces the behavior described by the `Dancer` class.

Testing the introduction is easy; we just get the bean from the context and check its type via `instanceof`, we convert it to `Performer` and call `perform()`. The testing method is depicted in Listing 5-70.

**Listing 5-70.** `AnnotatedIntroductionTest` Method

```
package com.apress.prospring6.five.annotated;

import com.apress.prospring6.five.common.Performer;
// other import statements omitted

public class AnnotatedIntroductionTest {
    private static Logger LOGGER = LoggerFactory.getLogger(AnnotatedIntroductionTest.class);

    @Test
    void testAnnotatedIntroduction() {
        var ctx = new AnnotationConfigApplicationContext();
    }
}
```



```

ctx.register(AspectJAopConfig.class, AnnotatedIntroduction.class);
ctx.refresh();
assertTrue(Arrays.asList(ctx.getBeanDefinitionNames()).contains("annotated
Introduction"));

var guitar = new Guitar();
var guitarist = ctx.getBean("agustin", PretentiousGuitarist.class);

assertTrue(guitarist instanceof Singer);
guitarist.sing(guitar);

LOGGER.info("Proxy type: {} ", guitar.getClass().getName());

assertTrue(guitarist instanceof Performer);
Performer performer = (Performer)guitarist;
performer.perform();

ctx.close();
}
}

```

Running the test should pass and output from the target bean and the `Dancer` type should be present in the console log, as shown in Listing 5-71.

**Listing 5-71.** AnnotatedIntroduction Test Output

```

INFO : PretentiousGuitarist - play: G C G C Am D7
INFO : AnnotatedIntroductionTest - Proxy type: com.apress.prospring6.five.common.Guitar
INFO : Dancer - Shake it to the left, shake it to the right!

```

## Aspect Instantiation Models



In Spring AOP, aspect classes cannot be the targets of advice from other aspects. The `@Aspect` annotation is also a marker interface, excluding the resulting beans from auto-proxying.

---

Since the `@Aspect` annotation is not sufficient for auto-detection in the classpath, aspect classes were registered as beans using `@Component` in the examples shown so far. They can be registered using `@Bean` as well. This means that each aspect class becomes a singleton bean in the Spring `ApplicationContext`.

To test this, we declare a `BeforeAdviceV5` class that declares a single simple before advice, but we declare the default constructor to print the instantiation time of the object. The code of this aspect is almost identical to that of `BeforeAdviceV2`, the only extra thing being the constructor with the logging statement, so we won't list it here again. Listing 5-72 shows the method testing that the constructor of this aspect is called only once. The configuration declares two `Singer` beans: `johnMayer` and `agustin`.

**Listing 5-72.** BeforeAdviceV5 Test Method

```

package com.apress.prospring6.five.annotated;

import com.apress.prospring6.five.advice.BeforeAdviceV5;
// other import statements omitted

public class AnnotatedAdviceTest {
    private static Logger LOGGER = LoggerFactory.getLogger(AnnotatedAdviceTest.class);

    @Test
    void testAfterThrowingAdviceV5(){
        var ctx = new AnnotationConfigApplicationContext();
        ctx.register(AspectJAopConfig.class, BeforeAdviceV5.class);
        ctx.refresh();
        assertTrue(Arrays.asList(ctx.getBeanDefinitionNames()).contains("beforeAdviceV5"));

        var johnMayer = ctx.getBean("johnMayer", GrammyGuitarist.class);
        johnMayer.sing(new Guitar());

        var pretentiousGuitarist = ctx.getBean("agustin", PretentiosGuitarist.class);
        pretentiousGuitarist.sing(new Guitar());

        ctx.close();
    }
}

```

The test method retrieves these beans and calls `sing(Guitar)` on them. When looking in the console, we should see the `BeforeAdviceV5` constructor message printed only once. Listing 5-73 shows the output of executing the test method in Listing 5-72.

**Listing 5-73.** BeforeAdviceV5 Test Method Output

```

INFO : BeforeAdviceV5 - BeforeAdviceV5 creation time: 2022-04-24T18:08:05.971660Z
...
INFO : BeforeAdviceV5 - > Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : BeforeAdviceV5 - > Executing: sing from com.apress.prospring6.five.annotated.
    PretentiosGuitarist
INFO : PretentiosGuitarist - play: G C G C Am D7

```

The message is printed only once since the aspect class is annotated with `@Component` and the scope is not explicitly configured, so the resulting aspect is a singleton bean.

This leads to the conclusion that there is a way to do things differently. Consider a scenario where you need more than one aspect bean to be created, such as one per target. This is possible via configuration. The `@Aspect` annotation declares a single attribute that can be initialized with an `AspectJ` expression configuring how many aspect beans should be created and when.



Of course, the Spring configuration must be modified to match, which means the aspect bean scope cannot be singleton anymore.

To create an aspect bean for each target bean, the `@Aspect` annotation should receive as a parameter a `pertarget` expression pointing at the type of the intended target beans, in this case `Singer`. The `BeforeAdviceV6` is depicted in Listing 5-74.

**Listing 5-74.** `BeforeAdviceV6` Aspect Class Declaring an Aspect for Each `Singer` Bean

```
package com.apress.prospring6.five.advice;

import java.time.Instant;
// other import statements omitted

@Component
@Scope("prototype")
@Aspect("pertarget(targetIdentifier())")
public class BeforeAdviceV6 {
    private static Logger LOGGER = LoggerFactory.getLogger(BeforeAdviceV6.class);

    public BeforeAdviceV6() {
        LOGGER.info("BeforeAdviceV6 creation time: {}", Instant.now());
    }

    @Pointcut("target(com.apress.prospring6.five.common.Singer+)")
    public void targetIdentifier() {
    }

    // pointcut and advice for the 'sing' method omitted.
}
```

The method used for testing `BeforeAdviceV6` is almost identical to the one for `BeforeAdviceV5`, the only difference being the number in the names, so the method won't be shown here. However, the output produced by it is interesting. The new aspect configuration causes an aspect to be created for each of the `Singer` beans in the configuration, and this is shown by the `BeforeAdviceV6` constructor message being printed twice, with different date and time, as shown in Listing 5-75.

**Listing 5-75.** `BeforeAdviceV6` Test Method Output

```
INFO : BeforeAdviceV6 - BeforeAdviceV5 creation time: 2022-04-24T18:34:23.037830Z
INFO : BeforeAdviceV6 - > Executing: sing from com.apress.prospring6.five.annotated.
    GrammyGuitarist
INFO : GrammyGuitarist - play: G C G C Am D7
INFO : BeforeAdviceV6 - BeforeAdviceV5 creation time: 2022-04-24T18:34:23.053335Z
INFO : BeforeAdviceV6 - > Executing: sing from com.apress.prospring6.five.annotated.
    PretentiousGuitarist
INFO : PretentiousGuitarist - play: G C G C Am D7
```

An alternative configuration involves the `@Aspect` annotation receiving as a parameter a `perthis` expression, pointing at the target method, in this case the `sing(Guitar)` method. The `BeforeAdviceV7` aspect configuration is shown in Listing 5-76.

**Listing 5-76.** `BeforeAdviceV7` Aspect Class Declaring an Aspect for Each Singer Bean

```

package com.apress.prospring6.five.advice;
// import statement omitted

@Component
@Scope("prototype")
@Aspect("perthis(singExecution())")
public class BeforeAdviceV7 {
    private static Logger LOGGER = LoggerFactory.getLogger(BeforeAdviceV7.class);

    public BeforeAdviceV7() {
        LOGGER.info("BeforeAdviceV7 creation time: {}" , Instant.now());
    }

    @Pointcut("execution(* com.apress.prospring6.five..sing*(com.apress.prospring6.five.
common.Guitar))")
    public void singExecution() {
    }

    @Before("singExecution()")
    public void simpleBeforeAdvice(JoinPoint joinPoint) {
        var signature = (MethodSignature) joinPoint.getSignature();
        LOGGER.info(" > Executing: {} from {}", signature.getName(), signature.
getDeclaringTypeName() );
    }
}

```

The test method is almost identical, and the test output shows two aspect beans being created.



So what is the difference between `perthis(Pointcut)` and `pertarget(Pointcut)`? The difference is represented by the object being examined when an advised joinpoint is reached. `Pertarget` specifies a type expression, which means a new aspect is to be instantiated for every new object that is the target of an advice-triggering joinpoint. `perthis` specifies a method expression and, thus, a new aspect is to be instantiated for every new object referenced by `this` at the advice-triggering joinpoint.

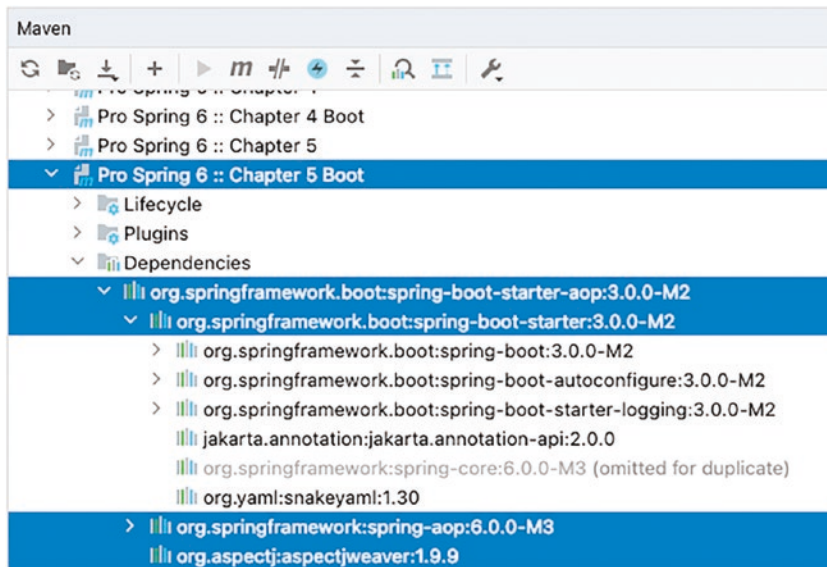
---

You would rarely need to write your own aspects, since almost anything you might need when building a Spring application is already provided by Spring, but it is good to understand what happens under the hood and how Spring does its magic. And this is all that can be said about aspects with Spring, so let's turn to how you can work with aspects in a Spring Boot application.

## Spring Boot AOP

Spring Boot provides a special AOP starter library, `spring-boot-starter-aop`, that removes the hassle of configuration, even if there is not much of it anyway. To use the library in a Spring Boot project, just create a Spring Boot project and add it as a dependency.

In Figure 5-11 you can see the set of libraries added as dependencies to the Spring Boot project (the screenshot is from the Maven View; the Gradle View is almost identical).



**Figure 5-11.** Spring Boot AOP starter transitive dependencies as depicted in IntelliJ IDEA

By adding this library to your project as a dependency, the `@EnableAspectJAutoProxy(proxyTargetClass = true)` annotation is no longer needed because the AOP Spring support is already enabled by default. The `proxyTargetClass` attribute does not have to be set anywhere either, because Spring Boot automatically detects what type of proxies you need.

Any of the aspects introduced in previous sections can be added to the Spring Boot project, and when proxies are used, you can watch the advice work as expected. But let's keep things simple. A `GrammyGuitarist` type is declared and its implementation is identical that used in the rest of the chapter, except that for the Spring Boot project, `GrammyGuitarist` does not implement the `Singer` interface. With these beans in the project, the Spring application can be configured using the class shown in Listing 5-77.

**Listing 5-77.** Spring Boot Chapter5Application Main Class

```
package com.apress.prospring6.five;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
public class Chapter5Application {
```

```

public static void main(String... args) throws Exception{
    var ctx = SpringApplication.run(Chapter5Application.class, args);
    assert (ctx != null);

    // If you want to run this class to test the advice remove comment from the
    // next 2 lines
    /* var documentarist = ctx.getBean("documentarist", NewDocumentarist.class);
    documentarist.execute();*/

    System.in.read();
    ctx.close();
}
}

```

Simple, right? Also, the reason those two lines are commented is because the `Chapter5Application` class is used to only configure the Spring application. Since testing was mentioned in previous chapters, it only makes sense to test our application using a Spring Boot test class. Take a look at Listing 5-78.

**Listing 5-78.** Spring Boot `Chapter5ApplicationTest` Main Class

```

package com.apress.prospring6.five;

import org.springframework.boot.test.context.SpringBootTest;
import static org.junit.jupiter.api.Assertions.*;
// other imports omitted

@SpringBootTest
public class Chapter5ApplicationTest {

    @Autowired
    NewDocumentarist documentarist;

    @Autowired
    GrammyGuitarist guitarist;

    @Test
    void testDocumentarist(){
        assertAll(
            () -> assertNotNull(documentarist.getGuitarist()),
            () -> assertNotNull(guitarist),
            () -> assertTrue(guitarist.getClass().getName().contains("SpringCGLIB"))
        );
        documentarist.execute();
    }
}

```

The `@SpringBootTest` annotation ensures that the test context is populated with the beans declared in the Spring Boot configuration class, which means we can use `@Autowired` to access the beans in the test context.

When this test passes, this means the application context was created correctly, the two beans of type `GrammyGuitarist` and `NewDocumentarist` were created, and the `GrammyGuitarist` bean, is a GCLIB proxy, since a JDK proxy is not suitable for it as its type does not implement an interface.

This is all that can be said about AOP with Spring Boot; Spring Boot provides no fancy, specialized components to simplify AOP with Spring because there is almost nothing to simplify.

## Considerations for Declarative Spring AOP Configuration

This book has shown two ways to write your code using Spring AOP: using `ProxyFactoryBean` and using the `@AspectJ`-style annotations. XML AOP configuration is not the focus of this book, but its main advantage is that it makes easy to separate the configuration from your code. On the other hand, if your application is mainly annotation based, use the `@AspectJ` annotation. Again, let the requirements of your application drive the configuration approach, and make your best effort to be consistent.

Moreover, there are some other differences between the `aop` namespace and `@AspectJ` annotation approaches:

- The pointcut expression syntax has some minor differences (for example, in XML configuration, when using the `aop` namespace, we need to use `and` to aggregate conditions, but `&&` in `@AspectJ` annotation).
- In XML configuration, the `aop` namespace approach supports only the singleton aspect instantiation model.
- In XML configuration, using the `aop` namespace, you can't "combine" multiple pointcut expressions. In the example using `@AspectJ`, we can combine the two pointcut definitions (that is, `singExecution(value) && isJohn()`) in the `before` and `around` advice. When using the `aop` namespace and needing to create a new pointcut expression that combines the matching conditions, you need to use the `ComposablePointcut` class.

## Summary

In this chapter, we covered a large number of AOP core concepts and looked at how these concepts translate into the Spring AOP implementation. We discussed the features that are (and are not) implemented in Spring AOP, and we pointed to `AspectJ` as an AOP solution for those features that Spring does not implement. We spent some time explaining the details of the advice types available in Spring, and you saw examples of the four types in action. We also looked at how you limit the methods to which advice applies by using pointcuts. In particular, we looked at the six basic pointcut implementations available with Spring. We also covered the details of how the AOP proxies are constructed, the different options, and what makes them different. We compared performance among three proxy types and highlighted some major differences and restrictions for choosing between a JDK vs. CGLIB proxy. We covered the advanced options for pointcutting, as well as how to extend the set of interfaces implemented by an object using introductions.

We also covered Spring Framework services to configure AOP declaratively, thus avoiding the need to hard-code AOP proxy construction logic into your code. We spent some time looking at how Spring and `AspectJ` are integrated to allow you to use the added power of `AspectJ` without losing any of the flexibility of Spring. That's certainly a lot of AOP!

In the next chapter, we move on to a completely different topic—how we can use Spring's JDBC support to radically simplify the creation of JDBC-based data access code.

## CHAPTER 6



# Spring Data Access with JDBC

By now you have seen how easy it is to build a fully Spring-managed application. You have a solid understanding of bean configuration and aspect-oriented programming (AOP). However, one part of the puzzle is missing: how do you get the data that drives the application?

Besides simple throwaway command-line utilities, almost every application needs to persist data to some sort of data store. The most usual and convenient data store is a database.

These are the top seven enterprise databases for 2023:

- *MariaDB*: One of the most popular databases for web applications (all WordPress blogs store their data in a MariaDB database).
- *Oracle Database*: The most widely used commercial relational database management system (especially in financial applications).
- *PostgreSQL*: A database management system written in C and used by businesses that deal with huge amounts of data.
- *Microsoft SQL Server*: Yet another favorite of financial companies, both on-premises and in the cloud.
- *MongoDB*: Most popular NoSQL database, a document-oriented database, available in the cloud as a service via self-healing clusters, known as MongoDB Atlas.
- *Redis*: A distributed in-memory key-value store, with great scalability.
- *Elasticsearch*: A full-text search engine based on Lucene.

Also, Oracle pushes seriously for the replacement of MariaDB with MySQL. If you are not working for a big company that can afford licenses for enterprise database or database cloud instances such as GCP Managed SQL instance or Amazon RDS or Aurora, you probably are using MariaDB, PostgreSQL, or other free database not listed here. MariaDB is generally more widely used for web application development, especially on the Linux platform; on the other side, PostgreSQL is friendlier to Oracle developers because its procedural language, PL/pgSQL, is very close to Oracle's PL/SQL language.

Even if you choose the fastest and most reliable database, you cannot afford to lose its speed and flexibility by using a poorly designed and implemented data access layer. Applications tend to use the data access layer very frequently; thus, any unnecessary bottlenecks in the data access code impact the entire application, no matter how well designed it is. This chapter is the first in a series of five that will show you how to work with SQL and NoSQL databases, how to manage transactions, and how to use a persistence tool such as Hibernate. Specifically, we'll discuss the following:



- *Comparing traditional JDBC code and Spring JDBC support:* We explore how Spring simplifies the old-style JDBC code while keeping the same functionality. You will also see how Spring accesses the low-level JDBC API and how this low-level API is mapped into convenient classes such as `JdbcTemplate`.
- *Connecting to the database:* Even though we do not go into every little detail of database connection management, we do show you the fundamental differences between a simple `Connection` and a `DataSource`. Naturally, we discuss how Spring manages the data sources and which data sources you can use in your applications. Various libraries for connection pooling—the process through which connections are reused, rather than created every time a connection is requested—are also introduced.
- *Retrieving and mapping the data to Java objects:* We show you how to retrieve data and then how to effectively map the selected data to Java objects. You also learn that Spring JDBC is a viable alternative to object-relational mapping (ORM) tools (which will be introduced in **Chapter 7**).
- *Inserting, updating, and deleting data:* We discuss how you can implement the insert, update, and delete operations by using Spring to execute these types of queries.
- *Testing JDBC code using an in-memory database:* We discuss approaches to testing JDBC code, explain why in-memory databases are suitable for testing, and introduce the `@Sql*` annotations family that provides support to write concise tests for your JDBC code. We also introduce you to a very practical library called `Testcontainers` that allows starting up and tearing down a Docker container within the life cycle of a test or test class.
- *Using Spring Boot JDBC:* We show how easy it is to configure distinct databases for production and test environments using the Spring Boot JDBC starter library.

Let's start with the simplest scenario involving databases: writing code to work with SQL databases and JDBC.

## Sample Data Model for Example Code

Before proceeding with the discussion, we introduce a simple data model that is used for the examples throughout this chapter, as well as the next few chapters when discussing other data access techniques (we will expand the model accordingly to fulfill the needs of each topic as we go).

The model is a simple music database with two tables. The first one is the `SINGER` table, which stores a singer's information, and the other table is `ALBUM`, which stores details about the albums released by that singer. Each singer can have zero or more albums; in other words, it's a one-to-many relationship between `SINGER` and `ALBUM`. A singer's information includes their first and last names and date of birth. Figure 6-1 shows the entity-relationship (ER) diagram of the database.



**Figure 6-1.** Simple data model for the example code

As you can see, both tables have an ID column that will be automatically assigned by the database during insertion. For the ALBUM table, there is a foreign-key relation to the SINGER table, which is linked by the column SINGER\_ID with the primary key of the SINGER table (that is, the ID column).



In this chapter, we use the open source database MariaDB<sup>1</sup> to show interactions with a real database in some examples. MariaDB is a truly open source distribution of MySQL<sup>2</sup>, released as a response to Oracle buying MySQL. The interesting thing you should be aware of is that MariaDB shows improved speed when compared to MySQL. In particular, MariaDB offers better performance when it comes to views and handling flash storage through its RocksDB<sup>3</sup> engine.



This chapter, and probably the next ones in the data access series, requires you to have an instance of MariaDB available to use. We do not cover how to install MariaDB, but the `chapter06.adoc` file instructing you how to start MariaDB in a Docker container. You can use another database of your choice, but you may need to modify the schema and function definitions. We also cover embedded database usage, which does not require a MariaDB database.

In case you want to install MariaDB locally, on the official site you can find very good tutorials on installing and configuring MariaDB. After you have downloaded MariaDB<sup>4</sup> and installed it, you can access it using the root account. Usually, when you develop an application, you need a new schema and user. For the code samples in this chapter, the schema is named `musicdb`, and the user to access it is named `prospring6`. The SQL code to execute to create them is located in `docker-build/scripts/CreateTable.sql` in the directory of the `chapter06` project. The SQL code to execute to populate the tables is located in `docker-build/scripts/InsertData.sql` in the directory of the `chapter06` project.

<sup>1</sup><https://mariadb.com>

<sup>2</sup><https://www.mysql.com>

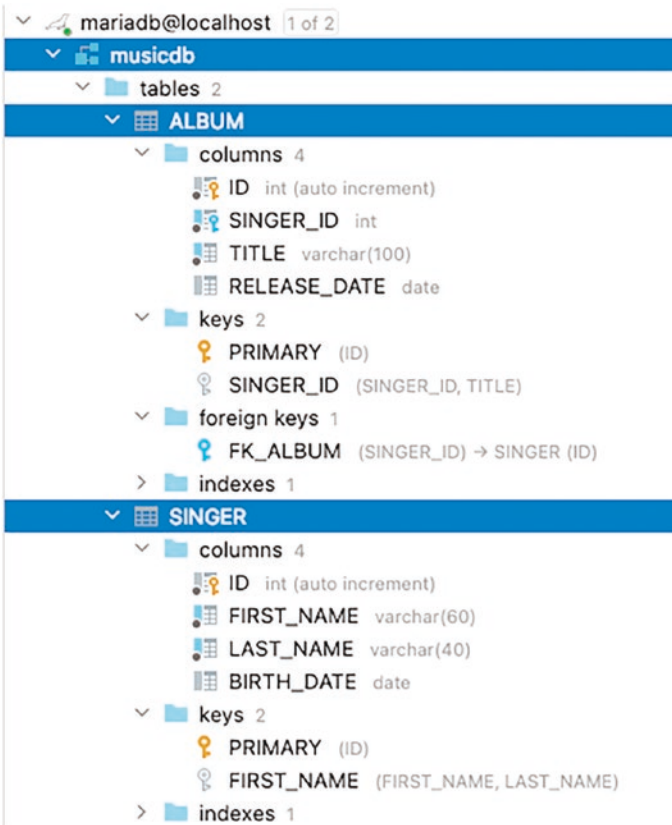
<sup>3</sup><https://rocksdb.org>

<sup>4</sup><https://mariadb.com/kb/en/binary-packages>



Using the Docker MariaDB container, you don't need to execute the scripts manually because they are automatically executed when the container is started. Follow the instructions in CHAPTER06.adoc if you are interested in this approach (and you should be, because containers are everywhere nowadays).

Following the instructions in the CHAPTER06.adoc should produce a MariaDB container named local-mariadb. If you use a smart editor (like IntelliJ IDEA, the editor recommended in this book), you can use the Database view to inspect your schema and tables. In Figure 6-2 you can see the contents of the musicdb schema as depicted in IntelliJ IDEA.



**Figure 6-2.** Contents of the musicdb schema

As you can see, we have a one-to-many relationship between the SINGER and ALBUM tables and both have a primary key named ID. The foreign key linking records in ALBUM to parent records in SINGER is named SINGER\_ID.

In later sections of this chapter, you will see examples of retrieving the data via JDBC from the database and directly mapping the result set into Java objects (that is, POJOs). These classes that map to the records in tables are also called **pojos**. For the SINGER table, a `Singer` class is and instances of this class map to rows in the SINGER table.

In the *I Love Lucy* episode “Paris at Last,” Lucy is rescued from arrest by an elaborate translation effort by Ricky, a Paris policeman, and a third man who helps<sup>5</sup>. The episode basically shows Lucy getting in trouble and getting arrested by the French police. The two police officers cannot speak English, but one speaks both French and German; Ricky and Lucy cannot speak French, but Ricky speaks Spanish; and the third man speaks only German and Spanish. This leads to a chain of three translators between Lucy, who speaks only English, and the police chief, who speaks only French.

In a similar way, a Java application and a database cannot communicate directly, so they need a translator, which in software is called a **driver**. In the *I Love Lucy* episode, they need three translators to get the job done. When it comes to Java and most databases, we have the following options:

- We usually need one translator, the driver.
- We might use two, if we want to introduce a persistence layer such as Hibernate.
- We might use three, if we add Spring Data to easily map records to POJOs and handle transactions easily.

In this book, we show you how to do all three. Let’s start with the basic one and define our POJOs. Listing 6-1 shows the `Singer` and `Album` classes that map to records in the `SINGER` and `ALBUM` tables, respectively.

**Listing 6-1.** POJOs for Working with the JDBC Driver

```
package com.apress.prospring6.six.plain.pojos;

import java.io.Serializable;
import java.time.LocalDate;
import java.util.HashSet;
import java.util.Set;

// maps to table SINGER
public class Singer implements Serializable {
    private Long id;
    private String firstName;
    private String lastName;
    private LocalDate birthDate;
    private Set<Album> albums;
    // getters and setters omitted
}

// maps to table ALBUM
public class Album implements Serializable {
    private Long id;
    private Long singerId;
    private String title;
    private LocalDate releaseDate;
    // getters and setters omitted
}
```

<sup>5</sup><https://youtu.be/Xle3I-5nfpI>

Let's start with a simple interface for `SingerDao` that encapsulates all the data access methods for Singer information. DAO is an acronym for *data access object*, and in the Spring world the term *repository* is used instead. The code is as shown in Listing 6-2.

**Listing 6-2.** `SingerDao` Interface

```
package com.apress.prospring6.six.plain.dao.pojos;

import com.apress.prospring6.six.entities.Singer;
import java.util.Set;
import java.util.Optional;

public interface SingerDao extends CoreDao {
    Set<Singer> findAll();
    Set<Singer> findByFirstName(String firstName);
    Optional<String> findNameById(Long id);
    Optional<String> findLastNameById(Long id);
    Optional<String> findFirstNameById(Long id);
    void insert(Singer singer);
    void update(Singer singer);
    void delete(Long singerId);
    Set<Singer> findAllWithAlbums();
    void insertWithAlbum(Singer singer);
}
```

In the `SingerDao` interface, we define two `find(..)` methods and the `insert(..)`, `update(..)`, and `delete(..)` methods, respectively. They correspond to the CRUD terms (create, read, update, delete).

A Java application needs a connection instance to communicate with the database, and retrieve or send data. The `CoreDao` interface extended by `SingerDao` is a simple interface that groups methods related to connection management: getting a connection and closing a connection. This interface and the JDBC infrastructure are discussed in the next section (and shown in Listing 6-4).

Finally, to facilitate testing, let's modify the `logback.xml` configuration file to turn the log level to `DEBUG` for all classes. At the `DEBUG` level, the application will output all the underlying SQL statements being fired to the database, so you know what exactly is going on; this is especially useful for troubleshooting SQL statement syntax errors. Listing 6-3 depicts the contents of the `logback.xml` file for the project containing the sources for **Chapter 6** project (`chapter06`).

**Listing 6-3.** `logback.xml` Contents

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration>

    <contextListener class="ch.qos.logback.classic.jul.LevelChangePropagator">
        <resetJUL>true</resetJUL>
    </contextListener>

    <appender name="console" class="ch.qos.logback.core.ConsoleAppender">
        <encoder>
            <pattern> %-5level: %class{0} - %msg%n</pattern>
        </encoder>
    </appender>
```

```

<logger name="com.apress.prospring6.six" level="debug"/>

<logger name="org.springframework" level="debug"/>

<root level="info">
  <appender-ref ref="console" />
</root>
</configuration>

```

## Exploring the JDBC Infrastructure

JDBC provides a standard way for Java applications to access data stored in a database. The core of the JDBC infrastructure is a driver that is specific to each database; it is this driver that allows Java code to access the database.

Once a driver is loaded, it registers itself with a `java.sql.DriverManager` class. This class manages a list of drivers and provides static methods for establishing connections to the database. The `DriverManager`'s `getConnection()` method returns a driver-implemented `java.sql.Connection` interface. This interface allows you to run SQL statements against the database.

The JDBC framework is quite complex and well tested; however, with this complexity comes difficulty in development. The first level of complexity lies in making sure your code manages the connections to the database. A connection is a scarce resource and is very expensive to establish. Generally, the database creates a thread or spawns a child process for each connection. Also, the number of concurrent connections is usually limited, and an excessive number of open connections will slow down the database.

We will show you how Spring helps manage this complexity, but before we can proceed any further, we need to show you how to select, delete, and update data in pure JDBC.

A Java application needs a connection instance to communicate with the database and retrieve or send data. The type for this instance is provided by the driver present on the project classpath. In our case the MariaDB driver was added to the classpath by declaring the `mariadb-java-client.jar` file as a dependency in the Maven/Gradle configuration. Listing 6-4 shows the `CoreDao` code that contains two default methods, one for retrieving a connection and one for closing it, that are inherited by any type implementing this interface, directly or indirectly.

### Listing 6-4. CoreDao Interface

```

package com.apress.prospring6.six.dao;

import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.SQLException;

public interface CoreDao {

    default Connection getConnection() throws SQLException {
        return DriverManager.getConnection(
            "jdbc:mariadb://localhost:3306/musicdb?useSSL=false",
            "prospring6", "prospring6");
    }
}

```

```

default void closeConnection(Connection connection) throws SQLException {
    if (connection == null) {
        return;
    }
    connection.close();
}

```

Keeping in mind what we already know about database connections, we will take the cautious and expensive (in terms of performance) approach of creating a connection for each statement. This greatly degrades the performance of Java and adds extra stress to the database because a connection must be established for each query. However, if we kept a connection open, we could bring the database server to a halt.

As you can see, the reference type for the connection is the `java.sql.Connection` interface that is part of the JDK. Any JDBC driver that plays the role of a translator between a Java application and a SQL database must have a class that implements this interface. The MariaDB implementation is the `org.mariadb.jdbc.Connection` interface. To check that a driver is present on the classpath, most applications declare a static block that uses reflection to find the core driver class of that driver, an implementation of `java.sql.Driver`. Listing 6-5 shows the static block that does this for the MariaDB driver.

**Listing 6-5.** Static Block Used to Check the Presence of a JDBC Driver on the Classpath

```

package com.apress.prospring6.six.plain;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
// other import statements omitted

public class PlainJdbcDemo {
    private static Logger LOGGER = LoggerFactory.getLogger(PlainJdbcDemo.class);

    static {
        try {
            Class.forName("org.mariadb.jdbc.Driver");
        } catch (ClassNotFoundException ex) {
            LOGGER.error("Problem loading DB Driver!", ex);
        }
    }
    // other code omitted
}

```

This code is far from complete, but it gives you an idea of the steps you need in order to manage a JDBC connection. This code does not even deal with connection pooling, which is a common technique for managing connections to the database more effectively. We do not discuss connection pooling at this point (connection pooling is discussed in the “Database Connections and DataSources” section later in this chapter); instead, the code snippet in Listing 6-6 shows an implementation of the `findAll()`, `insert(..)`, and `delete()` methods of the `SingerDao` interface using plain JDBC.

**Listing 6-6.** PlainSingerDao Implementation

```

package com.apress.prospring6.six.plain.dao.pojos;

import java.sql.Connection;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;
// other import statements omitted

public class PlainSingerDao implements SingerDao {
private static Logger LOGGER = LoggerFactory.getLogger(PlainSingerDao.class);

    @Override
    public Set<Singer> findAll() {
        Set<Singer> result = new HashSet<>();
        try (var connection = getConnection();
            var statement = connection.prepareStatement("select * from SINGER");
            var resultSet = statement.executeQuery()) {
            while (resultSet.next()) {
                var singer = new Singer();
                singer.setId(resultSet.getLong("id"));
                singer.setFirstName(resultSet.getString("first_name"));
                singer.setLastName(resultSet.getString("last_name"));
                singer.setBirthDate(resultSet.getDate("birth_date")
                    .toLocalDate());
                result.add(singer);
            }
        } catch (SQLException ex) {
            LOGGER.error("Problem when executing SELECT!", ex);
        }
        return result;
    }

    @Override
    public Singer insert(Singer singer) {
        try ( var connection = getConnection()){
            var statement = connection.prepareStatement(
                "insert into SINGER (first_name, last_name, birth_date) values
                (?, ?, ?)"
                , Statement.RETURN_GENERATED_KEYS);
            statement.setString(1, singer.getFirstName());
            statement.setString(2, singer.getLastName());
            statement.setDate(3, java.sql.Date.valueOf(singer.getBirthDate()));
            statement.execute();
            var generatedKeys = statement.getGeneratedKeys();
            if (generatedKeys.next()) {
                singer.setId(generatedKeys.getLong(1));
            }
            return singer;
        } catch (SQLException ex) {

```



```

        LOGGER.error("Problem executing INSERT", ex);
    }
    return null;
}

@Override
public void delete(Long singerId) {
    try (var connection = getConnection();
        var statement = connection.prepareStatement("delete from SINGER where id=?")) {
        statement.setLong(1, singerId);
        statement.execute();
    } catch (SQLException ex) {
        LOGGER.error("Problem executing DELETE", ex);
    }
}

// other methods omitted
}

```

Notice the amount of code needed for each method. We always have to make sure the connection to the database can be used, and using it requires us to treat the checked `SQLException` that might be thrown. In earlier versions of Java, when `java.sql.Connection` and other types needed to handle communication with the database, did not implement `java.lang.AutoCloseable`, and there was no *try-with-resources* statement, that code looked even uglier.

The class to test the methods in `PlainSingerDao` is shown in Listing 6-7.

**Listing 6-7.** `PlainJdbcDemo` Class That Tests Methods in `PlainSingerDao`

```

package com.apress.prospring6.six.plain;
// import statements omitted

public class PlainJdbcDemo {
    private static Logger LOGGER = LoggerFactory.getLogger(PlainJdbcDemo.class);

    public static void main(String... args) {
        LOGGER.info("Listing initial singer data:");

        listAllSingers();

        LOGGER.info("-----");
        LOGGER.info("Insert a new singer");
        Singer singer = new Singer();
        singer.setFirstName("Ed");
        singer.setLastName("Sheeran");
        singer.setBirthDate(new Date((new GregorianCalendar(1991, 2, 1991)).getTime().
            getTime()));
        singerDao.insert(singer);
        LOGGER.info("The singer has ID now: {}", singer.getId());
        LOGGER.info("-----");

        LOGGER.info("Listing singer data after new singer created:");
        listAllSingers();
    }
}

```

```

    LOGGER.info("-----");
    LOGGER.info("Deleting the previous created singer");
    singerDao.delete(singer.getId());
    LOGGER.info("Listing singer data after new singer deleted:");

    listAllSingers();
}

private static void listAllSingers() {
    var singers = singerDao.findAll();

    for (Singer singer: singers) {
        LOGGER.info(singer.toString());
    }
}
}

```

The logger is used a lot in the example to print the contents of the database after each method is called. Running this program yields the result shown in Listing 6-8 (assuming you have a locally installed MariaDB database called `musicdb` that has a username and password set to `prospring6` and the sample data was loaded).

#### Listing 6-8. PlainJdbcDemo Output

```

INFO : PlainJdbcDemo - Listing initial singer data:
INFO : PlainJdbcDemo - Singer[id=1,firstName=John,lastName=Mayer,birthDate=1977-10-16]
INFO : PlainJdbcDemo - Singer[id=2,firstName=Ben,lastName=Barnes,birthDate=1981-08-20]
INFO : PlainJdbcDemo - Singer[id=3,firstName=John,lastName=Butler,birthDate=1975-04-01]
INFO : PlainJdbcDemo - -----
INFO : PlainJdbcDemo - Insert a new singer
INFO : PlainJdbcDemo - The singer has ID now: 19
INFO : PlainJdbcDemo - -----
INFO : PlainJdbcDemo - Listing singer data after new singer created:
INFO : PlainJdbcDemo - Singer[id=1,firstName=John,lastName=Mayer,birthDate=1977-10-16]
INFO : PlainJdbcDemo - Singer[id=2,firstName=Ben,lastName=Barnes,birthDate=1981-08-20]
INFO : PlainJdbcDemo - Singer[id=3,firstName=John,lastName=Butler,birthDate=1975-04-01]
INFO : PlainJdbcDemo - Singer[id=19,firstName=Ed,lastName=Sheeran,birthDate=1996-08-11]
INFO : PlainJdbcDemo - -----
INFO : PlainJdbcDemo - Deleting the previous created singer
INFO : PlainJdbcDemo - Listing singer data after new singer deleted:
INFO : PlainJdbcDemo - Singer[id=1,firstName=John,lastName=Mayer,birthDate=1977-10-16]
INFO : PlainJdbcDemo - Singer[id=2,firstName=Ben,lastName=Barnes,birthDate=1981-08-20]
INFO : PlainJdbcDemo - Singer[id=3,firstName=John,lastName=Butler,birthDate=1975-04-01]

```

As shown in the output, the first block of lines shows the initial data. The second block of lines shows that the new record was added. The final block of lines shows that the newly created singer *Ed Sheeran* was deleted.

As you can see in the previous code samples, a lot of code needs to be moved to a helper class or, even worse, duplicated in each DAO class. This is the main disadvantage of JDBC from the application programmer's point of view; you just do not have time to write repetitive code in every DAO class. Instead, you want to concentrate on writing code that actually does what you need the DAO class to do: select, update, and delete the data. The more helper code you need to write, the more checked exceptions you need

to handle, and the more bugs you may introduce in your code. This is where a DAO framework and Spring come in. A framework eliminates the code that does not actually perform any custom logic and allows you to forget about all the housekeeping that needs to be performed. In addition, Spring's extensive JDBC support makes your life a lot easier.



The plain JDBC code shown in this section can also be written using Java records instead of POJOs. The project for this book contains code for this, but it won't be discussed in detail in the book since the focus of this book is Spring.

## Spring JDBC Infrastructure

The code we discussed in the first part of the chapter is not very complex, but it is tedious, and because there is so much of it to write, the likelihood of coding errors is quite high. It is time to take a look at how Spring makes things easier and more elegant.

### Overview and Used Packages

JDBC support in Spring is divided into the five packages detailed in Table 6-1; each handles different aspects of JDBC access.

**Table 6-1.** *Spring JDBC Packages*

Package	Description
org.springframework.jdbc.core	This package contains the foundations of JDBC classes in Spring. It includes the core JDBC class, <code>JdbcTemplate</code> , which simplifies programming database operations with JDBC. Several subpackages provide support of JDBC data access with more specific purposes (e.g., a <code>JdbcTemplate</code> class that supports named parameters) and related support classes as well.
org.springframework.jdbc.datasource	This package contains helper classes and <code>DataSource</code> implementations that you can use to run JDBC code outside a JEE container. Several subpackages provide support for embedded databases, database initialization, and various data source lookup mechanisms.
org.springframework.jdbc.object	This package contains classes that help convert the data returned from the database into objects or lists of objects. These objects and lists are plain Java objects and therefore are disconnected from the database.
org.springframework.jdbc.support	The most important class in this package is <code>SQLException</code> translation support. This allows Spring to recognize error codes used by the database and map them to higher-level exceptions.
org.springframework.jdbc.config	This package contains classes that support JDBC configuration within Spring's <code>ApplicationContext</code> . For example, it contains classes used to work with embedded databases.

Let's start the discussion of Spring JDBC support by looking at the lowest-level functionality. The first thing that you need to do before running SQL queries is to establish a connection to the database.

## Database Connections and DataSources

You can use Spring to manage the database connection for you by providing a bean that implements `javax.sql.DataSource`. The difference between a `DataSource` and a `Connection` is that a `DataSource` provides and manages connections.

`DriverManagerDataSource`, in package `org.springframework.jdbc.datasource`, is the simplest implementation of a `DataSource`. By looking at the class name, you can guess that it simply calls `DriverManager` to obtain a connection. The fact that `DriverManagerDataSource` doesn't support database connection pooling makes this class unsuitable for anything other than testing. The configuration of `DriverManagerDataSource` is quite simple, as you can see in Listing 6-9; you just need to supply the driver class name, a connection URL, a username, and a password.

### Listing 6-9. Contents of `jdbc.properties`

```
driverClassName=org.mariadb.jdbc.Driver
url=jdbc:mariadb://localhost:3306/musicdb?useSSL=false
username=prospring6
password=prospring6
```

You most likely recognize the properties in the listing. They represent the values you normally pass to JDBC to obtain a `Connection` interface. The database connection information typically is stored in a properties file for easy maintenance and substitution in different deployment environments. The properties in `jdbc.properties` are injected by Spring into the properties in a Java configuration class. Such a configuration class would look pretty much like the one shown in Listing 6-10.

### Listing 6-10. Database Configuration Class

```
package com.apress.prospring6.six.config;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.PropertySource;
import org.springframework.jdbc.datasource.SimpleDriverDataSource;

import javax.sql.DataSource;
import java.sql.Driver;

@Configuration
@PropertySource("classpath:db/jdbc.properties")
public class SimpleDataSourceCfg {
    private static Logger LOGGER = LoggerFactory.getLogger(SimpleDataSourceCfg.class);
    @Value("${jdbc.driverClassName}")
    private String driverClassName;

    @Value("${jdbc.url}")
```

```

private String url;

@Value("${jdbc.username}")
private String username;

@Value("${jdbc.password}")
private String password;

public DataSource dataSource() {
    try {
        var dataSource = new SimpleDriverDataSource();
        Class<? extends Driver> driver = (Class<? extends Driver>) Class.
            forName(driverClassName);
        dataSource.setDriverClass(driver);
        dataSource.setUrl(url);
        dataSource.setUsername(username);
        dataSource.setPassword(password);
        return dataSource;
    } catch (Exception e) {
        LOGGER.error("DBCP DataSource bean cannot be created!", e);
        return null;
    }
}

```

Testing a configuration class like this is easy; just create an application context based on it and inspect the beans in it. Listing 6-11 shows a test class containing a method that checks the existence of the DataSource bean and uses it to execute a simple SQL check statement.

**Listing 6-11.** Test Class Checking the Validity of the SimpleDataSourceCfg Class

```

package com.apress.prospring6.six.plain;
// import statements omitted

public class DataSourceConfigTest {
    private static Logger LOGGER = LoggerFactory.getLogger(DataSourceConfigTest.class);

    @Test
    public void testSimpleDataSource() throws SQLException {
        var ctx = new AnnotationConfigApplicationContext(SimpleDataSourceCfg.class);
        var dataSource = ctx.getBean("dataSource", DataSource.class);
        assertNotNull(dataSource);
        testDataSource(dataSource);
        ctx.close();
    }

    private void testDataSource(DataSource dataSource) throws SQLException{
        try (var connection = dataSource.getConnection();
            var statement = connection.prepareStatement("SELECT 1");
            var resultSet = statement.executeQuery()){
            while (resultSet.next()) {
                int mockVal = resultSet.getInt("1");
            }
        }
    }
}

```

```

        assertEquals(1, mockVal);
    }
} catch (Exception e) {
    LOGGER.debug("Something unexpected happened.", e);
}
}
}
}

```

A test class was used because it is more practical to reuse some of the code and also teach you to work with JUnit to quickly write tests for any piece of code you write. The `testOne()` method is used to test the `SimpleDataSourceCfg` configuration class. After obtaining the `dataSource` bean from any configuration, the mock query `SELECT 1` is used to test the connection to the MariaDB database.

In real-world applications, you can use the Apache Commons `BasicDataSource`<sup>6</sup> class or a `DataSource` implemented by a JEE application server (for example, JBoss, WildFly, WebSphere, WebLogic, or GlassFish), which may further increase the performance of the application. You could use a `DataSource` in the plain JDBC code and get the same pooling benefits; however, in most cases, you would still need a central place to configure the `DataSource`. Spring, on the other hand, allows you to declare a `dataSource` bean and set the connection properties in the `ApplicationContext` definition files. See the configuration sample in Listing 6-12, which instead of `SimpleDriverDataSource` uses an `org.apache.commons.dbcp2.BasicDataSource` implementation.

**Listing 6-12.** `BasicDataSourceCfg` Class

```

package com.apress.prospring6.six.config;

import org.apache.commons.dbcp2.BasicDataSource;
// other import statements omitted

@Configuration
@PropertySource("classpath:db/jdbc.properties")
public class BasicDataSourceCfg {
    private static Logger LOGGER = LoggerFactory.getLogger(BasicDataSourceCfg.class);

    // code omitted for duplication, same as in 6-10

    @Bean(destroyMethod = "close")
    public DataSource dataSource() {
        try {
            var dataSource = new BasicDataSource();
            dataSource.setDriverClassName(driverClassName);
            dataSource.setUrl(url);
            dataSource.setUsername(username);
            dataSource.setPassword(password);
            return dataSource;
        } catch (Exception e) {
            LOGGER.error("DBCP DataSource bean cannot be created!", e);
            return null;
        }
    }
}
}

```

<sup>6</sup><https://commons.apache.org/proper/commons-dbcp>

This particular Spring-managed `DataSource` is implemented in `org.apache.commons.dbcp2.BasicDataSource`. The most important bit is that the bean type implements `javax.sql.DataSource`, and you can immediately start using it in your data access classes.

Another way to configure a `DataSource` bean is to use JNDI. If the application you are developing is going to run in a JEE container, you can take advantage of the container-managed connection pooling. To use a JNDI-based data source, you need to change the `DataSource` bean declaration, as shown in Listing 6-13.

**Listing 6-13.** `JndiDataSourceCfg` Class

```
package com.apress.prospring6.six.config;

import org.springframework.jndi.JndiTemplate;
// other import statements omitted

@Configuration
public class JndiDataSourceCfg {
    private static Logger LOGGER = LoggerFactory.getLogger(JndiDataSourceCfg.class);

    @Bean
    public DataSource dataSource() {
        try {
            return (DataSource) new JndiTemplate().lookup("java:comp/env/jdbc/musicdb");
        } catch (Exception e) {
            LOGGER.error("JNDI DataSource bean cannot be created!", e);
            return null;
        }
    }
}
```

In this example the `JndiTemplate` class is used to obtain the data source by JNDI lookup. This is a very useful helper class that simplifies JNDI operations. It provides methods to look up and bind objects and allows implementations of the `JndiCallback` interface to perform any operation they like with a JNDI naming context provided.

As you can see, Spring allows you to configure the `DataSource` in almost any way you like, and it hides the actual implementation or location of the data source from the rest of the application's code. In other words, your DAO classes do not know and do not need to know where the `DataSource` points.

The connection management is also delegated to the `DataSource` bean, which in turn performs the management itself or uses the JEE container to do all the work.

## Embedded Database Support

Starting from version 3.0, Spring also offers embedded database support, which automatically starts an embedded database and exposes it as a `DataSource` for the application. The embedded database support is extremely useful for local development or unit testing. Throughout the rest of the chapters covering data access, we use the embedded database to run the sample code, so your machine doesn't require a database to be installed in order to run the samples, but if you want a true developer experience, consider setting up a Docker container.

The configuration class in Listing 6-14 shows the minimal configuration required to set up an embedded H2 database in a Spring application context.

**Listing 6-14.** EmbeddedJdbcConfig Class

```

package com.apress.prospring6.six.config;

import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseBuilder;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseType;
// other import statements omitted

@Configuration
public class EmbeddedJdbcConfig {
    private static Logger LOGGER = LoggerFactory.getLogger(EmbeddedJdbcConfig.class);

    @Bean
    public DataSource dataSource() {
        try {
            var dbBuilder = new EmbeddedDatabaseBuilder();
            return dbBuilder.setType(EmbeddedDatabaseType.H2)
                .addScripts("classpath:h2/schema.sql",
                    "classpath:h2/test-data.sql").build();
        } catch (Exception e) {
            LOGGER.error("Embedded DataSource bean cannot be created!", e);
            return null;
        }
    }
}

```

The `EmbeddedDatabaseBuilder` class uses the database creation and loading data scripts as arguments to create an instance of `EmbeddedDatabase` that implements `DataSource`.



Note that the order of the scripts is important, and the file that contains Data Definition Language (DDL) should always appear first, followed by the file with Data Manipulation Language (DML). For the `type` attribute, we specify the type of embedded database to use. As of version 4.0, Spring supports HSQL (the default), H2, and DERBY.

---

## Using DataSources in DAO Classes

The Data Access Object (DAO) pattern is used to separate low-level data accessing APIs or operations from high-level business services. The Data Access Object pattern requires the following components:

- *DAO interface*: This defines the standard operations to be performed on a model object (or objects).
- *DAO implementation*: This class provides a concrete implementation for the DAO interface. Typically, this uses a JDBC connection or data source to handle model object (or objects).
- *Model objects* (also called **data objects** or **entities**): This is a simple POJO mapping to a table record.



Let's create a `SingerDao` interface to implement for the sample, as shown in Listing 6-15.

**Listing 6-15.** `SingerDao` Interface

```
public interface SingerDao {
    String findNameById(Long id);
}
```

For the simple implementing class named `JdbcSingerDao`, first we will add a `dataSource` property. The reason we want to add the `dataSource` property to the implementation class rather than the interface should be quite obvious: the interface does not need to know how the data is going to be retrieved and updated. By adding `DataSource` mutator methods to the interface, in the best-case scenario this forces the implementations to declare the getter and setter stubs. Clearly, this is not a very good design practice. Take a look at the simple `JdbcSingerDao` class shown in Listing 6-16.

**Listing 6-16.** `JdbcSingerDao` Class

```
package com.apress.prospring6.six.plain;
class JdbcSingerDao implements SingerDao, InitializingBean {
    private static Logger LOGGER = LoggerFactory.getLogger(JdbcSingerDao.class);
    private DataSource dataSource;

    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
    }

    @Override
    public void afterPropertiesSet() throws Exception {
        if (dataSource == null) {
            throw new BeanCreationException("Must set dataSource on SingerDao");
        }
    }

    @Override
    public String findNameById(Long id) {
        var result = "";
        try (var connection = dataSource.getConnection());
            var statement = connection.prepareStatement("select first_name, last_name from
                SINGER where id=" + id);
            var resultSet = statement.executeQuery() {
                while (resultSet.next()) {
                    return resultSet.getString("first_name") + " " + resultSet.
                        getString("last_name");
                }
            }
        } catch (SQLException ex) {
            LOGGER.error("Problem when executing SELECT!",ex);
        }
        return result;
    }
}
```

We can now instruct Spring to configure our `singerDao` bean by using the `JdbcSingerDao` implementation and set the `dataSource` property as shown in the `SpringDataSourceCfg` configuration class, shown in Listing 6-17. (Notice that we import the `BasicDataSourceCfg` class introduced in the previous section, to avoid duplicating code.)

**Listing 6-17.** `SpringDataSourceCfg` Configuration Class

```
package com.apress.prospring6.six.plain;

import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.Import;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.context.annotation.Bean;
// other import statements omitted

import java.sql.SQLException;

@Import(BasicDataSourceCfg.class)
@Configuration
public class SpringDataSourceCfg {

    private static Logger LOGGER = LoggerFactory.getLogger(SpringDataSourceCfg.class);

    @Autowired
    DataSource dataSource;

    @Bean
    public SingerDao singerDao(){
        JdbcSingerDao dao = new JdbcSingerDao();
        dao.setDataSource(dataSource);
        return dao;
    }
}
```

Spring now creates the `singerDao` bean by instantiating the `JdbcSingerDao` class with the `dataSource` property set to the `dataSource` bean. It is good practice to make sure that all required properties on a bean have been set. The easiest way to do this is to implement the `InitializingBean` interface and provide an implementation for the `afterPropertiesSet()` method. This way, we make sure that all required properties have been set on our `JdbcSingerDao`. For further discussion of bean initialization, refer to **Chapter 4**.

The code we have looked at so far uses Spring to manage the data source and introduces the `SingerDao` interface and its JDBC implementation. We also set the `dataSource` property on the `JdbcSingerDao` class in the Spring Application Context file.

The `SpringDataSourceCfg` can be tested in the same way as `BasicDataSourceCfg`, but the test can also check the behavior of the `findNameById(..)` method. The test method is shown in Listing 6-18.

**Listing 6-18.** Testing the `SpringDataSourceCfg` Configuration Class

```
package com.apress.prospring6.six;

import static org.junit.jupiter.api.Assertions.assertEquals;
import static org.junit.jupiter.api.Assertions.assertNotNull;
// other import statements omitted
```

```

public class DataSourceConfigTest {
    private static Logger LOGGER = LoggerFactory.getLogger(DataSourceConfigTest.class);

    @Test
    public void testSpringJdbc() throws SQLException {
        var ctx = new AnnotationConfigApplicationContext(SpringDataSourceCfg.class);
        var dataSource = ctx.getBean("dataSource", DataSource.class);
        assertNotNull(dataSource);
        testDataSource(dataSource);
        var singerDao = ctx.getBean("singerDao", SingerDao.class);
        assertEquals("John Mayer", singerDao.findNameById(1L));
        ctx.close();
    }

    // other code omitted for duplication
}

```

## Exception Handling

Spring advocates using runtime exceptions rather than checked exceptions, so we need a mechanism to translate the checked `SQLException` into a runtime Spring JDBC exception. Because Spring's SQL exceptions are runtime exceptions, they can be much more granular than checked exceptions. By definition, this is not a feature of runtime exceptions, but it is inconvenient to have to declare a long list of checked exceptions in the `throws` clause; hence, checked exceptions tend to be much more coarse-grained than their runtime equivalents.

Spring provides a default implementation of the `SQLExceptionTranslator` interface, which takes care of translating the generic SQL error codes into Spring JDBC exceptions. In most cases, this implementation is sufficient, but you can extend Spring's default implementation and set your new `SQLExceptionTranslator` implementation to be used in `JdbcTemplate`, as shown in Listing 6-19.

*Listing 6-19.* `SQLExceptionTranslator` Custom Implementation

```

package com.apress.prospring6.six;

import org.springframework.dao.DataAccessException;
import org.springframework.dao.DeadlockLoserDataAccessException;
import org.springframework.jdbc.support.SQLExceptionCodeSQLExceptionTranslator;

import java.sql.SQLException;

public class MariaDBErrorCodesTranslator extends SQLExceptionCodeSQLExceptionTranslator {

    @Override
    protected DataAccessException customTranslate(String task, String sql, SQLException
    sqlEx) {
        if (sqlEx.getErrorCode() == -12345) {
            return new DeadlockLoserDataAccessException(task, sqlEx);
        }
        return null;
    }
}

```



At this point, it becomes clear that `SQLExceptionTranslator`, a practical Spring-provided implementation of `SQLExceptionTranslator`, is part of the `spring-jdbc.jar` library, so this library needs to be added to the classpath. Yes, this is the section where we leave behind plain JDBC and add Spring into the mix to make our development experience less of a headache when communicating with a database.

The `org.springframework.dao.DataAccessException` represents the Spring root of the hierarchy of runtime data access exceptions. Extensions of this class match specific data access exceptions and provide more information about the real cause of an exception when accessing a database. The full hierarchy is discussed later in the book.

To use the `MariaDBErrorCodesTranslator` we have to give up using the connection to communicate with the database directly and instead wrap the `DataSource` in Spring's `JdbcTemplate` as shown in Listing 6-20.

**Listing 6-20.** Introducing Spring's `JdbcTemplate`

```
package com.apress.prospring6.six.hybrid;

import org.springframework.jdbc.core.JdbcTemplate;
// other import statements omitted

class JdbcSingerDao implements SingerDao, InitializingBean {

    private static Logger LOGGER = LoggerFactory.getLogger(JdbcSingerDao.class);
    private DataSource dataSource;
    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
        var jdbcTemplate = new JdbcTemplate();
        jdbcTemplate.setDataSource(dataSource);

        var errorTranslator = new MariaDBErrorCodesTranslator();
        errorTranslator.setDataSource(dataSource);

        jdbcTemplate.setExceptionTranslator(errorTranslator);
        this.jdbcTemplate = jdbcTemplate;
    }
    // other code omitted
}
```

Having the custom SQL exception translator in place, Spring will invoke it upon SQL exceptions detected when executing SQL statements against the database, and custom exception translation will happen when the error code is -12345. For other errors, Spring will fall back to its default mechanism for exception translation. Obviously, nothing can stop you from creating `SQLExceptionTranslator` as a Spring-managed bean and using the `JdbcTemplate` bean in your DAO classes. Don't worry if you don't remember reading about the `JdbcTemplate` class; we are going to discuss it in more detail right now.

## The JdbcTemplate Class

This class represents the core of Spring’s JDBC support. It can execute all types of SQL statements. In the most simplistic view, you can classify the data definition and data manipulation statements. Data definition statements cover creating various database objects (tables, views, stored procedures, and so on). Data manipulation statements manipulate the data and can be classified as select and update statements. A select statement generally returns a set of rows; each row has the same set of columns. An update statement modifies the data in the database but does not return any results.

The JdbcTemplate class allows you to issue any type of SQL statement to the database and return any type of result. In this section, we will go through several common use cases for JDBC programming in Spring with the JdbcTemplate class.

## Initializing JdbcTemplate in a DAO Class

Before discussing how to use JdbcTemplate, let’s take a look at how to prepare JdbcTemplate for use in the DAO class. It’s straightforward; most of the time you just need to construct the class by passing in the data source object (which should be injected by Spring into the DAO class). The last code snippet in the previous section in Listing 6-20 shows how to initialize the JdbcTemplate object. The general practice is to initialize JdbcTemplate within the same method/constructor where the data source object is injected by Spring. This ensures that JdbcTemplate will also be initialized and ready for use.

Once configured, JdbcTemplate is thread-safe. That means you can also choose to initialize a single instance of JdbcTemplate in Spring’s configuration and have it injected into all DAO beans. A configuration like this is depicted in Listing 6-21.

**Listing 6-21.** JdbcTemplate Configured As a Bean

```

package com.apress.prospring6.six.template;

import org.springframework.jdbc.core.JdbcTemplate;
// other import statements omitted

@Import(BasicDataSourceCfg.class)
@Configuration
class SpringJdbcTemplateCfg {

    private static Logger LOGGER = LoggerFactory.getLogger(SpringJdbcTemplateCfg.class);

    @Autowired
    DataSource dataSource;

    @Bean
    public SingerDao singerDao(){
        JdbcSingerDao dao = new JdbcSingerDao();
        dao.setDataSource(dataSource);
        return dao;
    }

    @Bean public JdbcTemplate jdbcTemplate(){
        JdbcTemplate jdbcTemplate = new JdbcTemplate();
        jdbcTemplate.setDataSource(dataSource);
    }
}

```

```

        return jdbcTemplate;
    }
}

```

Now that we have a `JdbcTemplate` bean, let's rewrite `JdbcSingerDao` to make use of it. Listing 6-22 makes it quite obvious that it is way easier to use the `JdbcTemplate` bean to communicate with the database, especially for retrieving a single value.

**Listing 6-22.** Using the `JdbcTemplate` Bean

```

package com.apress.prospring6.six.template;

class JdbcSingerDao implements SingerDao {
    private JdbcTemplate jdbcTemplate;

    public void setJdbcTemplate(JdbcTemplate jdbcTemplate) {
        this.jdbcTemplate = jdbcTemplate;
    }

    @Override
    public String findNameById(Long id) {
        return jdbcTemplate
            .queryForObject("select CONCAT(first_name , ' ' , last_name) from SINGER
                where id = ?", String.class, id);
    }
}

```

In Listing 6-22, we use the `queryForObject(..)` method of `JdbcTemplate` to retrieve the value of the first name in a record identified by its `id`. The first argument is the SQL string, and the last consists of the parameters to be passed to the SQL for parameter binding in `varargs` format. The second argument is the type to be returned, which is `String` in this case. Besides `String`, you can also query for other types such as `Long` and `Integer`. Let's take a look at the outcome. Listing 6-23 shows the testing program. A JUnit test class is used because this allows us to run test methods separately.

**Listing 6-23.** Testing `JdbcSingerDao` That Uses the `JdbcTemplate` Bean

```

package com.apress.prospring6.six.template;

import com.apress.prospring6.six.config.EmbeddedJdbcConfig;
// other import statements omitted

public class JdbcTemplateConfigTest {

    @Test
    public void testSpringJdbcWithH2Db() {
        var ctx = new AnnotationConfigApplicationContext(TestDbCfg.class);
        var jdbcTemplate = ctx.getBean("jdbcTemplate", JdbcTemplate.class);
        assertNotNull(jdbcTemplate);

        var singerDao = ctx.getBean("singerDao", SingerDao.class);
    }
}

```

```

        assertEquals("John Mayer", singerDao.findNameById(1L));
        ctx.close();
    }

    @Import(EmbeddedJdbcConfig.class)
    @Configuration
    public static class TestDbCfg {

        @Autowired
        DataSource dataSource;

        @Bean
        public JdbcTemplate jdbcTemplate(){
            JdbcTemplate jdbcTemplate = new JdbcTemplate();
            jdbcTemplate.setDataSource(dataSource);
            return jdbcTemplate;
        }

        @Bean
        public SingerDao singerDao(){
            var dao = new JdbcSingerDao();
            dao.setJdbcTemplate(jdbcTemplate());
            return dao;
        }
    }
}

```

When executing the test method `testSpringJdbcWithH2Db()`, we expect the *John Mayer* string to be returned by the `singerDao.findNameById(1L)` call, and we test this assumption using the `assertTrue` method. The test can be run with the original configuration class, the `SpringJdbcTemplateCfg` class, but this means the data source for this is MariaDB, and the test won't pass unless there is a MariaDB database installed and configured properly on the machine where the test is run. For this reason, the static class `TestDbCfg` was declared within the body of the test class, to inject an embedded database, instead of a real one. This test class is identical to the `SpringJdbcTemplateCfg` class, but instead of importing the `BasicDataSourceCfg` class, which configures an actual database, it imports the `EmbeddedJdbcConfig` class that configures an in-memory H2 database, which is more suitable for a test environment.

Of course, profiles could have been used for this example, but in this chapter, it was hinted at the possibility to declare a static configuration class to be used in a test context, and we wanted to cover this scenario as well.

## Using Named Parameters with `NamedParameterJdbcTemplate`

In previous examples, the SQL query used as an argument for the `jdbcTemplate.queryForObject(..)` method is declared using the normal placeholder (the `?` character) as a query parameter, and the parameter values are passed using varargs:

```
select CONCAT(first_name , ' ' , last_name) from SINGER where id = ?
```

When using a normal placeholder, the order is important, and the order in which you put the parameters into the varargs should be the same as the order of the parameters in the query.

Some developers prefer to use named parameters to ensure that each parameter is being bound exactly as intended. In Spring, an extension of the `JdbcTemplate` class, called `NamedParameterJdbcTemplate` (under the package `org.springframework.jdbc.core.namedparam`), provides support for this.

The initialization of the `NamedParameterJdbcTemplate` bean is the same as for the `JdbcTemplate` bean. This means we just need to declare a bean of type `NamedParameterJdbcTemplate` and inject it in the DAO class. In Listing 6-24, you can see the `NamedTemplateDao` equivalent of `JdbcSingerDao` that uses a `NamedParameterJdbcTemplate`.

**Listing 6-24.** `NamedTemplateDao` That Uses the `NamedParameterJdbcTemplate` Bean

```
package com.apress.prospring6.six.named;

import org.springframework.jdbc.core.namedparam.NamedParameterJdbcTemplate;
// other import statements omitted

class NamedTemplateDao implements SingerDao {

    private NamedParameterJdbcTemplate namedTemplate;

    public void setNamedTemplate(NamedParameterJdbcTemplate namedTemplate) {
        this.namedTemplate = namedTemplate;
    }

    @Override
    public String findNameById(Long id) {
        return namedTemplate.queryForObject( "select CONCAT(first_name , ' ' , last_name)
            from SINGER where id = :singerId"
            , Map.of("singerId", id), String.class);
    }
}
```

Instead of the `?` placeholder, the named parameter (prefixed by a semicolon) is used: `:singerId`. Testing `NamedTemplateDao` is identical to testing `JdbcSingerDao`, so the code for this is omitted from the book, but it is part of the project.

## Retrieving Domain Objects with `RowMapper<T>`

Examples using `JdbcTemplate` and related classes presented so far have been quite simple: a single value was returned by the query of a simple type, such as `String`. When the query returns multiple rows that need to be converted in POJOs (like we did in the plain JDBC section), things get a little more complicated. However, Spring is here to help with its `RowMapper<T>` interface. As its name indicates, an instance of a type implementing `RowMapper<T>` is suitable only for row mapping to a single domain object. Spring's `RowMapper<T>` interface (in package `org.springframework.jdbc.core`) provides a simple way for you to perform mapping from a JDBC result set to POJOs or records. Let's see it in action by implementing the `findAll()` method of the `SingerDao` using the `RowMapper<T>` interface. In Listing 6-25, you can see the implementation of the `findAll()` method that returns a list of `Singer` records.

**Listing 6-25.** `findAll()` Using `RowMapper<Singer>`

```
package com.apress.prospring6.six.plain.records;

import java.time.LocalDate;
```



```

import java.util.Set;

// in file Singer.java
public record Singer(Long id,
                    String firstName,
                    String lastName,
                    LocalDate birthDate,
                    Set<Album> albums) {}

// in file RowMapperCfg.java
package com.apress.prospring6.six.rowmapper;

import org.springframework.jdbc.core.RowMapper;
// other imports statements omitted
interface SingerDao {
    Set<Singer> findAll();
}

class RowMapperDao implements SingerDao {

    private NamedParameterJdbcTemplate namedTemplate;

    public void setNamedTemplate(NamedParameterJdbcTemplate namedTemplate) {
        this.namedTemplate = namedTemplate;
    }

    @Override
    public Set<Singer> findAll() {
        return new HashSet<>(namedTemplate.query("select * from SINGER", new
        SingerMapper()));
    }

    static class SingerMapper implements RowMapper<Singer> {

        @Override
        public Singer mapRow(ResultSet rs, int rowNum)
            throws SQLException {
            return new Singer(rs.getLong("id"),
                rs.getString("first_name"),
                rs.getString("last_name"),
                rs.getDate("birth_date").toLocalDate(),
                Set.of());
        }
    }
}

```

In Listing 6-25 we define a static inner class named `SingerMapper` that implements the `RowMapper<Singer>` interface. The class needs to provide the `mapRow()` implementation, which transforms the values in a specific record of the `ResultSet` into the domain object you want. In this case records were used, because they exist, and they are suitable for this example. Making it a static inner class allows you to

share the `RowMapper<Singer>` among multiple finder methods in the same DAO class. If sharing the class is not necessary, `SingerMapper` explicit implementation can be skipped altogether using Java 8 lambda expressions; thus, the `findAll()` method can be refactored as shown in Listing 6-26.

**Listing 6-26.** Using Lambdas to Avoid an Explicit Implementation of `RowMapper<Singer>`

```

package com.apress.prospring6.six.rowmapper;
// other import statements omitted
class RowMapperDao implements SingerDao {

    @Override
    public Set<Singer> findAll() {
        return new HashSet<>(namedTemplate.query("select * from SINGER", (rs, rowNum) -> {
            return new Singer(rs.getLong("id"),
                rs.getString("first_name"),
                rs.getString("last_name"),
                rs.getDate("birth_date").toLocalDate(),
                Set.of());
        }));
    }
    // other code omitted
}

```

Testing the `findAll()` method is done in the same way everything has been tested so far. The configuration class that configures a MariaDB data source is named `RowMapperCfg` and is almost identical to previous classes using `JdbcTemplate` (or related implementations), so it won't be depicted here, but testing is always useful, so Listing 6-27 shows the test method and static test class for testing the `findAll()` method using an in-memory H2 database.

**Listing 6-27.** Method Testing `findAll()` and Output

```

package com.apress.prospring6.six.rowmapper;

import org.junit.jupiter.api.Test;
import static org.junit.jupiter.api.Assertions.assertEquals;
// other import statements omitted

public class JdbcNamedTemplateConfigTest {

    private static Logger LOGGER = LoggerFactory.getLogger(JdbcNamedTemplateConfigTest.class);

    @Test
    public void testSpringJdbc() {
        var ctx = new AnnotationConfigApplicationContext(TestDbCfg.class);

        var singerDao = ctx.getBean("singerDao", SingerDao.class);

        var singers = singerDao.findAll();
        assertEquals(3, singers.size());
        singers.forEach(singer -> LOGGER.info(singer.toString()));
    }
}

```

```

        ctx.close();
    }

    @Import(EmbeddedJdbcConfig.class)
    @Configuration
    public static class TestDbCfg {

        // other config omitted
        @Bean
        public SingerDao singerDao(){
            var dao = new RowMapperDao();
            dao.setNamedTemplate(namedTemplate());
            return dao;
        }
    }
}

# test method result
INFO : JdbcNamedTemplateConfigTest - Singer[id=1, firstName=John, lastName=Mayer,
birthdate=1977-10-16, albums=[]]
INFO : JdbcNamedTemplateConfigTest - Singer[id=2, firstName=Ben, lastName=Barnes,
birthdate=1981-08-20, albums=[]]
INFO : JdbcNamedTemplateConfigTest - Singer[id=3, firstName=John, lastName=Butler,
birthdate=1975-04-01, albums=[]]

```

The albums are not printed because the `RowMapper<Singer>` implementation does not actually set them on the returned `Singer` records. This is because they are not actually loaded from the database; for this we need a more complex query and something more powerful than `RowMapper<Singer>`.

## Retrieving Nested Domain Objects with `ResultSetExtractor`

Let's proceed to a somewhat more complicated example, in which we need to retrieve the data from the parent (`SINGER`) and child (`ALBUM`) tables with a join and then transform the data back into the nested object (`Set<Album>` within `Singer`) accordingly.

For a more complicated scenario, we need to use the `ResultSetExtractor<T>` interface. To demonstrate its use, let's implement `findAllWithAlbums()` into the `SingerDao` interface. The method should populate the list of singers with their albums. Listing 6-28 shows the addition of the `findAllWithAlbums()` method to the interface and the implementation of the method using `ResultSetExtractor<T>`.

**Listing 6-28.** `findAllWithAlbums()` Using `ResultSetExtractor<List<Singer>>`

```

package com.apress.prospring6.six.rowmapper;

import org.springframework.jdbc.core.ResultSetExtractor;
// other import statements omitted

interface SingerDao {
    Set<Singer> findAllWithAlbums();
}

class RowMapperDao implements SingerDao {

```

```

private NamedParameterJdbcTemplate namedTemplate;

public void setNamedTemplate(NamedParameterJdbcTemplate namedTemplate) {
    this.namedTemplate = namedTemplate;
}

@Override
public Set<Singer> findAllWithAlbums() {
    var sqlQuery = "select s.id, s.first_name, s.last_name, s.birth_date, "+
        "a.id AS album_id, a.title, a.release_date " +
        "from SINGER s " +
        "left join ALBUM a on s.id = a.singer_id";
    return new HashSet<>(namedTemplate.query(sqlQuery, new
        SingerWithAlbumsExtractor()));
}

static class SingerWithAlbumsExtractor implements ResultSetExtractor<Set<Singer>> {
    @Override
    public Set<Singer> extractData(ResultSet rs) throws SQLException,
        DataAccessException {
        Map<Long, Singer> map = new HashMap<>();
        Singer singer;
        while (rs.next()) {
            Long id = rs.getLong("id");
            singer = map.get(id);
            if (singer == null) {
                singer = new Singer(id,rs.getString("first_name"),rs.getString("last_
                    name"),rs.getDate("birth_date"),new HashSet<>());
                map.put(id, singer);
            }

            var albumId = rs.getLong("album_id");
            if (albumId > 0) {
                Album album = new Album(albumId,id,rs.getString("title"),rs.
                    getDate("release_date"));
                singer.albums().add(album);
            }
        }
        return new HashSet<>(map.values());
    }
}
}
}

```

The code looks quite like the `RowMapper<T>` sample, but this time we declare an inner class that implements `ResultSetExtractor<T>`. Then we implement the `extractData(..)` method to transform the result set into a list of `Singer` records accordingly. For the `findAllWithDetail()` method, the query uses a `left join` to join the two tables so that singers with no albums will also be retrieved. The result is a cartesian product of the two tables. Finally, we use the `namedTemplate.query()` method, passing in the query string and the result set extractor.

Of course, the `SingerWithDetailExtractor` inner class is not actually necessary because lambda expressions are an option. In Listing 6-29 you can see the `findAllWithAlbums()` version that makes use of Java 8 lambda expressions.

**Listing 6-29.** findAllWithAlbums() Using Lambda Expressions

```

package com.apress.prospring6.six.rowmapper;
// other import statements omitted

class RowMapperDao implements SingerDao {

    public static final String ALL_JOIN_SELECT = "select s.id, s.first_name, s.last_name,
s.birth_date, "+
        "a.id AS album_id, a.title, a.release_date " +
        "from SINGER s " +
        "left join ALBUM a on s.id = a.singer_id";
    public List<Singer> findAllWithAlbums() {
        return namedTemplate.query(ALL_JOIN_SELECT, rs -> {
            Map<Long, Singer> map = new HashMap<>();
            Singer singer;
            while (rs.next()) {
                Long id = rs.getLong("id");
                singer = map.get(id);
                if (singer == null) {
                    singer = new Singer(id,rs.getString("first_name"),rs.getString(
                        "last_name"),rs.getDate("birth_date"),new ArrayList<>());
                    map.put(id, singer);
                }

                var albumId = rs.getLong("album_id");
                if (albumId > 0) {
                    Album album = new Album(albumId,id,rs.getString("title"),rs.
                        getDate("release_date"));
                    singer.albums().add(album);
                }
            }
            return new ArrayList<>(map.values());
        });
    }
// other code omitted
}

```

Testing the `findAllWithAlbums()` method requires writing a method like the one depicted in Listing 6-27, the only thing being different this time is that the albums are part of the output, as shown in Listing 6-30.

**Listing 6-30.** Method Testing `findAllWithAlbums()` Output

```

INFO : JdbcNamedTemplateConfigTest - Singer[id=1, firstName=John, lastName=Mayer,
birthDate=1977-10-16,
    albums=[Album[id=1, singerId=1, title=The Search For Everything, date=2017-01-20],
Album[id=2, singerId=1, title=Battle Studies, date=2009-11-17]]]
INFO : JdbcNamedTemplateConfigTest - Singer[id=2, firstName=Ben, lastName=Barnes,
birthDate=1981-08-20,
    albums=[Album[id=3, singerId=2, title= 11:11 , date=2021-09-18]]]
INFO : JdbcNamedTemplateConfigTest - Singer[id=3, firstName=John, lastName=Butler,
birthDate=1975-04-01, albums=[]]

```

You can see the singers and their album details are listed accordingly. The data is based on the data population script that you can find in `resources/h2/test-data.sql` for each of the JDBC sample projects. So far, you have seen how to use `JdbcTemplate` to perform some common query operations. `JdbcTemplate` (and the `NamedParameterJdbcTemplate` class too) provides a number of overloading `update()` methods that support data update operations, including insert, update, delete, and so on. However, the `update()` method is quite self-explanatory, so we leave it as an exercise for you to explore. On the other side, as you will see in later sections, we will use the Spring-provided `SqlUpdate` class to perform data update operations.

## Spring Classes That Model JDBC Operations

In the preceding section, you saw how `JdbcTemplate` and the related data mapper utility classes greatly simplify the programming model in developing data access logic with JDBC. Built on top of `JdbcTemplate`, Spring also provides a number of useful classes that model JDBC data operations and let developers maintain the query and transformation logic from `ResultSet` to domain objects in a more object-oriented fashion. Specifically, this section presents the following:

- `MappingSqlQuery<T>`: The `MappingSqlQuery<T>` abstract class allows you to wrap the query `String` together with the `mapRow()` method into a single class.
- `SqlUpdate`: The `SqlUpdate` class allows you to wrap any SQL update statement into it. It also provides a lot of useful functions for you to bind SQL parameters, retrieve the RDBMS-generated key after a new record is inserted, and so on.
- `BatchSqlUpdate`: As its name indicates, this class allows you to perform batch update operations. For example, you can loop through a Java `List` object and have the `BatchSqlUpdate` queue up the records and submit the update statements for you in a batch. You can set the batch size and flush the operation at any time.
- `SqlFunction<T>`: The `SqlFunction<T>` class allows you to call stored functions in the database with argument and return types. Another class, `StoredProcedure`, also helps you to invoke stored procedures.
- Setting up JDBC DAO by using annotations

First let's take a look at how to set up the DAO implementation class by using annotations. Listing 6-31 shows the `SingerRepo` interface class with a complete listing of the data access services it provides.

**Listing 6-31.** `SingerRepo` Complete DAO Interface

```
package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.plain.records.Singer;

import java.util.List;

public interface SingerRepo {
    Set<Singer> findAll();
    List<Singer> findByFirstName(String firstName);
    String findNameById(Long id);
    String findLastNameById(Long id);
    String findFirstNameById(Long id);
    List<Singer> findAllWithAlbums();

    void insert(Singer singer);
}
```

```

    void update(Singer singer);
    void delete(Long singerId);
    void insertWithAlbum(Singer singer);
}

```

**Chapter 3** introduced stereotype annotations, including `@Repository`, a specialization of the `@Component` annotation, that is designed to be used for beans handling database operations<sup>7</sup>. Listing 6-32 shows the initial declaration and injection of the data source property into a `@Repository` annotated DAO class using the JSR-250 annotation.

**Listing 6-32.** `SingerJdbcRepo` Class Implementing `SingerRepo`

```

package com.apress.prospring6.six.repo;

import jakarta.annotation.Resource;
import org.springframework.stereotype.Repository;
// other import statements omitted

@Repository("singerRepo")
public class SingerJdbcRepo implements SingerRepo {

    private static Logger LOGGER = LoggerFactory.getLogger(SingerJdbcRepo.class);

    private DataSource dataSource;

    @Autowired
    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
    }
    public DataSource getDataSource() {
        return dataSource;
    }
    ...
}

```

In Listing 6-32, we use `@Repository` to declare the Spring bean with a name of `singerRepo`, and since the class contains data access code, `@Repository` also instructs Spring to perform database-specific SQL exceptions to the more application-friendly `DataAccessException` hierarchy in Spring.

The `BasicDataSourceCfg` configuration class, introduced earlier in the chapter, declaring a MariaDB poolable `BasicDataSource` bean, works with this type of bean as well. You were instructed at the beginning of the chapter how to install and set up a MariaDB database and create the `musicdb` schema. Having the infrastructure in place, we can now proceed to writing the implementation of JDBC operations.

---

<sup>7</sup>This indicates that the annotated class is a repository, originally defined by Eric Evans in *Domain-Driven Design* (Addison-Wesley Professional, 2003) as “a mechanism for encapsulating storage, retrieval, and search behavior which emulates a collection of objects.”

## Querying Data by Using MappingSqlQuery<T>

Spring provides the `MappingSqlQuery<T>` abstract class for modeling query operations. Basically, we construct a `MappingSqlQuery<T>` class by using the data source and the query string. We then implement the `mapRow()` method to map each `ResultSet` record into the corresponding domain object. Let's begin by creating the `SelectAllSingers` class (which represents the query operation for selecting all singers) that extends the `MappingSqlQuery<T>` abstract class. The `SelectAllSingers` class is shown in Listing 6-33.

**Listing 6-33.** `SelectAllSingers` Implementation

```
package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.plain.records.Singer;
import org.springframework.jdbc.object.MappingSqlQuery;
//other import statements omitted

public class SelectAllSingers extends MappingSqlQuery<Singer> {

    public SelectAllSingers(DataSource dataSource) {
        super(dataSource, "select * from SINGER");
    }
    @Override
    protected Singer mapRow(ResultSet rs, int rowNum)
        throws SQLException {
        return new Singer(rs.getLong("id"),
            rs.getString("first_name"),
            rs.getString("last_name"),
            rs.getDate("birth_date"),
            List.of());
    }
}
```

Within the `SelectAllSingers` class, the SQL for selecting all singers is declared. In the class constructor, the `super(..)` method is called to construct the class, using the `DataSource` as well as the SQL statement. Moreover, the `MappingSqlQuery<T>.mapRow()` method is implemented to provide the mapping of the result set to the `Singer` record.

Having the `SelectAllSingers` class in place, we can implement the `findAll()` method in the `SingerJdbcRepo` class. The code snippet in Listing 6-34 depicts a section of the `SingerJdbcRepo` class.

**Listing 6-34.** `SingerJdbcRepo.findAll()` Implementation

```
package com.apress.prospring6.six.repo;

// import statements omitted

@Repository("singerRepo")
public class SingerJdbcRepo implements SingerDao {

    private static Logger LOGGER = LoggerFactory.getLogger(SingerJdbcRepo.class);

    private DataSource dataSource;
    private SelectAllSingers selectAllSingers;
```



```

@Autowired
public void setDataSource(DataSource dataSource) {
    this.dataSource = dataSource;
    this.selectAllSingers = new SelectAllSingers(dataSource);
}

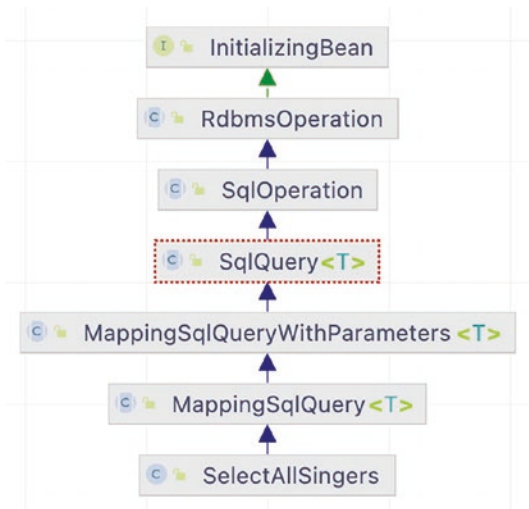
@Override
public List<Singer> findAll() {
    return selectAllSingers.execute();
}

// other code omitted
}

```

In the `setDataSource()` method, upon the injection of the `DataSource`, an instance of the `SelectAllSingers` class is constructed. In the `findAll()` method, we simply invoke the `execute()` method, which is inherited from the `SqlQuery<T>` abstract class indirectly. That’s all we need to do.

Figure 6-3 shows the full `SelectAllSingers` class hierarchy, with the `SqlQuery<T>` class shown in a red dotted rectangle to make its place in the hierarchy obvious.



**Figure 6-3.** *SelectAllSingers* class hierarchy

The `findAll()` method implemented this way can be run on the MariaDB database by creating an executable class that creates a Spring application context using the `BasicDataSourceCfg` class or can be tested against an embedded database in a test context.

Listing 6-35 depicts the `RepoDemo` class and its output.

**Listing 6-35.** *RepoDemo* Class and Its Output

```

package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.config.BasicDataSourceCfg;
// other import statements omitted

```

```

public class RepoDemo {
    private static Logger LOGGER = LoggerFactory.getLogger(RepoDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(BasicDataSourceCfg.class,
            SingerJdbcRepo.class);
        var singerRepo = ctx.getBean("singerRepo", SingerDao.class);

        List<Singer> singers = singerRepo.findAll();
        singers.forEach(singer -> LOGGER.info(singer.toString()));

        ctx.close();
    }
}

```

# output

```

INFO : RepoDemo - Singer[id=1, firstName=John, lastName=Mayer, birthDate=1977-10-16,
albums=[]]
INFO : RepoDemo - Singer[id=2, firstName=Ben, lastName=Barnes, birthDate=1981-08-20,
albums=[]]
INFO : RepoDemo - Singer[id=3, firstName=John, lastName=Butler, birthDate=1975-04-01,
albums=[]]

```

Testing the method requires creating a test context based on the `EmbeddedJdbcConfig` class that we used earlier to declare an embedded in-memory H2 database (see Listing 6-14). The code from the `main(...)` method is almost identical to the code in the test method, but it is depicted in Listing 6-36 to make obvious how easy it is to test Spring JDBC methods.

#### Listing 6-36. SingerJdbcRepo Test Method and Output

```

package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.config.EmbeddedJdbcConfig;
// other import statements omitted

public class RepoBeanTest {
    private static Logger LOGGER = LoggerFactory.getLogger(RepoBeanTest.class);

    @Test
    public void testFindAllWithMappingSqlQuery() {
        var ctx = new AnnotationConfigApplicationContext(EmbeddedJdbcConfig.class,
            SingerJdbcRepo.class);
        var singerRepo = ctx.getBean("singerRepo", SingerDao.class);
        assertNotNull(singerRepo);

        List<Singer> singers = singerRepo.findAll();
        assertEquals(3, singers.size());
        singers.forEach(singer -> LOGGER.info(singer.toString()));

        ctx.close();
    }
}

```

```
# output
DEBUG: RdbmsOperation - SQL operation not compiled before execution - invoking compile
DEBUG: RdbmsOperation - RdbmsOperation with SQL [select * from SINGER] compiled
INFO : RepoBeanTest - Singer[id=1, firstName=John, lastName=Mayer, birthDate=1977-10-16,
albums=[]]
INFO : RepoBeanTest - Singer[id=2, firstName=Ben, lastName=Barnes, birthDate=1981-08-20,
albums=[]]
INFO : RepoBeanTest - Singer[id=3, firstName=John, lastName=Butler, birthDate=1975-04-01,
albums=[]]
```

If DEBUG logging is enabled for the `org.springframework.jdbc` package, you can also see the query that was submitted by Spring.

The implementation for the `findByFirstName(..)` method is pretty similar to the implementation for `findAll()`, but it also involves a parameter. To keep things consistent, the `SelectSingerByFirstName` class is created for this operation and the code is depicted in Listing 6-37.

**Listing 6-37.** `SelectSingerByFirstName` Implementation

```
package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.plain.records.Singer;
import org.springframework.jdbc.core.SqlParameter;
import org.springframework.jdbc.object.MappingSqlQuery;
// other import statements omitted

public class SelectSingerByFirstName extends MappingSqlQuery<Singer> {

    public SelectSingerByFirstName(DataSource dataSource) {
        var sqlQuery = "select id, first_name, last_name, birth_date from singer where
first_name = :first_name";
        super(dataSource, sqlQuery);
        super.declareParameter(new SqlParameter("first_name", Types.VARCHAR));
    }
    protected Singer mapRow(ResultSet rs, int rowNum) throws SQLException {
        return new Singer(rs.getLong("id"),rs.getString("first_name"),rs.getString("last_
name"),rs.getDate("birth_date"), List.of());
    }
}
```

The `SelectSingerByFirstName` class is similar to the `SelectAllSingers` class. One difference is that the SQL statement is different and carries a named parameter called `first_name`. Also, in the constructor method, the `declareParameter()` method is called (which is inherited from the `org.springframework.jdbc.object.RdbmsOperation` abstract class indirectly). Let's proceed to implement the `findByFirstName(..)` method in the `SingerJdbcRepo` class. Listing 6-38 shows the updated code.

**Listing 6-38.** `SingerJdbcRepo.findByFirstName(..)` Implementation

```
package com.apress.prospring6.six.repo;

// import statements omitted

@Repository("singerRepo")
```

```

public class SingerJdbcRepo implements SingerDao {

    private static Logger LOGGER = LoggerFactory.getLogger(SingerJdbcRepo.class);

    private DataSource dataSource;
    private SelectSingerByFirstName selectSingerByFirstName;

    @Autowired
    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
        this.selectSingerByFirstName = new SelectSingerByFirstName(dataSource);
    }

    public DataSource getDataSource() {
        return dataSource;
    }

    @Override
    public List<Singer> findByFirstName(String firstName) {
        return selectSingerByFirstName.executeByNamedParam(Map.of("first_name", firstName));
    }
    // other code omitted
}

```

Upon data source injection, an instance of `SelectSingerByFirstName` is constructed. Afterward, in the `findByFirstName(..)` method, a `HashMap<K,V>` is constructed with the named parameters and values. Finally, the `executeByNamedParam(..)` method (inherited from the `SqlQuery<T>` abstract class indirectly) is called. Testing this method requires a configuration class providing the database, and the `EmbeddedJdbcConfig` suits this purpose well. Listing 6-39 shows the test method and the output.

**Listing 6-39.** `SingerJdbcRepo.findByFirstName(..)` Test Method

```

package com.apress.prospring6.six.repo;

// import statements omitted

public class RepoBeanTest {
    private static Logger LOGGER = LoggerFactory.getLogger(RepoBeanTest.class);

    @Test
    public void testFindByNameWithMappingSqlQuery() {
        var ctx = new AnnotationConfigApplicationContext(EmbeddedJdbcConfig.class,
            SingerJdbcRepo.class);
        var singerRepo = ctx.getBean("singerRepo", SingerDao.class);
        assertNotNull(singerRepo);

        var singers = singerRepo.findByFirstName("Ben");
        assertEquals(1, singers.size());
        LOGGER.info("Result: {}", singers.get(0));

        ctx.close();
    }
}

```

```

}
# output
DEBUG: RdbmsOperation - SQL operation not compiled before execution - invoking compile
DEBUG: RdbmsOperation - RdbmsOperation with SQL [select id, first_name, last_name, birth_
date from singer where first_name = :first_name] compiled
INFO : RepoBeanTest - Result: Singer[id=2, firstName=Ben, lastName=Barnes,
birthDate=1981-08-20, albums=[]]

```

## Updating Data by Using SqlUpdate

For updating data, Spring provides the `SqlUpdate` class. Listing 6-40 shows the `UpdateSinger` class that extends the `SqlUpdate` class for update operations using `Singer` records.

**Listing 6-40.** `SqlUpdate` Extension to Update Singer Database Entries

```

package com.apress.prospring6.six.repo;

import org.springframework.jdbc.core.SqlParameter;
import org.springframework.jdbc.object.SqlUpdate;
import java.sql.Types;
// other import statements omitted

public class UpdateSinger extends SqlUpdate {
    public static final String UPDATE_SINGER = "update SINGER set first_name=:first_name," +
        " last_name=:last_name, birth_date=:birth_date where id=:id";

    public UpdateSinger(DataSource dataSource) {
        super(dataSource, UPDATE_SINGER);
        super.declareParameter(new SqlParameter("first_name", Types.VARCHAR));
        super.declareParameter(new SqlParameter("last_name", Types.VARCHAR));
        super.declareParameter(new SqlParameter("birth_date", Types.DATE));
        super.declareParameter(new SqlParameter("id", Types.INTEGER));
    }
}

```

`UpdateSinger` is a customization of the `SqlUpdate` class with a custom query and custom-named parameters. Listing 6-41 shows the implementation of the `update()` method in the `SingerJdbcRepo` class.

**Listing 6-41.** Using `SqlUpdate` in a Repo Class

```

package com.apress.prospring6.six.repo;
// import statements omitted

@Repository("singerRepo")
public class SingerJdbcRepo implements SingerDao {
    private static Logger LOGGER = LoggerFactory.getLogger(SingerJdbcRepo.class);

    private DataSource dataSource;
    private UpdateSinger updateSinger;
}

```

```

@Autowired
public void setDataSource(DataSource dataSource) {
    this.dataSource = dataSource;
    this.updateSinger = new UpdateSinger(dataSource);
}

@Override
public void update(Singer singer) {
    updateSinger.updateByNamedParam(
        Map.of("first_name", singer.firstName(),
              "last_name", singer.lastName(),
              "birth_date", singer.birthDate(),
              "id", singer.id())
    );
    LOGGER.info("Existing singer updated with id: " + singer.id());
}

// other code omitted
}

```

Upon data source injection, an instance of `UpdateSinger` is constructed. In the `update()` method, a `Map<K,V>` instance containing parameter names and their values is constructed from the passed-in `Singer` record, and then `updateByNamedParam()` is called to update the `Singer` database entry. Testing the operation is just as simple as the previous operations, and the test method (and output) is shown in Listing 6-42.

**Listing 6-42.** Method Used to Test the `UpdateSinger` Implementation and Its Output

```

@Test
public void testUpdateWithSqlUpdate() {
    var ctx = new AnnotationConfigApplicationContext(EmbeddedJdbcConfig.class,
        SingerJdbcRepo.class);
    var singerRepo = ctx.getBean("singerRepo", SingerDao.class);
    assertNotNull(singerRepo);

    Singer singer = new Singer(1L, "John Clayton", "Mayer",
        new Date((new GregorianCalendar(1977, 9, 16)).getTime().getTime()),
        List.of());
    singerRepo.update(singer);

    var singers = singerRepo.findByFirstName("John Clayton");
    assertEquals(1, singers.size());
    LOGGER.info("Result: {}", singers.get(0));

    ctx.close();
}

# output
DEBUG: RdbmsOperation - RdbmsOperation with SQL [update SINGER set first_name=:first_name,
last_name=:last_name, birth_date=:birth_date where id=:id] compiled
INFO : SingerJdbcRepo - Existing singer updated with id: 1

```

```
DEBUG: RdbmsOperation - RdbmsOperation with SQL [select id, first_name, last_name,
birth_date from SINGER where first_name = :first_name] compiled
INFO : RepoBeanTest - Result: Singer[id=1, firstName=John Clayton, lastName=Mayer,
birthdate=1977-10-16, albums=[]]
```

As you can see, we construct a `Singer` record with an existing ID and a new `firstName` and pass it to the `update(..)` method. The `id` field is used to identify the database records, and all other fields are used as new values for the matching columns.

## Inserting Data and Retrieving the Generated Key

Inserting data is implemented by extending `SqlUpdate` as well.

One interesting point is how the primary key is generated (which is typically the ID column). This value is available only after the insert statement has completed; that's because the RDBMS generates the identity value for the record on insert. The column ID is declared with the attribute `AUTO_INCREMENT` and is the primary key, and this value will be assigned by the RDBMS during the insert operation. If you are using Oracle, you will probably get a unique ID first from an Oracle sequence and then execute an insert statement with the query result.

In old versions of JDBC, the method is a bit tricky. For example, if we are using MariaDB, we need to execute the SQL `select last_insert_id()` function. For Microsoft SQL Server, we execute `select @@IDENTITY` statements. Fortunately, starting from JDBC version 3.0, a new feature was added that allows the retrieval of an RDBMS-generated key in a unified fashion. Listing 6-43 shows the implementation of the `insert()` method, which also retrieves the generated key for the inserted contact record. It will work in most databases (if not all); just make sure you are using a JDBC driver that is compatible with JDBC 3.0 or newer. We start by creating the `InsertSinger` class for the insert operation, which extends the `SqlUpdate` class. The code is shown in Listing 6-43.

**Listing 6-43.** `SqlUpdate` Extension to Insert a Singer Database Entry

```
package com.apress.prospring6.six.repo;

import org.springframework.jdbc.object.SqlUpdate;
import java.sql.Types;
// import statements omitted

public class InsertSinger extends SqlUpdate {
    public static final String INSERT_SINGER = "insert into singer (first_name, last_name,
    birth_date) " +
        " values (:first_name, :last_name, :birth_date)";

    public InsertSinger(DataSource dataSource) {
        super(dataSource, INSERT_SINGER);
        super.declareParameter(new SqlParameter("first_name", Types.VARCHAR));
        super.declareParameter(new SqlParameter("last_name", Types.VARCHAR));
        super.declareParameter(new SqlParameter("birth_date", Types.DATE));
        super.setGeneratedKeysColumnNames("id");
        super.setReturnGeneratedKeys(true);
    }
}
```

The `InsertSinger` class is almost the same as the `UpdateSinger` class; we need to do just two more things. When constructing the `InsertSinger` class, we call the method `setGeneratedKeysColumnNames()` to declare the name of the ID column. The method `setReturnGeneratedKeys()` then instructs the underlying JDBC driver to retrieve the generated key. In Listing 6-44 you can see the implementation of the `insert()` method in the `SingerJdbcRepo` class.

**Listing 6-44.** Using `SqlUpdate` in a Repo Class to Insert a Singer Entry

```
package com.apress.prospring6.six.repo;

import org.springframework.jdbc.support.GeneratedKeyHolder;
import org.springframework.jdbc.support.KeyHolder;
// other import statements missing

@Repository("singerRepo")
public class SingerJdbcRepo implements SingerDao {
    private static Logger LOGGER = LoggerFactory.getLogger(SingerJdbcRepo.class);

    private InsertSinger insertSinger;

    @Autowired
    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
        this.insertSinger = new InsertSinger(dataSource);
    }

    @Override
    public void insert(Singer singer) {
        KeyHolder keyHolder = new GeneratedKeyHolder();
        insertSinger.updateByNamedParam(Map.of("first_name", singer.firstName(),
            "last_name", singer.lastName(),
            "birth_date", singer.birthDate()), keyHolder);
        var generatedId = keyHolder.getKey().longValue();
        LOGGER.info("New singer {} {} inserted with id {}", singer.firstName(), singer.
            lastName(), generatedId);
    }
    // other code omitted
}
```

Upon data source injection, an instance of `InsertSinger` is constructed. In the `insert(..)` method, we also use the `SqlUpdate.updateByNamedParam()` method. Additionally, we pass in an instance of `KeyHolder` to the method, which will have the generated ID stored in it. After the data is inserted, we can then retrieve the generated key from the `KeyHolder`. Testing the `insert(..)` method does not introduce anything new at this point, but just in case, the test method is depicted in Listing 6-45.

**Listing 6-45.** Method Used to Test the `InsertSinger` Implementation and Its Output

```
@Test
public void testInsertWithSqlUpdate() {
    var ctx = new AnnotationConfigApplicationContext(EmbeddedJdbcConfig.class,
        SingerJdbcRepo.class);
    var singerRepo = ctx.getBean("singerRepo", SingerDao.class);
    assertNotNull(singerRepo);
}
```



```

    Singer singer = new Singer(null, "Ed", "Sheeran", new Date((new
    GregorianCalendar(1991, 1, 17)).getTime().getTime()), List.of());
    singerRepo.insert(singer);

    var singers = singerRepo.findByFirstName("Ed");
    assertEquals(1, singers.size());
    LOGGER.info("Result: {}", singers.get(0));

    ctx.close();
}
# output
DEBUG: RdbmsOperation - RdbmsOperation with SQL [insert into singer (first_name, last_name,
birth_date) values (:first_name, :last_name, :birth_date)] compiled
INFO : SingerJdbcRepo - New singer Ed Sheeran inserted with id 4
DEBUG: RdbmsOperation - RdbmsOperation with SQL [select id, first_name, last_name, birth_
date from SINGER where first_name = :first_name] compiled
INFO : RepoBeanTest - Result: Singer[id=4, firstName=Ed, lastName=Sheeran,
birthDate=1991-02-17, albums=[]]

```

## Batching Operations with BatchSqlUpdate

For batch operations, we use the `BatchSqlUpdate` class. The new `insertWithAlbum()` method will insert both the singer and its released album into the database. To be able to insert the album record, we need to create the `InsertSingerAlbum` class, which is shown in Listing 6-46.

**Listing 6-46.** `BatchSqlUpdate` Extension to Insert a Singer with an Album Collection in the Database

```

package com.apress.prospring6.six.repo;

import org.springframework.jdbc.core.SqlParameter;
import org.springframework.jdbc.object.BatchSqlUpdate;
import java.sql.Types;
// other import statements omitted

public class InsertSingerAlbum extends BatchSqlUpdate {

    public static final int BATCH_SIZE = 10;
    public static final String INSERT_SINGER_ALBUM = "insert into album (singer_id, title,
    release_date) " +
        "values (:singer_id, :title, :release_date)";

    public InsertSingerAlbum(DataSource dataSource) {
        super(dataSource, INSERT_SINGER_ALBUM);
        declareParameter(new SqlParameter("singer_id", Types.INTEGER));
        declareParameter(new SqlParameter("title", Types.VARCHAR));
        declareParameter(new SqlParameter("release_date", Types.DATE));
        setBatchSize(BATCH_SIZE);
    }
}

```

Note that in the constructor, we call the `BatchSqlUpdate.setBatchSize()` method to set the batch size for the JDBC insert operation. Listing 6-47 shows the implementation of the `insertWithAlbum()` method in the `SingerJdbcRepo` class.

**Listing 6-47.** `insertWithAlbum()` Implementation Using the `InsertSingerAlbum` Class

```

package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.plain.records.Album;
import com.apress.prospring6.six.plain.records.Singer;
// other import statements omitted

@Repository("singerRepo")
public class SingerJdbcRepo implements SingerDao {
    private static Logger LOGGER = LoggerFactory.getLogger(SingerJdbcRepo.class);

    private InsertSinger insertSinger;
    private InsertSingerAlbum insertSingerAlbum;

    @Resource(name = "dataSource")
    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
        this.insertSinger = new InsertSinger(dataSource);
        this.insertSingerAlbum = new InsertSingerAlbum(dataSource);
    }

    @Override
    public void insertWithAlbum(Singer singer) {
        var keyHolder = new GeneratedKeyHolder();
        insertSinger.updateByNamedParam(Map.of("first_name", singer.firstName(),
            "last_name", singer.lastName(),
            "birth_date", singer.birthDate()), keyHolder);
        var newSingerId = Objects.requireNonNull(keyHolder.getKey()).longValue();
        LOGGER.info("New singer {} {} inserted with id {} ", singer.firstName(), singer.
            lastName(), newSingerId);

        var albums = singer.albums();
        if (albums != null) {
            for (Album album : albums) {
                insertSingerAlbum.updateByNamedParam(Map.of("singer_id", newSingerId,
                    "title", album.title(),
                    "release_date", album.releaseDate()));
            }
        }
        insertSingerAlbum.flush();
    }
}

```

Each time the `insertWithAlbum()` method is called, a new instance of `InsertSingerAlbum` is constructed because the `BatchSqlUpdate` class is not thread safe. Then we use it just like `SqlUpdate`. The main difference is that the `BatchSqlUpdate` class will queue up the insert operations and submit them to the database in batch. Every time the number of records equals the batch size, Spring will execute a bulk

insert operation to the database for the pending records. On the other hand, upon completion, we call the `BatchSqlUpdate.flush()` method to instruct Spring to flush all pending operations (that is, the insert operations being queued that still haven't reached the batch size yet). Finally, we loop through the list of `Album` objects in the `Singer` object and invoke the `BatchSqlUpdate.updateByNamedParam()` method. To facilitate testing, the `insertWithAlbum()` method is also implemented. As this implementation is pretty big, it can be reduced by making use of Java 8 lambda expressions and records, as shown in Listing 6-48.

**Listing 6-48.** `findAllWithAlbum()` Implementation Using a `JdbcTemplate` Instance

```
@Override
public List<Singer> findAllWithAlbums() {
    var jdbcTemplate = new JdbcTemplate(getDataSource());

    return jdbcTemplate.query(FIND_SINGER_ALBUM, rs -> {
        Map<Long, Singer> map = new HashMap<>();
        Singer singer;
        while (rs.next()) {
            var singerID = rs.getLong("id");
            singer = map.computeIfAbsent(singerID,
                s-> {
                    try {
                        return new Singer(singerID, rs.getString("first_name"),
                            rs.getString("last_name"),
                            rs.getDate("birth_date"), new ArrayList<>());
                    } catch (SQLException sex) {
                        LOGGER.error("Malformed data!", sex);
                    }
                }
            );
            return null;
        }
    });

    var albumID = rs.getLong("album_id");
    if (albumID > 0) {
        Objects.requireNonNull(singer).albums().add(
            new Album(albumID, singerID, rs.getString("title"), rs.getDate(
                "release_date")));
    }
}
return new ArrayList<>(map.values());
});
}
```

Testing this method does not present any special challenge. The test method and the output are shown in Listing 6-49.

**Listing 6-49.** Test Method `insertAllWithAlbum()` and `findAllWithAlbum()` and the Output

```
@Test
public void testInsertAlbumsWithBatchSqlUpdate() {
    var ctx = new AnnotationConfigApplicationContext(EmbeddedJdbcConfig.class,
        SingerJdbcRepo.class);
    var singerRepo = ctx.getBean("singerRepo", SingerDao.class);
    assertNotNull(singerRepo);
}
```

```

var singer = new Singer(null, "BB", "King", new Date((new GregorianCalendar(1940,
8, 16)).getTime().getTime()), new ArrayList<>());

var album = new Album(null, null, "My Kind of Blues", new Date(
    (new GregorianCalendar(1961, 7, 18)).getTime().getTime()));
singer.albums().add(album);

album = new Album(null, null, "A Heart Full of Blues", new Date(
    (new GregorianCalendar(1962, 3, 20)).getTime().getTime()));
singer.albums().add(album);

singerRepo.insertWithAlbum(singer);

var singers = singerRepo.findAllWithAlbums();
assertEquals(4, singers.size());
singers.forEach(s -> LOGGER.info(s.toString()));

ctx.close();
}
# output
DEBUG: RdbmsOperation - RdbmsOperation with SQL [insert into SINGER (first_name, last_name,
birth_date) values (:first_name, :last_name, :birth_date)] compiled
INFO : SingerJdbcRepo - New singer BB King inserted with id 4

DEBUG: RdbmsOperation - RdbmsOperation with SQL [insert into ALBUM (singer_id, title,
release_date) values (:singer_id, :title, :release_date)] compiled

INFO : RepoBeanTest - Singer[id=1, firstName=John, lastName=Mayer, birthDate=1977-10-16,
albums=[Album[id=1, singerId=1, title=The Search For Everything, releaseDate=2017-01-20],
Album[id=2, singerId=1, title=Battle Studies, releaseDate=2009-11-17]]]
INFO : RepoBeanTest - Singer[id=2, firstName=Ben, lastName=Barnes, birthDate=1981-08-20,
albums=[Album[id=3, singerId=2, title= 11:11 , releaseDate=2021-09-18]]]
INFO : RepoBeanTest - Singer[id=3, firstName=John, lastName=Butler, birthDate=1975-04-01,
albums=[]]
INFO : RepoBeanTest - Singer[id=4, firstName=BB, lastName=King, birthDate=1940-09-16,
albums=[Album[id=4, singerId=4, title=My Kind of Blues, releaseDate=1961-08-18], Album[id=5,
singerId=4, title=A Heart Full of Blues, releaseDate=1962-04-20]]]

```

## Calling Stored Functions by Using `SqlFunction`

Spring also provides classes to simplify the execution of stored procedures/functions using JDBC. In this section, we show you how to execute a simple function by using the `SqlFunction<T>` class. We show how to use MariaDB for the database, create a stored function, and call it by using the `SqlFunction<T>` class. We're assuming you have a MariaDB database with a schema called `musicdb`, with a username and password both equaling `prospring6` (the same as in the example in the section "Exploring the JDBC Infrastructure"). Let's create a stored function called `getFirstNameById(...)`, which accepts the singer's ID and returns the first name of the singer. Listing 6-50 shows the script to create the stored function in MariaDB (`resources/stored-function.sql`). Run the script against the MariaDB database.

**Listing 6-50.** MariaDB Stored Function

```

CREATE FUNCTION IF NOT EXISTS getFirstNameById(in_id INT) RETURNS VARCHAR(60)
LANGUAGE SQL
BEGIN
  RETURN (SELECT first_name FROM SINGER WHERE id = in_id);
END;

```

The stored function simply accepts the ID and returns the first name of the singer record with the ID. Next we create a `StoredFunctionFirstNameById` class to represent the stored function operation, which extends the `SqlFunction<String>` class. The generic type is the type of the result returned by the stored function. You can see the content of the class in Listing 6-51.

**Listing 6-51.** `StoredFunctionFirstNameById`, Which Extends the `SqlFunction<T>` Class

```

package com.apress.prospring6.six.repo;

import org.springframework.jdbc.object.SqlFunction;
// other import statements omitted

public class StoredFunctionFirstNameById extends SqlFunction<String> {
  private static final String SQL_CALL = "select getfirstnamebyid(?)";
  public StoredFunctionFirstNameById (DataSource dataSource) {
    super(dataSource, SQL_CALL);
    declareParameter(new SqlParameter(Types.INTEGER));
    compile();
  }
}

```

The SQL to call the stored function in MariaDB is very simple: `select getfirstnamebyid(?)`. Notice that it requires a parameter. Afterward, in the constructor, the parameter is declared, and we compile the operation. The class is now ready for use in the implementation class. Listing 6-52 shows the updated `SingerJdbcRepo` class to use the stored function.

**Listing 6-52.** `SingerJdbcRepo` Modified to Call a Stored Function

```

package com.apress.prospring6.six.repo;
// import statements omitted

@Repository("singerRepo")
public class SingerJdbcRepo implements SingerDao {
  private StoredFunctionFirstNameById storedFunctionFirstNameById;

  @Resource(name = "dataSource")
  public void setDataSource(DataSource dataSource) {
    this.dataSource = dataSource;
    this.storedFunctionFirstNameById = new StoredFunctionFirstNameById(dataSource);
  }

  @Override
  public Optional<String> findFirstNameById(Long id) {
    var result = storedFunctionFirstNameById.execute(id).get(0);
  }
}

```

```

        return result != null ? Optional.of(storedFunctionFirstNameById.execute(id).get(0)):
            Optional.empty();
    }
    // other code omitted
}

```

Upon data source injection, an instance of `StoredFunctionFirstNameById` is constructed. Then in the `findFirstNameById()` method, its `execute()` method is called, passing in the contact ID. The method will return a list of `Strings`, and we need only the first one, because there should be only one record returned in the result set. Testing this functionality is not possible with H2, since the lightweight in-memory database does not have the concept of stored functions or procedures, so we'll test the method by invoking it in the `RepoDemo.main(..)` method. Listing 6-53 depicts the `RepoDemo` class.

**Listing 6-53.** `RepoDemo` Class and Its Output

```

package com.apress.prospring6.six.repo;
// import statements omitted

public class RepoDemo {
    private static final Logger LOGGER = LoggerFactory.getLogger(RepoDemo.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(BasicDataSourceCfg.class,
            SingerJdbcRepo.class);
        var singerRepo = ctx.getBean("singerRepo", SingerDao.class);

        LOGGER.info("-----");
        List<Singer> singers = singerRepo.findAll();
        singers.forEach(singer -> LOGGER.info(singer.toString()));

        LOGGER.info("-----");
        String firstName = singerRepo.findFirstNameById(2L).orElse(null);
        LOGGER.info("Retrieved {} ", firstName); // expect 'Ben'
        ctx.close();
    }
}

# output
INFO : RepoDemo - -----
DEBUG: RdbmsOperation - RdbmsOperation with SQL [select * from SINGER] compiled
INFO : RepoDemo - Singer[id=1, firstName=John, lastName=Mayer, birthDate=1977-10-16,
albums=[]]
INFO : RepoDemo - Singer[id=2, firstName=Ben, lastName=Barnes, birthDate=1981-08-20,
albums=[]]
INFO : RepoDemo - Singer[id=3, firstName=John, lastName=Butler, birthDate=1975-04-01,
albums=[]]
INFO : RepoDemo - -----
DEBUG: RdbmsOperation - RdbmsOperation with SQL [select getfirstnamebyid(?)] compiled
INFO : RepoDemo - Retrieved Ben

```

You can see that the first name is retrieved correctly. What is presented here is just a simple sample to demonstrate the Spring JDBC module's function capabilities. Spring also provides other classes (for example, `StoredProcedure`) for you to invoke complex stored procedures that return complex data types. We recommend you refer to Spring's reference manual in case you need to access stored procedures using JDBC.

## Spring Data Project: JDBC Extensions

In recent years, database technology has evolved so quickly with the rise of so many purpose-specific databases that, nowadays, an RDBMS is not the only choice for an application's back-end database. In response to this database technology evolution and the developer community's needs, Spring created the Spring Data project<sup>8</sup>. The major objective of the project is to provide useful extensions on top of Spring's core data access functionality to interact with databases other than traditional RDBMSs.

The Spring Data project comes with various extensions. One that we would like to introduce here is JDBC Extensions<sup>9</sup>. As its name implies, the extension provides some advanced features to facilitate the development of JDBC applications using Spring. The main features that JDBC Extensions provides are listed here:

- *QueryDSL support:* QueryDSL<sup>10</sup> is a domain-specific language that provides a framework for developing type-safe queries. Spring Data's JDBC Extensions provides `QueryDslJdbcTemplate` to facilitate the development of JDBC applications using QueryDSL instead of SQL statements.
- *Advanced support for Oracle Database:* The extension provides advanced features for Oracle Database users. On the database connection side, it supports Oracle-specific session settings, as well as Fast Connection Failover technology when working with Oracle RAC. It also provides classes that integrate with Oracle Advanced Queuing. On the data type side, it provides native support for Oracle's XML types, `STRUCT` and `ARRAY`, and so on.

If you are developing JDBC applications using Spring with Oracle Database, JDBC Extensions is really worth a look.

## Spring JDBC Testing Annotations

In **Chapter 4**, you were introduced to a few testing annotations. Some of them were very obviously related to the data access context. `@Sql`, `@SqlConfig`, `@SqlGroup`, and `@SqlMergeMode` are part of the `org.springframework.test.context.jdbc` package and are suitable for testing pure Spring JDBC implementations. In this chapter all test methods were designed to build their own application context to keep the configuration obvious. All test methods that are using an in-memory database can be written to share the same test context and use these specialized annotations to customize it for each test method.

---

<sup>8</sup><https://spring.io/projects/spring-data>

<sup>9</sup><https://spring.io/projects/spring-data-jdbc-ext>

<sup>10</sup><http://querydsl.com>

Let's start with `@Sql`. This annotation is used to annotate a test class or test method to configure SQL scripts and statements to be executed against a given database during integration tests. This annotation can be used with plain JDBC or with more complex applications that make use of persistence or transactions. `@Sql` can be used on a test class, and this means the statements or scripts configured with it will be applied to each test method in the class. Listing 6-54 shows a test class with a single test method for the `findAll()` method.

**Listing 6-54.** `JdbcRepoTest` Class Using `@Sql*` Annotations

```
package com.apress.prospring6.six.repo;

import org.junit.jupiter.api.DisplayName;
import org.junit.jupiter.api.Test;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseBuilder;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseType;
import org.springframework.test.context.jdbc.Sql;
import org.springframework.test.context.jdbc.SqlMergeMode;
import org.springframework.test.context.junit.jupiter.SpringJUnitConfig;
// other imports omitted

@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:h2/drop-schema.sql", "classpath:h2/create-schema.sql" })
@SpringJUnitConfig(classes = {JdbcRepoTest.EmptyEmbeddedJdbcConfig.class,
    SingerJdbcRepo.class})
public class JdbcRepoTest {
    private static final Logger LOGGER = LoggerFactory.getLogger(RepoBeanTest.class);

    @Autowired
    SingerDao singerRepo;

    @Test
    @DisplayName("should return all singers")
    @Sql(value = "classpath:h2/test-data.sql")
    void testFindAllWithMappingSqlQuery(){
        var singers = singerRepo.findAll();
        assertEquals(3, singers.size());
        singers.forEach(singer -> LOGGER.info(singer.toString()));
    }

    @Configuration
    public static class EmptyEmbeddedJdbcConfig {
        private static final Logger LOGGER = LoggerFactory.getLogger(EmptyEmbeddedJdbc
            Config.class);

        @Bean
        public DataSource dataSource() {
            try {
                var dbBuilder = new EmbeddedDatabaseBuilder();
                return dbBuilder.setType(EmbeddedDatabaseType.H2).setName("musicdb").
                    build();
            } catch (Exception e) {
                LOGGER.error("Embedded DataSource bean cannot be created!", e);
            }
        }
    }
}
```



```

        return null;
    }
}
}
}

```

The test `ApplicationContext` is created using the `@SpringJUnitJupiterConfig` annotation. This is a composed annotation that combines `@ExtendWith(SpringExtension.class)` from JUnit Jupiter with `@ContextConfiguration` from the Spring TestContext Framework. The `EmptyEmbeddedJdbcConfig` config class is declared static in the test class body for practical reasons: it is small and is relevant only to this test class. The resulting test `ApplicationContext` contains beans that define a data source pointing to an empty in-memory H2 database named `musicdb`. Since the test class is targeting methods of the `SingerJdbcRepo` bean, this class is also added to the context.

The database schema with the `SINGER` and `ALBUM` is initialized by annotating the test class with this annotation: `@Sql({ "classpath:h2/drop-schema.sql", "classpath:h2/create-schema.sql" })`. These two scripts contain the SQL code to do exactly what their names suggest—destroy and create the tables in the database schema.

Annotation `@Sql(value = "classpath:h2/test-data.sql")` is used to annotate the test method and is executed by default before the test method to prepare the database contents for the test. There would be no point in executing `findAll()` if there were no singers to be found, right?

This annotation is quite versatile and can be configured using `@SqlConfigure` to provide more details about the script being executed, such as encoding, the character used as a statement separator and the character used to prefix comments and many more. `@Sql` also provides an `executionPhase` attribute used to specify if the script or statements should be executed before or after the test method, which is useful for cleanup to avoid dirtying the context and preventing other tests from failing.

This means the annotation on the `testFindAllWithMappingSqlQuery()` test method can also be written as follows:

```

@Sql(value = "classpath:h2/test-data.sql",
    config = @SqlConfig(encoding = "utf-8", separator = ";", commentPrefix = "--"),
    executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)

```

The `@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)` annotation indicates that method-level `@Sql` declarations should be merged with `@Sql` declarations, with class-level SQL scripts and statements executed before method-level scripts and statements. The other option is to use `@SqlMergeMode(SqlMergeMode.MergeMode.OVERRIDE)`, which allows `@Sql` declaration annotations on methods to override the annotations at class level.

When `@Sql` annotations are used at class level, and `@SqlMergeMode` is not specified, the declarations configured by them are ignored, and this will almost definitely cause test failures.

As previously mentioned, `@Sql` can also specify statements, not only scripts. Listing 6-55 shows the `testFindByNameWithMappingSqlQuery()` method, used to check that the `findByFirstName(..)` method works as expected.

#### **Listing 6-55.** `JdbcRepoTest.testFindByNameWithMappingSqlQuery()` Test Method

```

package com.apress.prospring6.six.repo;

import org.springframework.test.context.jdbc.SqlGroup;
// other import statements omitted

@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:h2/drop-schema.sql", "classpath:h2/create-schema.sql" })

```

```

@SpringJUnitConfig(classes = {JdbcRepoTest.EmptyEmbeddedJdbcConfig.class,
SingerJdbcRepo.class})
public class JdbcRepoTest {

    @Test
    @DisplayName("should return Chuck Berry")
    @SqlGroup({
        @Sql(statements = "insert into SINGER (first_name, last_name, birth_date) values
('Chuck', 'Berry', '1926-09-18')",
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD),
        @Sql(statements = "delete from SINGER where first_name = 'Chuck'",
            executionPhase = Sql.ExecutionPhase.AFTER_TEST_METHOD)
    })
    public void testFindByNameWithMappingSqlQuery() {
        var singers = singerRepo.findByFirstName("Chuck");
        assertEquals(1, singers.size());
        LOGGER.info("Result: {}", singers.get(0));
    }

    // other code omitted
}

```

Listing 6-55 shows how `@Sql` annotations can be grouped using the `@SqlGroup` annotation. Having multiple `@Sql` annotations on the same test method (or class) is allowed, but `@SqlGroup` is just a nicer way to group them to make it obvious that they are all relevant to the item they are set on. For the same method, notice how the `executionPhase` attribute is used to insert the item targeted by the test method, by setting it to `Sql.ExecutionPhase.BEFORE_TEST_METHOD` for one of the `@Sql` annotations. For the other one, `executionPhase` is set to `Sql.ExecutionPhase.AFTER_TEST_METHOD` to delete the item from the database. This ensures that the test context is kept clean, and that the methods in the test class can be run in any order, and will still pass.

The `@DisplayName` annotation is a typical JUnit Jupiter annotation used to declare a custom display value for the annotated test class or test method. In an editor that supports JUnit 5, this can look very pretty, as shown in Figure 6-4.

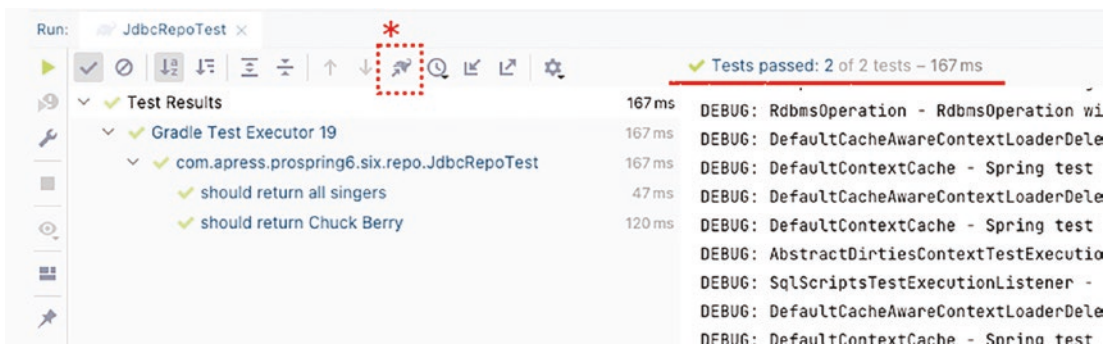


Figure 6-4. Tests with pretty name

In Figure 6-4, IntelliJ IDEA uses Gradle to run the tests, and by clicking the icon marked with a box and asterisk, a tab is opened in your browser showing the test results in HTML format. Notice that the display name is kept, which gives a lot of context for the assumptions checked by the test methods. The HTML format for the test results is shown in Figure 6-5.

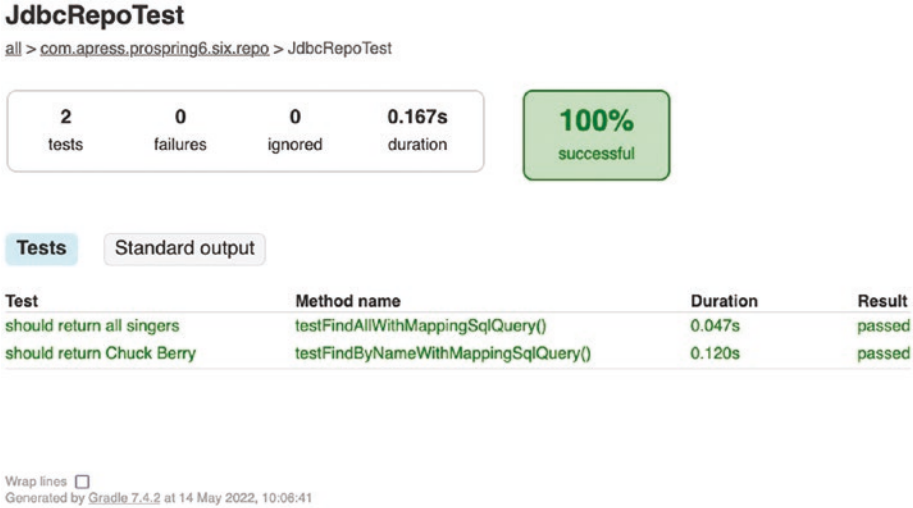


Figure 6-5. HTML test results generated by Gradle

The log level for the test can be configured to show more details. We recommend using `<logger name="com.apress.prospring6.six" level="debug"/>`. This way, queries, parameters, and results become visible. Also, you might see this exception being reported:

```
DEBUG: TestContextTransactionUtils - Caught exception while retrieving PlatformTransactionManager for test context
[
  DefaultTestContext@2320fa6f testClass = JdbcRepoTest, testInstance = com.apress.prospring6.six.repo.JdbcRepoTest@7c1e2a2d,
  testMethod = testFindByNameWithMappingSqlQuery@JdbcRepoTest,
  testException = [null],
  mergedContextConfiguration = [MergedContextConfiguration@7a560583 testClass = JdbcRepoTest, locations = '{}',
  classes = {
    'class com.apress.prospring6.six.repo.JdbcRepoTest$EmptyEmbeddedJdbcConfig, '
    'class com.apress.prospring6.six.repo.SingerJdbcRepo',
  },
  contextInitializerClasses = [],
  activeProfiles = '{}',
  propertySourceLocations = '{}',
  propertySourceProperties = '{}',
  contextCustomizers = set[[empty]],
  contextLoader = 'org.springframework.test.context.support.DelegatingSmartContextLoader',
  parent = [null]],
```

```

        attributes = map['org.springframework.test.context.event.
        ApplicationEventsTestExecutionListener.recordApplicationEvents' -> false]
    ]
org.springframework.beans.factory.NoSuchBeanDefinitionException: No bean named
'transactionManager' available
...

```

This exception shows that the `@Sql*` annotations family is suitable for applications using transactions as well (which will be covered in **Chapter 7**).

## Introducing Testcontainers

As previously mentioned, testing stored functions and procedures is not possible with H2, since the lightweight in-memory database does not have these concepts. However, *not* testing the code written is not something that we want to encourage you to do. When in production, the code runs on an actual database. During daily development builds, the tests run a test database, or a database in a container. Since preparing a test database might still be a costly operation, the most suitable alternative is to run the tests in a database in a container. To make this easy, the Testcontainers<sup>11</sup> library was invented.

Testcontainers is a Java library that supports JUnit tests, providing lightweight, throwaway instances of common databases, Selenium web browsers, or anything else that can run in a Docker container. Using this library, we can start a container using a lightweight MariaDB image and write a test for our stored function. This obviously requires Docker being installed on your computer. The good news is that you don't have to create the container manually, or run Docker commands, because Testcontainers provides all the components to do so from the code. These components integrate nicely with the JUnit Jupiter and Spring JDBC testing annotations introduced thus far.

The approach is similar to testing when using an embedded database, but instead of creating a `DataSource` bean using `EmbeddedDatabaseBuilder`, an `org.testcontainers.containers.MariaDBContainer` instance is used. The test configuration class is shown in Listing 6-56.

**Listing 6-56.** TestContainersConfig Using a MariaDBContainer Instance

```

package com.apress.prospring6.six.repo;

import org.testcontainers.containers.MariaDBContainer;
// other import statements omitted

// annotations omitted
public class StoredFunctionV1Test {

    // test methods omitted for relevance

    @Configuration
    public static class TestContainersConfig {
        private static final Logger LOGGER = LoggerFactory.getLogger(
            (TestContainersConfig.class));

        MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");
    }
}

```

<sup>11</sup> <https://www.testcontainers.org/>

```

@PostConstruct
void initialize() {
    mariaDB.start();
}

@PreDestroy
void tearDown(){
    mariaDB.stop();
}

@Bean
DataSource dataSource() {
    try {
        var dataSource = new BasicDataSource();
        dataSource.setDriverClassName(mariaDB.getDriverClassName());
        dataSource.setUrl(mariaDB.getJdbcUrl());
        dataSource.setUsername(mariaDB.getUsername());
        dataSource.setPassword(mariaDB.getPassword());
        return dataSource;
    } catch (Exception e) {
        LOGGER.error("MariaDB TestContainers DataSource bean cannot be
        created!", e);
        return null;
    }
}
}
}
}

```

Any code that might distract you from the TestContainers central configuration was stripped away from the `StoredFunctionV1TestTest` class, the class where `TestContainersConfig` is declared. It was declared inside the test class because this is the only place where it is used.

As you can see, the `MariaDBContainer` class provides all the properties necessary to create a `DataSource` bean. When instantiated, the `MariaDBContainer` constructor requires a single `String` argument representing the Docker container image and a tag representing the MariaDB version. To make sure the container is started gracefully, an `initialize()` method was added to the configuration annotated with `@PostConstruct` that calls `mariaDB.start()` to start the container. To make sure the container is stopped gracefully, a `tearDown()` method annotated with `@PreDestroy` that calls `mariaDB.stop()` was added to stop the container. These two methods are needed because the container is treated like a bean, and thus we must make sure that when the context is destroyed, the container is shut down gracefully and terminated as well.

Although this approach gets the job done, the recommended way is to rely on JUnit Jupiter life-cycle management to start and stop the container. This allows us to reuse the `BasicDataSourceCfg` configuration class. The practical part here is that the same `DataSource` bean declared in `BasicDataSourceCfg` can be used; since only the database location changes, the database is the same as the one declared for production, `MariaDB`. To make this work, we need to do the following three things:

- Declare our `MariaDBContainer` as a static field in our test class and add the `@Testcontainers` annotation that is a JUnit Jupiter extension to activate automatic startup and stop of containers used in a test case.
- Annotate the container static field with `@Container` to let JUnit Jupiter know that this is the container instance we want managed. (Both `@Testcontainers` and this annotation are part of the `junit-jupiter.jar` Testcontainers library that is added to the classpath of the project.)

- Use `@DynamicPropertySource` on a method to register the container properties as configuration properties for the `dataSource` bean. This annotation was mentioned in **Chapter 4** and this test case is the first suitable place to use it in this book. It is used here to dynamically add properties to the `Environment`'s set of `PropertySources`.

With this configuration the container is created and MariaDB is installed and started, but the schema, the data, and the stored function required for the tests are not there yet. The SQL scripts to do that still have to be configured using various `@Sql*` annotations. Listing 6-57 shows the full implementation of the `StoredFunctionV2Test` with the two methods: one testing the `singerRepo.findAll()` query and one testing the `singerRepo.findFirstNameById(..)` stored function.

**Listing 6-57.** `StoredFunctionV2Test` Using a `MariaDBContainer` to Test JDBC Methods On

```
package com.apress.prospring6.six.repo;

import org.testcontainers.containers.MariaDBContainer;
import org.testcontainers.junit.jupiter.Container;
import org.testcontainers.junit.jupiter.Testcontainers;

// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-schema.
sql" }) // This works
@SpringJUnitConfig(classes = { BasicDataSourceCfg.class, SingerJdbcRepo.class})
public class StoredFunctionV2Test {

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @DynamicPropertySource // this does the magic
    static void setUp(DynamicPropertyRegistry registry) {
        registry.add("jdbc.driverClassName", mariaDB::getDriverClassName);
        registry.add("jdbc.url", mariaDB::getJdbcUrl);
        registry.add("jdbc.username", mariaDB::getUsername);
        registry.add("jdbc.password", mariaDB::getPassword);
    }

    @Autowired
    SingerRepo singerRepo;

    @Test
    void testFindAllQuery(){
        var singers = singerRepo.findAll();
        assertEquals(3, singers.size());
    }

    @Test
    @Sql({ "classpath:testcontainers/original-stored-function.sql" }) // this does not!
    Testcontainers simply can't support all SQL dialects to 100%.
    void testStoredFunction(){
```

```

    var firstName = singerRepo.findFirstNameById(2L).orElse(null);
    assertEquals("Ben", firstName);
}
}

```

Using Testcontainers simplifies testing, but Testcontainers is not perfect, and simply can't support all SQL dialects to 100%. Sometimes perfectly valid SQL syntax is not recognized and some adjustments have to be made or files have to be copied onto the container and executed there. For example, the initial version of the `getFirstNameById(..)` stored function shown in Listing 6-50 caused the `testStoredFunction()` test method to fail, as shown in Figure 6-6.



Figure 6-6. Failing test using MariaDB test container

To make `StoredFunctionV1Test` and `StoredFunctionV2Test` pass completely, the `getFirstNameById(..)` stored function declaration needs to be changed to the one in `testcontainers/stored-function.sql` that is depicted here:

```

CREATE FUNCTION getFirstNameById (in_id INT) RETURNS VARCHAR(60)
RETURN (SELECT first_name FROM SINGER WHERE id = in_id);

```

However, when the right SQL changes can't be figured out, issues like these can be overcome by copying the SQL scripts onto the container and letting them be executed by Docker when creating the container. Of course, this means we no longer need the `@Sql*` annotations and the `initialization()` method is needed to copy the scripts onto the container and execute them. Listing 6-58 shows the full implementation of `StoredFunctionV3Test` that actually works with the original SQL syntax of the stored function. A `TestContainersConfig` class is needed to declare the `initialization()` method.

**Listing 6-58.** GoodStoredFunctionTest Using a MariaDBContainer to Test JDBC Methods On

```

package com.apress.prospring6.six.repo;

import org.testcontainers.ext.ScriptUtils;
import org.testcontainers.jdbc.JdbcDatabaseDelegate;
import org.testcontainers.shaded.com.google.common.io.Resources;
import java.nio.charset.StandardCharsets;
import javax.script.ScriptException;
import java.io.IOException;
// other import statements omitted

@Testcontainers
@SpringJUnitConfig(classes = {StoredFunctionV3Test.TestContainersConfig.class,
    SingerJdbcRepo.class})
public class StoredFunctionV3Test {

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @DynamicPropertySource // this does the magic
    static void setUp(DynamicPropertyRegistry registry) {
        registry.add("jdbc.driverClassName", mariaDB::getDriverClassName);
        registry.add("jdbc.url", mariaDB::getJdbcUrl);
        registry.add("jdbc.username", mariaDB::getUsername);
        registry.add("jdbc.password", mariaDB::getPassword);
    }

    @Autowired
    SingerRepo singerRepo;

    @Test
    void testFindAllQuery(){
        var singers = singerRepo.findAll();
        assertEquals(3, singers.size());
    }

    @Test
    void testStoredFunction(){
        var firstName = singerRepo.findFirstNameById(2L).orElse(null);
        assertEquals("Ben", firstName);
    }

    @Configuration
    @Import(BasicDataSourceCfg.class)
    public static class TestContainersConfig {

        @PostConstruct
        public void initialize() throws ScriptException, IOException {
            final String script1 = Resources.toString(Resources.getResource("testcontainers/
                create-schema.sql"), StandardCharsets.UTF_8);

```



```

        final String script2 = Resources.toString(Resources.getResource("testcontainers/
            original-stored-function.sql"), StandardCharsets.UTF_8);
        mariaDB.start();
        ScriptUtils.executeDatabaseScript(new JdbcDatabaseDelegate(mariaDB,""), "schema.
            sql", script1, false, false, ScriptUtils.DEFAULT_COMMENT_PREFIX,
                ScriptUtils.DEFAULT_STATEMENT_SEPARATOR, "$$", "$$$");
        ScriptUtils.executeDatabaseScript(new JdbcDatabaseDelegate(mariaDB,""), "schema.
            sql", script2, false, false, ScriptUtils.DEFAULT_COMMENT_PREFIX,
                ScriptUtils.DEFAULT_STATEMENT_SEPARATOR, "$$", "$$$");
    }
}
}

```

Copying the files onto the container can be done in more than one way, but the only way we've found that works with the MariaDB image used for this example is the one depicted in Listing 6-58. The code is not the prettiest, but it gets the job done.

To add Testcontainers support to your project, you need to add the library specific to the type of container image you need. For this book, the `org.testcontainers: mariadb:1.17.2` library was added to the Maven/Gradle configuration.

To benefit of JUnit Jupiter flawless integration provided by the `@Testcontainers` and the `@Container` annotations, the `org.testcontainers:junit-jupiter:1.17.2` library was added to the Maven/Gradle configuration.

There are other Testcontainers libraries available, and you can find them at the Maven Repository<sup>12</sup>.

## Considerations for Using JDBC

With this rich feature set, you can see how Spring can make your life much easier when using JDBC to interact with the underlying RDBMS. However, there is still quite a lot of code you need to develop, especially when transforming the result set into the corresponding domain objects.

On top of JDBC, a lot of open source libraries have been developed to help close the gap between the relational data structure and Java's OO model. For example, iBATIS is a popular DataMapper framework that is also based on SQL mapping. iBATIS lets you map objects with stored procedures or queries to an XML descriptor file. Like Spring, iBATIS provides a declarative way to query object mapping, greatly saving you the time it takes to maintain SQL queries that may be scattered around various DAO classes. There are also many other ORM frameworks that focus on the object model, rather than the query. Popular ones include Hibernate, EclipseLink (also known as TopLink), and OpenJPA. All of them comply with the JCP's JPA specification.

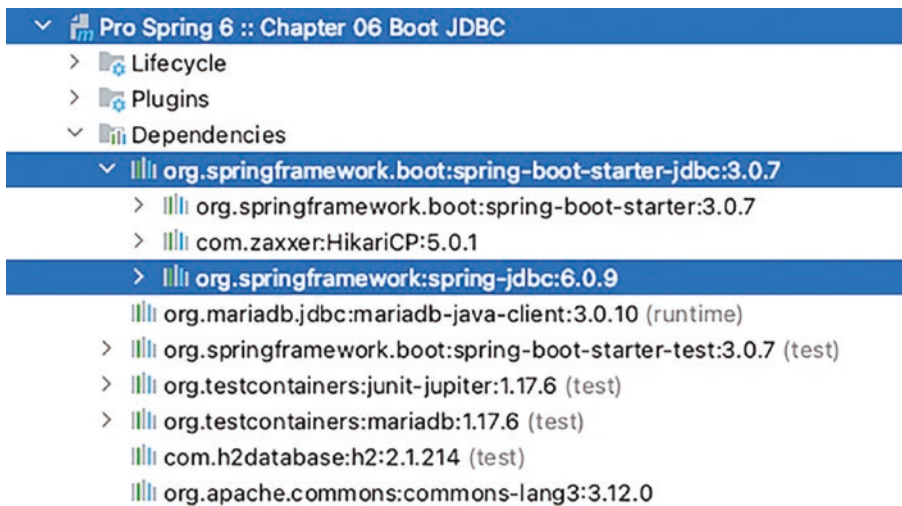
In recent years, these ORM tools and mapping frameworks have become much more mature so that most developers will settle on one of them, instead of using JDBC directly. However, in cases where you need to have absolute control over the query that will be submitted to the database for performance purposes (for example, using a hierarchical query in Oracle), Spring JDBC is really a viable option. And when using Spring, one great advantage is that you can mix and match different data access technologies. For example, you can use Hibernate as the main ORM and then JDBC as a supplement for some of the complex query logic or batch operations; you can mix and match them in a single business operation and then wrap them under the same database transaction. Spring will help you handle those situations easily.

<sup>12</sup><https://mvnrepository.com/artifact/org.testcontainers>

## Spring Boot JDBC

As we've already introduced Spring Boot for simple console applications, it is only logical to cover a Spring Boot starter library for JDBC in this book. It helps you remove boilerplate configurations and jump directly into implementation.

When `spring-boot-starter-jdbc` is added as a dependency to a project, a group of libraries is added to the classpath of the project. What is not added is a database driver. That decision must be taken by the developer. In this case, the `mysql-java-client` is added as a dependency just as for the non-Spring Boot project. In the same way, for running tests, the `h2` library must be explicitly configured. The project that will be covered in this section is `chapter06-boot`. The autoconfigured libraries are depicted in Figure 6-7 in the IntelliJ IDEA Gradle Projects view.



**Figure 6-7.** Spring Boot JDBC starter dependencies

The `spring-boot-starter-jdbc` library uses `HikariCP`<sup>13</sup> to configure the `DataSource` bean, which is a fast, reliable, and simple production-ready connection pool library. Thus, if there is no `DataSource` bean explicitly configured and there is an embedded database driver in the classpath, Spring Boot will automatically register the `DataSource` bean using in-memory database settings. Spring Boot also registers the following beans automatically:

- A `JdbcTemplate` bean
- A `NamedParameterJdbcTemplate` bean
- A `PlatformTransactionManager (DataSourceTransactionManager)` bean

The `PlatformTransactionManager` bean is not of interest at this time, since it is covered in **Chapter 7**. The first two are, since in this chapter we configured them manually, when Spring Boot was not used. Using Spring Boot that is no longer needed.

<sup>13</sup> <https://github.com/brettwooldridge/HikariCP>

Another interesting thing to note is that, to make sure the MariaDB datasource is used when running the application, and the H2 datasource is used for tests, two application profiles are used: "dev" and "test". Here are other things that might be interesting that reduce the amount of environment setup work:

- Spring Boot database connection details are configured in the `application-{profileName}.properties/application-{profileName}.yaml` file, which is located under `src/main/resources`. Listing 6-59 shows the configuration for the local containerized MariaDB database recommended in this chapter and the in-memory H2 configuration, used for tests.

**Listing 6-59.** MariaDB and H2 Database Connection Details for a Spring Boot Application

```
# application-dev.yaml
spring:
  datasource:
    driverClassName: org.mariadb.jdbc.Driver
    url: jdbc:mariadb://localhost:3306/musicdb?useSSL=false
    username: prospring6
    password: prospring6

# application-test.yaml
spring:
  datasource:
    url: "jdbc:h2:mem:mydb"
    username: "sa"
```

- Spring Boot looks for embedded database initialization files under `src/main/resources`. It expects to find a file named `schema.sql` that contains SQL DDL statements (for example, `CREATE TABLE` statements) and a file named `data.sql` that contains DML statements (for example, `INSERT` statements). It uses this file to initialize a database at boot time.
- The location and names for these files can be configured in the `application.properties/application.yaml` file, which is located under `src/main/resources` as well. A sample configuration file that would allow the Spring Boot application to use SQL files is shown in Listing 6-60.

**Listing 6-60.** Database Initialization Spring Boot Configurations

```
# application-{profileName}.properties
spring.datasource.schema=db/schema.sql
spring.datasource.data=db/test-data.sql

# application-{profileName}.yaml
spring:
  datasource:
    schema: db/schema.sql
    data: db/test-data.sql
```

- By default, Spring Boot initializes the database at boot time (unless already there), but this can be changed as well by adding the property `spring.datasource.initialize=false` to the application-`{profileName}.properties/application-{profileName}.yaml file.`

Aside from all that was mentioned, what is left to do with Spring Boot is to provide some domain classes and a DAO bean. As previously mentioned, Spring Boot automatically configures a `JdbcTemplate` bean automatically, so what we need to do is to create a simple `SingerJdbcRepo` this bean gets injected into and use it to manage data. As for domain classes, the `Singer` and `Album` records introduced previously in the chapter suffice. Listing 6-61 shows a simple `SingerRepo` interface and `SingerJdbcRepo` implementing it.

**Listing 6-61.** `SingerJdbcRepo` repository class and bean definition

```
// SingerDao.java
package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.records.Singer;
import java.util.stream.Stream;

public interface SingerRepo {
    Stream<Singer> findAll();
}

// SingerJdbcRepo.java
package com.apress.prospring6.six.repo;

import com.apress.prospring6.six.records.Singer;
import org.springframework.jdbc.core.JdbcTemplate;
import java.util.List;
import java.util.stream.Stream;
// other import statements omitted

@Repository("singerRepo")
public class SingerJdbcRepo implements SingerRepo {
    private static final Logger LOGGER = LoggerFactory.getLogger(SingerJdbcRepo.class);
    public static final String ALL_SELECT = "select * from SINGER";
    private JdbcTemplate jdbcTemplate;

    @Autowired
    public void setJdbcTemplate(JdbcTemplate jdbcTemplate) {
        this.jdbcTemplate = jdbcTemplate;
    }

    @Override
    public Stream<Singer> findAll() {
        return jdbcTemplate.queryForStream(ALL_SELECT, (rs, rowNum) ->
            new Singer(rs.getLong("id"),
                rs.getString("first_name"),
                rs.getString("last_name"),
                rs.getDate("birth_date"),
                List.of()));
    }
}
```

As you (maybe) remember, the Spring Boot entry class is an executable class. The `ApplicationContext` created when running its main class can be used to retrieve the `singerRepo` bean and call the `findAll()` method. With the configurations in Listing 6-59, file `application-dev.yaml`, the `findAll()` method will be executed on the MariaDB `musicdb` database `SINGER` table. The code for this class and its output when executed are shown in Listing 6-62.

**Listing 6-62.** Chapter6Application Spring Boot Main Class and Output Sample of Its Execution

```

package com.apress.prospring6.six;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
// other import statements omitted

@SpringBootApplication
public class Chapter6Application {
    private static final Logger LOGGER = LoggerFactory.getLogger(Chapter6Application.class);

    public static void main(String... args) {
        System.setProperty(AbstractEnvironment.ACTIVE_PROFILES_PROPERTY_NAME,
            "dev"); // (1)
        var ctx = SpringApplication.run(Chapter6Application.class, args);

        var repo = ctx.getBean(SingerRepo.class);
        repo.findAll().forEach(singer -> LOGGER.info(singer.toString()));
    }
}
# output
INFO : StartupInfoLogger - Starting Chapter6Application using Java 17 on IulianasPrimary
with PID 95259 ...
INFO : SpringApplication - The following 1 profile is active: "dev"
INFO : StartupInfoLogger - Started Chapter6Application in 2.027 seconds (JVM running
for 3.023)
INFO : HikariDataSource - HikariPool-1 - Starting...
INFO : HikariPool - HikariPool-1 - Added connection org.mariadb.jdbc.
Connection@2301b75 # (2)
INFO : HikariDataSource - HikariPool-1 - Start completed.
INFO : Chapter6Application - Singer[id=1, firstName=John, lastName=Mayer,
birthDate=1977-10-16, albums=[]]
INFO : Chapter6Application - Singer[id=2, firstName=Ben, lastName=Barnes,
birthDate=1981-08-20, albums=[]]
INFO : Chapter6Application - Singer[id=3, firstName=John, lastName=Butler,
birthDate=1975-04-01, albums=[]]
INFO : HikariDataSource - HikariPool-1 - Shutdown initiated...
INFO : HikariDataSource - HikariPool-1 - Shutdown completed.

```

The line marked with (1) at the end sets the profile to be `dev`, which allows us to just run the class and get the expected behavior, instead of supplying the profile as a program argument. The line marked with (2) shows the connection type printed in the log. This makes it clear where the records are coming from.

A Spring Boot test class can be easily written, and the embedded database is automatically created based on the configurations in Listing 6-59 (application-test.yaml), so all we are left to do is decorate the class and the test method with the @Sql\* annotations introduced earlier in the chapter to make sure test data is available. Listing 6-63 shows this test class and the result of executing it.

**Listing 6-63.** Chapter6ApplicationTest Spring Boot Test Class and Output Sample of Its Execution

```

package com.apress.prospring6.six;

import com.apress.prospring6.six.repo.SingerRepo;
import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.test.context.jdbc.Sql;
import org.springframework.test.context.jdbc.SqlConfig;
import org.springframework.test.context.jdbc.SqlMergeMode;
import org.springframework.test.context.ActiveProfiles;
// other import statements omitted

@ActiveProfiles("test") // (1)
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:h2/drop-schema.sql", "classpath:h2/create-schema.sql" })
@SpringBootTest
public class Chapter6ApplicationTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(Chapter6ApplicationTest.class);

    @Autowired
    SingerRepo singerRepo;

    @Test
    @DisplayName("should return all singers")
    @Sql(value = "classpath:h2/test-data.sql",
        config = @SqlConfig(encoding = "utf-8", separator = ";", commentPrefix = "--"),
        executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
    void testFindAllWithJdbcTemplate(){
        var singers = singerRepo.findAll().toList();
        assertEquals(3, singers.size());
        singers.forEach(singer -> LOGGER.info(singer.toString()));
    }
}
# output
INFO : StartupInfoLogger - Starting Chapter6ApplicationTest using Java 17 on
IulianasPrimary with PID 95805 ...
INFO : SpringApplication - The following 1 profile is active: "test"
INFO : HikariDataSource - HikariPool-1 - Starting...
INFO : HikariPool - HikariPool-1 - Added connection conn0: url=jdbc:h2:mem:mydb
user=SA // (2)
INFO : HikariDataSource - HikariPool-1 - Start completed.
INFO : Chapter6ApplicationTest - Singer[id=1, firstName=John, lastName=Mayer,
birthdate=1977-10-16, albums=[]]
INFO : Chapter6ApplicationTest - Singer[id=2, firstName=Ben, lastName=Barnes,
birthdate=1981-08-20, albums=[]]

```

```
INFO : Chapter6ApplicationTest - Singer[id=3, firstName=John, lastName=Butler,
birthdate=1975-04-01, albums=[]]
INFO : HikariDataSource - HikariPool-1 - Shutdown initiated...
INFO : HikariDataSource - HikariPool-1 - Shutdown completed.
```

The line marked with (1) sets the profile to be `test`, which allows us to just run the test class using the test profile, meaning the `datasource` configured in the `application-test.yaml` is used. The line marked with (2) shows the connection type printed in the log. This makes it clear where the records are coming from.

What about Testcontainers? Does it work with Spring Boot? The answer is *yes*, and the setup is even easier because it benefits a lot from the Spring Boot autoconfiguration. The approach to using Testcontainers in Spring Boot tests can be similar to what we did for Spring classic applications, but there is another way that will result in a database instance per test class being created. After adding the Testcontainers libraries mentioned previously in the chapter to the Spring Boot application classpath, the `spring.datasource.url` property can be set in the configuration file to `jdbc:tc:mariadb:10.7.4-focal:///testdb`. The `tc:` after the `jdbc:` prefix will make Testcontainers instantiate database instances without any code change. Hostname, port, and database name are ignored; you can set them to custom values or leave them as they are. The `///` are used to emphasize the unimportance of the `host:port` pair.

To keep test contexts separated in the project, we introduced the `testcontainers` profile with its corresponding `application-testcontainers.yaml` configuration file, depicted in Listing 6-64.

**Listing 6-64.** The Contents of the `application-testcontainers.yaml` Configuration File

```
spring:
  datasource:
    url: "jdbc:tc:mariadb:10.7.4-focal:///musicdb"

# Logging config
logging:
  pattern:
    console: "%-5level: %class{0} - %msg%n"
  level:
    root: INFO
    org.springframework.boot: DEBUG
    com.apress.prospring6.six: DEBUG
    org.testcontainers: DEBUG
```

Using this profile and configuration file, a Spring Boot test class is written that is almost identical to the one in Listing 6-63. The only difference are that the `testcontainers` profile is used and the scripts preparing the database for tests are MariaDB scripts. The test class is shown in Listing 6-65.

**Listing 6-65.** The Contents of the `Chapter6ApplicationV2Test` Configuration File

```
package com.apress.prospring6.six;

import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.test.context.ActiveProfiles;
import org.springframework.test.context.jdbc.Sql;
import org.springframework.test.context.jdbc.SqlConfig;
import org.testcontainers.junit.jupiter.Testcontainers;
// other imports omitted

@ActiveProfiles("testcontainers")
```

```

@Testcontainers
@Sql(value = "classpath:testcontainers/create-schema.sql",
      config = @SqlConfig(encoding = "utf-8", separator = ";", commentPrefix = "--"),
      executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
@SpringBootTest(classes = Chapter6Application.class)
public class Chapter6ApplicationV2Test {

    private static final Logger LOGGER = LoggerFactory.getLogger(Chapter6ApplicationV2Test.class);

    @Autowired
    SingerRepo singerRepo;

    @Test
    @DisplayName("should return all singers")
    void testFindAllWithJdbcTemplate(){
        var singers = singerRepo.findAll().toList();
        assertEquals(3, singers.size());
        singers.forEach(singer -> LOGGER.info(singer.toString()));
    }

    @Test
    @DisplayName("find singer by name")
    @Sql({ "classpath:testcontainers/stored-function.sql" })
    void testStoredFunction(){
        var firstName = singerRepo.findFirstNameById(2L).orElse(null);
        assertEquals("Ben", firstName);
    }
}

```

Notice that there's no need to use `@DynamicPropertySource` to register dynamic properties for the `spring.datasource.*` property group. In the `Chapter6ApplicationV2Test`, the script to initialize the database was configured on the test class using a `@Sql` annotation, but the test script can be configured using the `TC_INITSCRIPT` variable inside the `spring.datasource.url` value. So, in the `application-testcontainers.yaml` configuration file, the `spring.datasource.url` property can be set to the following:

```
jdbc:tc:mariadb:10.7.4-focal:///testdb?TC_INITSCRIPT=testcontainers/create-schema.sql
```

Also, the `@Sql` annotation can be removed from the `Chapter6ApplicationV2Test` class and the tests will still pass, because `Testcontainers` is looking for that initialization script on the classpath. You can also point to a location relative to the working directory, which will usually be the project root, using `file:`.

We encourage you to read more about `Testcontainers`; it provides a very practical way to write integration tests that run on a setup very similar to production and prove that the code being written will have the expected results in a production environment as well. In this book, whenever a database is needed for running tests, `Testcontainers` is recommended.



## Summary

This chapter showed you how to use Spring to simplify JDBC programming. You learned how to connect to a database and perform selects, updates, deletes, and inserts, as well as call database stored functions. In production, using the `DataSource` bean or `JdbcTemplate` is rarely needed. This might be needed only if you have a very complex query, or a stored procedure or function to execute. Regardless, we covered `JdbcTemplate` and other Spring classes that are built on top of `JdbcTemplate` and that help you model various JDBC operations. We also showed how to use the new lambda expressions from Java 8 where appropriate. And because code is written by humans, and humans are not infallible, you were shown how to test your JDBC code in Spring Classic and Spring Boot applications.

In addition, Spring Boot JDBC was covered, because whatever helps you focus more on the implementation of the business logic of an application and less on the configurations is a great tool to know. In the next couple of chapters, we discuss how to use Spring with popular ORM technologies when developing data access logic and how to interact with NoSQL databases.

## CHAPTER 7



# Spring with Hibernate

**Chapter 6** introduced you to how to use JDBC drivers to communicate to SQL databases. However, even though Spring goes a long way toward simplifying JDBC development, you still have a lot of code to write. To avoid this and provide support for easier querying, persistence frameworks were invented, such as MyBatis<sup>1</sup> and Hibernate<sup>2</sup>. jOOQ<sup>3</sup>, one of the most recent libraries to emerge, is a database-mapping software library that generates Java code from your database and lets you build type-safe SQL queries through its fluent API. Some users have reported positive experiences when combining jOOQ with Hibernate, letting Hibernate do the tedious CRUD work, and jOOQ the complex querying and reporting through its sophisticated, yet intuitive query DSL. This chapter focuses mostly on Hibernate, one of the most commonly used object-relational mapping (ORM) libraries, but given its potential, jOOQ is going to be introduced as well. In **Chapter 6**, working with Java and databases was compared to the *I Love Lucy* episode “Paris at Last,” where three translators were needed to resolve a misunderstanding. If JDBC was the first translator, Hibernate is the second.

If you have experience developing data access applications using EJB entity beans (prior to EJB 3.0), you may remember the painful process. Tedious configuration of mappings, transaction demarcation, and much boilerplate code in each bean to manage its life cycle greatly reduced productivity when developing enterprise Java applications. Just like Spring was developed to embrace POJO-based development and declarative configuration management rather than EJB’s heavy and clumsy setup, the developer community realized that a simpler, lightweight, and POJO-based framework could ease the development of data access logic. Since then, many libraries have appeared; they are generally referred to as ORM libraries. The main objectives of an ORM library are to close the gap between the relational data structure in the relational database management system (RDBMS) and the object-oriented (OO) model in Java so that developers can focus on programming with the object model and at the same time easily perform actions related to persistence.

Among the many ORM libraries available in the open source community, Hibernate is one of the most successful. Its features, such as a POJO-based approach, ease of development, and support of sophisticated relationship definitions, have won the heart of the mainstream Java developer community. Hibernate’s popularity has also influenced the Java Community Process (JCP), which developed the Java Data Objects (JDO) specification as one of the standard ORM technologies in Java EE. Starting from EJB 3.0, the EJB entity bean was even replaced with the Java Persistence API (JPA). JPA has a lot of concepts that were influenced by popular ORM libraries such as Hibernate, TopLink, and JDO. The relationship between Hibernate and

---

<sup>1</sup><https://mybatis.org/mybatis-3>

<sup>2</sup><https://hibernate.org>

<sup>3</sup><https://www.jooq.org>

JPA is also very close. Gavin King, the founder of Hibernate, represented JBoss as one of the JCP expert group members in defining the JPA specification. Starting from version 3.2, Hibernate provides an implementation of JPA. That means when you develop applications with Hibernate, you can choose to use either Hibernate's own API or the JPA API with Hibernate as the persistence service provider.

Having offered a brief history of Hibernate, this chapter will cover how to use Spring with Hibernate when developing data access logic. Hibernate is such an extensive ORM library that covering every aspect in just one chapter is simply not possible, and numerous books are dedicated to discussing Hibernate.

This chapter covers the basic ideas and main use cases of Hibernate in Spring. In particular, we discuss the following topics:

- *Configuring Hibernate SessionFactory*: The core concept of Hibernate revolves around the `Session` interface, which is managed by `SessionFactory`. We show you how to configure Hibernate's session factory to work in a Spring application.
- *Major concepts of ORMs using Hibernate*: We go through the major concepts of how to use Hibernate to map a POJO to the underlying relational database structure. We also discuss some commonly used relationships, including one-to-many and many-to-many.
- *Data operations*: We present examples of how to perform data operations (query, insert, update, delete) by using Hibernate in the Spring environment. When working with Hibernate, its `Session` interface is the main interface that you will interact with.

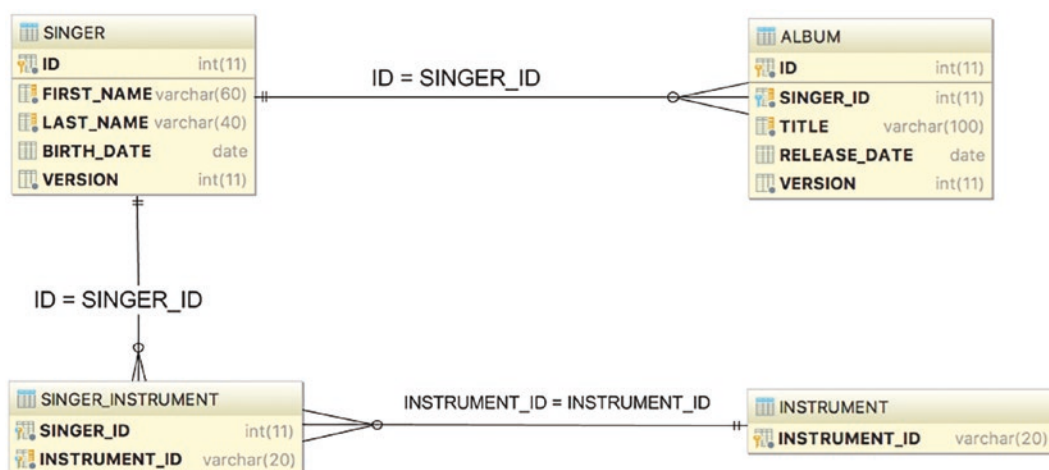


When defining object-to-relational mappings, Hibernate supports two configuration styles. One is to configure the mapping information in XML files, and the other is to use Java annotations within the entity classes (in the ORM or JPA world, a Java class that is mapped to the underlying relational database structure is called an *entity class*). This chapter focuses on using the annotation approach for object-relational mapping. For the mapping annotation, we use the JPA standards (for example, under the `jakarta.persistence` package) because they are interchangeable with Hibernate's own annotations and will help you with future migrations to a JPA environment.

---

## Sample Data Model for Example Code

Figure 7-1 shows the data model used in this chapter.



**Figure 7-1.** Sample data model

As shown in this data model, two new tables were added, namely, `INSTRUMENT` and `SINGER_INSTRUMENT` (the join table). `SINGER_INSTRUMENT` models the many-to-many relationships between the `SINGER` and `INSTRUMENT` tables. A `VERSION` column was added to the `SINGER` and `ALBUM` tables for optimistic locking, which will be discussed in detail later.



In the examples in this chapter, we will use MariaDB in a Docker container manually built to simulate a local instance available on port 3306 for production-like code. The instructions for building the image and starting the container are provided in the project repository through the `chapter07/CHAPTER07.adoc` file. A Testcontainers MariaDB instance container is used for testing.

---

## Configuring Hibernate's SessionFactory

As mentioned earlier in this chapter, the core concept of Hibernate is based on the `org.hibernate.Session` interface, which is obtained from `org.hibernate.SessionFactory`. Spring provides classes to support the configuration of Hibernate's session factory as a Spring bean with the desired properties. To use Hibernate, you must add the `hibernate-core-jakarta` library as a dependency to the project. To integrate it with Spring, `spring-orm` must be added as a dependency as well.



As this chapter is being written, the most recent Hibernate version compatible with Spring ORM is `5.6.9.Final`. Hibernate `6.1.0.Final` has already been released, but Spring ORM does not currently support it.

---



The reason why `hibernate-core-jakarta` is used as a dependency instead of `hibernate-core` is because of its dependency of Java Persistence API, which is part of Java EE. Oracle made Java EE open source and gave the rights over it to the Eclipse Foundation, which was legally required to change the package name from `java`, as Oracle legally owns the Java brand now. So newer versions of Hibernate use package name `jakarta.*` instead of `javax.*`.

The Spring Hibernate configuration is built on top of a `DataSource` configuration. The `DataSource` configuration was already introduced in **Chapter 6**. Apache DBCP2 was used to set up connection pooling, but in this chapter, to keep things interesting, we replaced this library with `hikariCP.jar`. The HikariCP<sup>4</sup> GitHub main page shows various benchmark results proving this library to be the most efficient connection pooling library there is. With the purpose of improving performance and enriching the collection tools, we decided to add this dependency for the project in this chapter. From a configuration point of view, not much changes: the class that needs to be configured is named `HikariDataSource` instead of `BasicDataSource`, and it comes from the `com.zaxxer.hikari` package.

Listing 7-1 shows the new and improved `BasicDataSourceCfg` configuration class.

**Listing 7-1.** MariaDB `DataSource` Configuration Class

```
package com.apress.prospring6.seven.base.config;

import com.zaxxer.hikari.HikariConfig;
import com.zaxxer.hikari.HikariDataSource;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.Profile;
import org.springframework.context.annotation.PropertySource;

import javax.sql.DataSource;

@Configuration
@PropertySource("classpath:db/jdbc.properties") // file already introduced in Chapter 6
public class BasicDataSourceCfg {
    private static Logger LOGGER = LoggerFactory.getLogger(BasicDataSourceCfg.class);
    @Value("${jdbc.driverClassName}")
    private String driverClassName;

    @Value("${jdbc.url}")
    private String url;

    @Value("${jdbc.username}")
    private String username;
```

<sup>4</sup><https://github.com/brettwooldridge/HikariCP>

```

@Value("${jdbc.password}")
private String password;

@Bean(destroyMethod = "close")
public DataSource dataSource() {
    try {
        var hc = new HikariConfig();
        hc.setJdbcUrl(url);
        hc.setDriverClassName(driverClassName);
        hc.setUsername(username);
        hc.setPassword(password);
        var dataSource= new HikariDataSource(hc);
        dataSource.setMaximumPoolSize(25); // 25 is a good enough data pool size, it is
        a database in a container after all
        return dataSource;
    } catch (Exception e) {
        LOGGER.error("DBCP DataSource bean cannot be created!", e);
        return null;
    }
}
}

```

Since we are using Testcontainers, replacement of the production-like DataSource bean with a MariaDB test container can easily be done as it was shown in [Chapter 6](#).

Listing 7-2 shows the HibernateConfig class that groups Hibernate-specific configurations.

**Listing 7-2.** HibernateConfig Configuration Class

```

package com.apress.prospring6.seven.base.config;

import org.hibernate.cfg.Environment;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.ComponentScan;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.Import;
import org.springframework.orm.hibernate5.HibernateTransactionManager;
import org.springframework.orm.hibernate5.LocalSessionFactoryBean;
import org.springframework.transaction.PlatformTransactionManager;
import org.springframework.transaction.annotation.EnableTransactionManagement;

import javax.sql.DataSource;
import java.util.Properties;

@Import(BasicDataSourceCfg.class)
@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.seven.base"})
@EnableTransactionManagement
public class HibernateConfig {
    private static Logger LOGGER = LoggerFactory.getLogger(HibernateConfig.class);

```

```

@Autowired
DataSource dataSource;

@Bean
public Properties hibernateProperties() {
    Properties hibernateProp = new Properties();
    // hibernateProp.put(Environment.DIALECT, "org.hibernate.dialect.
    MariaDB106Dialect ");
    hibernateProp.put(Environment.HBM2DDL_AUTO, "none");
    hibernateProp.put(Environment.FORMAT_SQL, false);
    hibernateProp.put(Environment.USE_SQL_COMMENTS, false);
    hibernateProp.put(Environment.SHOW_SQL, false);
    hibernateProp.put(Environment.MAX_FETCH_DEPTH, 3);
    hibernateProp.put(Environment.STATEMENT_BATCH_SIZE, 10);
    hibernateProp.put(Environment.STATEMENT_FETCH_SIZE, 50);
    // hibernateProp.put(Environment.JTA_PLATFORM, "org.springframework.orm.hibernate5.
    ConfigurableJtaPlatform");
    return hibernateProp;
}

@Bean
public LocalSessionFactoryBean sessionFactory() {
    LocalSessionFactoryBean sessionFactory = new LocalSessionFactoryBean();
    sessionFactory.setDataSource(dataSource);
    sessionFactory
        .setPackagesToScan("com.apress.prospring6.seven.base.entities");
    sessionFactory.setHibernateProperties(hibernateProperties());
    return sessionFactory;
}

@Bean public PlatformTransactionManager transactionManager() {
    var transactionManager = new HibernateTransactionManager();
    transactionManager.setSessionFactory(sessionFactory().getObject());
    return transactionManager;
}
}

```

The Spring Hibernate configuration declares the following beans to support Hibernate's session factory:

- **dataSource**: This bean is imported from the `BasicDataSourceCfg` configuration class using the `@Import` annotation and injected into the `HibernateConfig` class using autowiring.
- **transactionManager**: The Hibernate session factory requires a transaction manager for transactional data access. Spring provides a transaction manager specifically for Hibernate 5 declared in package `org.springframework.orm.hibernate5.HibernateTransactionManager`. The bean was declared with the `transactionManager` name. By default, when using XML configuration, Spring will look up the bean with the name `transactionManager` within its `ApplicationContext` whenever transaction management is required. Java configuration is a little more flexible because the bean is being searched by its type, not by its name. We discuss transactions in detail in **Chapter 9**. In addition, the configuration class is annotated with `@EnableTransactionManagement` to support the declaration of transaction demarcation requirements using annotations (enables support for Spring's `@Transactional`).

- *Component scan*: The `@ComponentScan` annotation should be familiar to you from the previous chapters. We use it to instruct Spring to scan the components under the package `com.apress.prospring6.seven` (not configured explicitly since this is the package the configuration class is declared in) to detect the beans annotated with `@Repository`, which contain methods for accessing data.
- *SessionFactory*: The Hibernate `sessionFactory` bean is the most important part of this configuration. Within the bean, several properties are configured:
  - First, we need to inject the `dataSource` bean into the `sessionFactory` bean.
  - Second, we instruct Hibernate to scan for the domain objects under the package `com.apress.prospring6.seven.entities`.
  - Finally, the `hibernateProperties` bean provides configuration details for Hibernate. There are many configuration parameters, and we define only a few important properties that should be provided for every application. Table 7-1 lists the configuration properties for the Hibernate session factory in our example, the constant names and their String values; you can find the other properties in interface `org.hibernate.cfg.AvailableSettings`, which is implemented by `org.hibernate.cfg.Environment`.

**Table 7-1.** *Hibernate Properties*

Property (Constant/Value)	Description
<code>Environment.FORMAT_SQL/hibernate.format_sql</code>	Indicates whether SQL output in the log or console should be formatted. Default value is <code>false</code> .
<code>Environment.USE_SQL_COMMENTS/hibernate.use_sql_comments</code>	If set to <code>true</code> , Hibernate generates comments inside the SQL for easier debugging. Default value is <code>false</code> .
<code>Environment.SHOW_SQL/hibernate.show_sql</code>	Indicates whether Hibernate should output the SQL queries to the logfile or console. You should turn this on in a development environment, which can greatly help in the testing and troubleshooting process. Default value is <code>false</code> .
<code>Environment.MAX_FETCH_DEPTH/hibernate.max_fetch_depth</code>	Declares the “depth” for outer joins when the mapping objects have associations with other mapped objects. This setting prevents Hibernate from fetching too much data with a lot of nested associations. A commonly used value is 3. A value of 0 disables default outer join fetching.
<code>Environment.STATEMENT_BATCH_SIZE/hibernate.jdbc.batch_size</code>	Instructs Hibernate on the number of update operations that should be grouped together into a batch. This is useful for performing batch job operations in Hibernate. Obviously, when we are doing a batch job updating hundreds of thousands of records, we would like Hibernate to group the queries in batches, rather than submit the updates one by one. The recommended value is between 5 and 30.

*(continued)*



**Table 7-1.** (continued)

Property (Constant/Value)	Description
<code>Environment.STATEMENT_FETCH_SIZE/hibernate.jdbc.fetch_size</code>	Specifies the number of records from the underlying JDBC <code>ResultSet</code> that Hibernate should use to retrieve the records from the database for each fetch. For example, a query was submitted to the database, and <code>ResultSet</code> contains 500 records. If the fetch size is set to 50, Hibernate will need to fetch ten times to get all the data.
<code>Environment.JTA_PLATFORM/hibernate.transaction.jta.platform</code>	This property, when present, should be set to a qualified class name representing an implementation of <code>org.hibernate.engine.transaction.jta.platform.spi.JtaPlatform</code> that defines how Hibernate interacts with JTA on a certain platform. If not present, Hibernate uses default <code>org.hibernate.engine.transaction.jta.platform.internal.NoJtaPlatform</code> , which means no transactions are used. In our configuration, it is set to Spring's <code>ConfigurableJtaPlatform</code> implementation. Since this chapter does not focus on transactions, this property can be safely removed from the configuration.
<code>Environment.HBM2DDL_AUTO/hibernate.hbm2ddl.auto</code>	Traditionally, the process of generating schema from entity mapping has been called HBM2DDL. This property can have any of the following values: <ul style="list-style-type: none"> <li>• <code>* none</code> tells Hibernate to do nothing with the existing schema.</li> <li>• <code>* create</code> tells Hibernate to generate the schema matching the managed entity classes.</li> <li>• <code>* validate</code> tells Hibernate to validate the schema; it makes no changes to the database.</li> <li>• <code>* update</code> tells Hibernate to update the schema, according to the changes made to the entity classes.</li> <li>• <code>* create-drop</code> tells Hibernate to create the schema matching the managed entity classes and drop the schema when the <code>SessionFactory</code> is closed explicitly, typically when the application is stopped.</li> </ul>

For the full list of properties that Hibernate supports, please refer to Hibernate's ORM user guide<sup>5</sup>, specifically, Section 24.2.

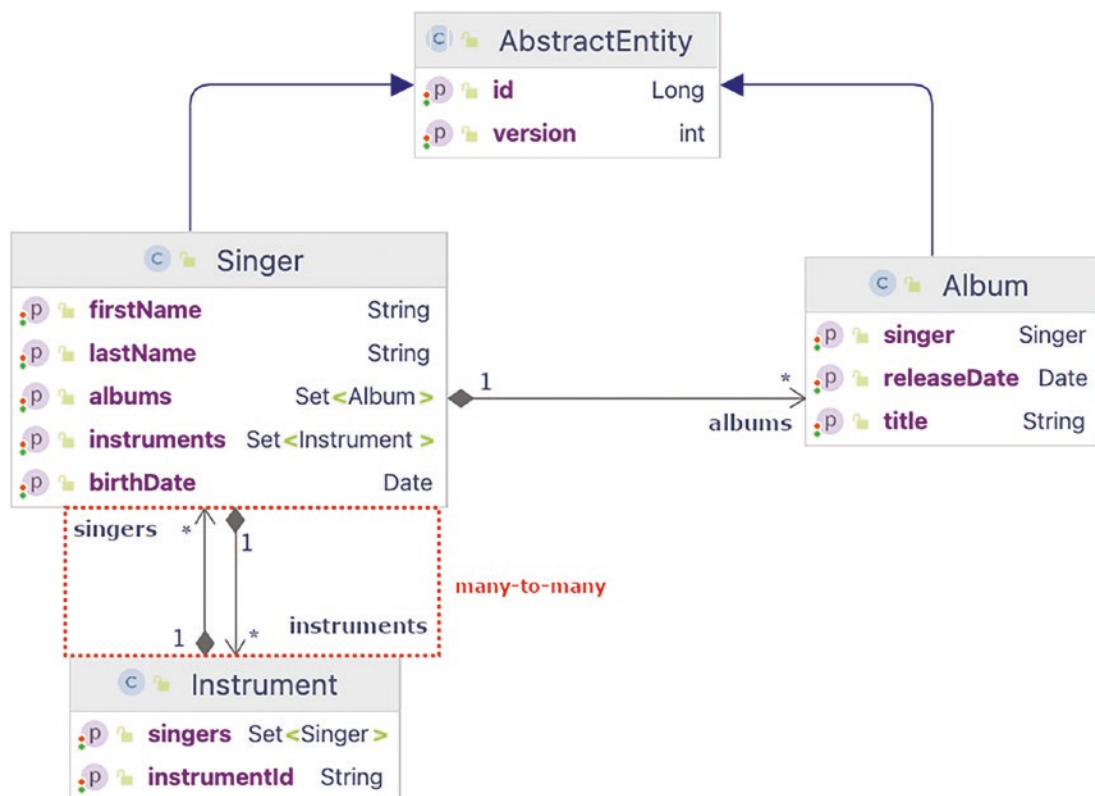
## ORM Mapping Using Hibernate Annotations

Having the configuration in place, the next step is to model the Java POJO entity classes and their mapping to the underlying relational data structure.

<sup>5</sup>[https://docs.jboss.org/hibernate/orm/5.6/userguide/html\\_single/Hibernate\\_User\\_Guide.html#configurations-general](https://docs.jboss.org/hibernate/orm/5.6/userguide/html_single/Hibernate_User_Guide.html#configurations-general)

There are two approaches to the mapping. The first one is to design the object model and then generate the database scripts based on the object model. Configuring the Hibernate property `hibernate.hbm2ddl.auto` to `create` or `create-drop` takes care of this approach. However, this approach is not suitable for production environments, but rather for test environments that use in-memory databases, for which generating the tables based on Java POJOs is not a costly operation.

The second approach is to start with the data model (the tables) and then model the POJOs with the desired mappings. The latter approach is recommended for development and production environments, because it provides more control over the data model, which is useful in optimizing the performance of data access. Based on the data model, Figure 7-2 shows the corresponding Java object model class diagram.



**Figure 7-2.** Class diagram for the sample data model

You can see there is a one-to-many relationship between Singer and Album, and there's a many-to-many relationship between the Singer and Instrument objects. The table that models the many-to-many relationship, the `SINGER_INSTRUMENT`, is not mapped to a Java class.

Notice that also Singer and Album have the `id` and `version` fields in common, and they are grouped into an abstract class named `AbstractEntity` to simplify the other entity classes. In production applications where auditing is usually set up, other fields that are part of this abstract class could be any of the following: `createdAt`, `updatedAt`, `createdBy`, `updatedBy`, and so on. The `AbstractEntity` class is annotated with the `@MappedSuperclass` annotation that designates a class whose mapping information is applied to the entities that inherit from it.

## Simple Mappings

First let's start by mapping the simple attributes of the class. Listing 7-3 shows the `AbstractEntity` class with the mapping information inherited by `Singer` and `Album`.

**Listing 7-3.** `AbstractEntity` Base Entity Class

```

package com.apress.prospring6.seven.base.entities;

import jakarta.persistence.Column;
import jakarta.persistence.GeneratedValue;
import jakarta.persistence.Id;
import jakarta.persistence.MappedSuperclass;
import jakarta.persistence.Version;
// other import statements omitted

import static jakarta.persistence.GenerationType.IDENTITY;

@MappedSuperclass
public abstract class AbstractEntity implements Serializable {
    @Serial
    private static final long serialVersionUID = 1L;

    protected Long id;
    protected int version;

    @Id
    @GeneratedValue(strategy = IDENTITY)
    @Column(name = "ID")
    public Long getId() {
        return this.id;
    }

    public void setId(Long id) {
        this.id = id;
    }

    @Version
    @Column(name = "VERSION")
    public int getVersion() {
        return version;
    }

    public void setVersion(int version) {
        this.version = version;
    }
    // other methods omitted
}

```

The `AbstractEntity` class does not map to any table, but annotations used in its configuration might be used in classes mapped to tables as well.

Listing 7-4 shows the Singer class with its mapping annotations.

**Listing 7-4.** Singer Entity Class

```

package com.apress.prospring6.seven.base.entities;

import jakarta.persistence.Column;
import jakarta.persistence.Entity;
import jakarta.persistence.Table;
// other import statements omitted

@Entity
@Table(name = "SINGER")
public class Singer extends AbstractEntity {
    @Serial
    private static final long serialVersionUID = 2L;

    private String firstName;
    private String lastName;
    private LocalDate birthDate;

    @Column(name = "FIRST_NAME")
    public String getFirstName() {
        return this.firstName;
    }

    @Column(name = "LAST_NAME")
    public String getLastName() {
        return this.lastName;
    }

    @Column(name = "BIRTH_DATE")
    public LocalDate getBirthDate() {
        return birthDate;
    }

    public void setFirstName(String firstName) {
        this.firstName = firstName;
    }

    public void setLastName(String lastName) {
        this.lastName = lastName;
    }

    public void setBirthDate(LocalDate birthDate) {
        this.birthDate = birthDate;
    }

    // other methods omitted
}

```

First, we annotate the type with `@Entity`, which means that this is a mapped entity class. Also, a class annotated with `@Entity` must have a column annotated with `@Id`, this column representing the primary key of that table. The `@Table` annotation defines the table name in the database that this entity is being mapped to. For each mapped attribute, you annotate it with the `@Column` annotation, with the column names provided.



Table and column names can be skipped if the type and attribute names are the same as the table and column names.

---

Here are a few highlights of this configuration:

- For the `id` attribute, we annotate it with `@Id`. This means it is mapped to the primary key of the record. Hibernate will use it as the unique identifier when managing the contact entity instances within its session. Additionally, the `@GeneratedValue` annotation tells Hibernate how the `id` value was generated. The `IDENTITY` strategy means that the `id` value was generated by the back end during insert.
- For the `version` attribute, we annotate it with `@Version`. This instructs Hibernate that we would like to use an *optimistic locking* mechanism, using the `version` attribute as a control. Every time Hibernate updates a record, it compares the version of the entity instance to that of the record in the database. If both versions are the same, it means that no one updated the data before, thus Hibernate will update the data and increment the `version` column. However, if the version is not the same, it means that someone has updated the record before, and Hibernate will throw a `StaleObjectStateException` exception, which Spring will translate to `HibernateOptimisticLockingFailureException`. In this example we used an `Integer` for version control. In addition to an `integer`, Hibernate supports using a `timestamp`. However, using an `integer` for version control is recommended since Hibernate will always increment the version number by 1 after each update. When using a `timestamp`, Hibernate will update the latest `timestamp` after each update. A `timestamp` is slightly less safe because two concurrent transactions may both load and update the same item in the same millisecond.

Another mapped object is `Album`, as shown in Listing 7-5.

**Listing 7-5.** Album Entity Class

```
package com.apress.prospring6.seven.base.entities;

// other import statements omitted

@Entity
@Table(name = "ALBUM")
public class Album extends AbstractEntity {
    @Serial
    private static final long serialVersionUID = 3L;

    private String title;
    private LocalDate releaseDate;
```

```

@Column
public String getTitle() {
    return this.title;
}

@Column(name = "RELEASE_DATE")
public LocalDate getReleaseDate() {
    return this.releaseDate;
}

public void setTitle(String title) {
    this.title = title;
}

public void setReleaseDate(LocalDate releaseDate) {
    this.releaseDate = releaseDate;
}

// other methods omitted
}

```

The third entity class is named `Instrument` and maps to the `INSTRUMENT` table, a very simple table with a single column. This table was introduced just so that a many-to-many relationship is part of the code samples. This class is shown in Listing 7-6.

**Listing 7-6.** Instrument Entity Class

```

package com.apress.prospring6.seven.base.entities;

// import statements omitted

@Entity
@Table(name = "INSTRUMENT")
public class Instrument implements Serializable {
    @Serial
    private static final long serialVersionUID = 4L;
    private String instrumentId;

    @Id
    @Column(name = "INSTRUMENT_ID")
    public String getInstrumentId() {
        return this.instrumentId;
    }

    public void setInstrumentId(String instrumentId) {
        this.instrumentId = instrumentId;
    }

    // other methods omitted
}

```

## One-to-Many Mappings

Hibernate has the capability to model many kinds of associations. The most common associations are one-to-many and many-to-many. In this chapter's source examples, each `Singer` has zero or more albums, so it's a one-to-many association (in ORM terms, the one-to-many association is used to model both zero-to-many and one-to-many relationships within the data structure). Listing 7-7 depicts the properties and the methods necessary to define the one-to-many relationship between the `Singer` and `Album` entities.

**Listing 7-7.** `Singer` and `Album` Code Snippets Used to Model One-to-Many and Many-to-One Relationships

```

package com.apress.prospring6.seven.base.entities;

import jakarta.persistence.OneToOne;
import jakarta.persistence.CascadeType;
// other import statements omitted

// Singer.java
@Entity
@Table(name = "SINGER")
public class Singer extends AbstractEntity {
    private Set<Album> albums = new HashSet<>();

    @OneToOne(mappedBy = "singer", cascade=CascadeType.ALL, orphanRemoval=true)
    public Set<Album> getAlbums() {
        return albums;
    }

    public boolean addAlbum(Album album) {
        album.setSinger(this);
        return getAlbums().add(album);
    }

    public void removeAlbum(Album album) {
        getAlbums().remove(album);
    }

    public void setAlbums(Set<Album> albums) {
        this.albums = albums;
    }
    // other methods and properties omitted
}

// Album.java

import jakarta.persistence.ManyToOne;
import jakarta.persistence.JoinColumn;
// other import statements omitted

@Entity
@Table(name = "ALBUM")
public class Album extends AbstractEntity {
    private Singer singer;

```

```

@ManyToOne
@JoinColumn(name = "SINGER_ID")
public Singer getSinger() {
    return this.singer;
}

public void setSinger(Singer singer) {
    this.singer = singer;
}
// other methods and properties omitted
}

```

The getter method of the attribute `getAlbums` is annotated with `@OneToMany`, which indicates the one-to-many relationship with the `Album` class. Several attributes are passed to the annotation. The `mappedBy` attribute indicates the property in the `Album` class that provides the association (that is, linked up by the foreign-key definition in the `FK_ALBUM_SINGER` table).

The cascade attribute set to `CascadeType.ALL` means that any operation done on the `Singer` record are propagated to albums linked to it. The `orphanRemoval` attribute means that after the albums set has been updated, the `Album` entries that no longer exist in the set should be deleted from the database.

The `Singer` class declares the one-to-many part of the relationship with `Album`. This means the `Album` entity must declare the many-to-one part of the relationship with `Singer`, and this is done using the `@ManyToOne` annotation. The `@JoinColumn` annotation associated with it is necessary to specify the underlying foreign-key column name.

## Many-to-Many Mappings

Every singer can play zero or more instruments, and each instrument is also associated with zero or more singers, which means it's a many-to-many mapping. A many-to-many mapping requires a join table, which is `SINGER_INSTRUMENT` in this case. Listing 7-8 shows the code that needs to be added to the `Singer` class to implement this relationship.

**Listing 7-8.** Singer and Instrument Code Snippets Used to Model Many-to-Many Relationships

```

package com.apress.prospring6.seven.base.entities;

import jakarta.persistence.ManyToMany;
import jakarta.persistence.JoinTable;
import jakarta.persistence.JoinColumn;
// other import statements omitted

// Singer.java
@Entity
@Table(name = "SINGER")
public class Singer extends AbstractEntity {
    private Set<Instrument> instruments = new HashSet<>();

    @ManyToMany
    @JoinTable(name = "SINGER_INSTRUMENT",
        joinColumns = @JoinColumn(name = "SINGER_ID"),
        inverseJoinColumns = @JoinColumn(name = "INSTRUMENT_ID"))

```



```

    public Set<Instrument> getInstruments() {
        return instruments;
    }

    public void setInstruments(Set<Instrument> instruments) {
        this.instruments = instruments;
    }

    public boolean addInstrument(Instrument instrument) {
        return getInstruments().add(instrument);
    }
    // other methods omitted
}

// Instrument.java
@Entity
@Table(name = "INSTRUMENT")
public class Instrument implements Serializable {

    private Set<Singer> singers = new HashSet<>();

    @ManyToMany
    @JoinTable(name = "SINGER_INSTRUMENT",
        joinColumns = @JoinColumn(name = "INSTRUMENT_ID"),
        inverseJoinColumns = @JoinColumn(name = "SINGER_ID"))
    public Set<Singer> getSingers() {
        return this.singers;
    }

    public void setSingers(Set<Singer> singers) {
        this.singers = singers;
    }
    // other methods omitted
}

```

The getter method of the attribute `instruments` in the `Singer` class is annotated with `@ManyToMany`. The `@JoinTable` annotation is used to indicate the underlying join table that Hibernate should look for. The name is the join table's name, `joinColumns` defines the column that is the foreign key to the `SINGER` table, and `inverseJoinColumns` defines the column that is the foreign key to the other side of the association (that is, the `INSTRUMENT` table). The code in the `Instrument` class is more or less the same as the one for `Singer`, but the `joinColumns` and `inverseJoinColumns` attributes are reversed to reflect the association.

## The Hibernate Session Interface

In Hibernate, when interacting with the database, the main interface you need to deal with is the `Session` interface, which is obtained from an instance of `SessionFactory`. A `SessionFactory` instance is created and added to the application context and this is caused by configuring a `LocalSessionFactoryBean` as shown in the `HibernateConfig` class introduced earlier in the chapter (see Listing 7-2). This instance can then be autowired in repository classes and used to create a `Hibernate Session` used to communicate with the database. Listing 7-9 shows the `SingerDaoImpl` class that is used in the samples in this chapter and has the configured `Hibernate SessionFactory` injected into the class.

**Listing 7-9.** SingerDaoImpl Repository Class That Uses Hibernate's SessionFactory

```

package com.apress.prospring6.seven.base.dao;

import com.apress.prospring6.seven.base.entities.Singer;
import jakarta.annotation.Resource;
import org.hibernate.SessionFactory;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.stereotype.Repository;
import org.springframework.transaction.annotation.Transactional;

import java.util.List;

@Transactional(readOnly = true)
@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    private static final Logger LOGGER = LoggerFactory.getLogger(SingerDaoImpl.class);
    private SessionFactory sessionFactory;

    public SingerDaoImpl(SessionFactory sessionFactory) {
        this.sessionFactory = sessionFactory;
    }
    // other methods omitted
}

```

We declare the DAO class as a Spring bean by using the `@Repository` annotation. This integrates it into the Spring Context and exception translation to Spring's runtime and the `DataAccessException` family use is enabled. The `@Transactional` annotation defines the transaction requirements that we discuss further in [Chapter 9](#). The `sessionFactory` property is autowired by Spring using the constructor. The `SingerDao` interface is quite simple, and it has just three finder methods, one save method, and one delete method. The `save(..)` method performs both the insert and update operations. This interface is shown in [Listing 7-10](#).

**Listing 7-10.** SingerDao Interface

```

package com.apress.prospring6.seven.base.dao;

import com.apress.prospring6.seven.base.entities.Singer;

import java.util.Set;

public interface SingerDao {

    List<Singer> findAll();
    List<Singer> findAllWithAlbum();
    Singer findById(Long id);
    Singer save(Singer singer);
    void delete(Singer singer);
}

```

## Querying Data by Using the Hibernate Query Language

Hibernate, together with other ORM tools such as JDO and JPA, is engineered around the object model. So, after the mappings are defined, we don't need to construct SQL to interact with the database. Instead, for Hibernate, we use the Hibernate Query Language (HQL) to define our queries. When interacting with the database, Hibernate will translate the queries into SQL statements on our behalf. When coding HQL queries, the syntax is quite like SQL. However, you need to think on the object side rather than database side. We will take you through several examples in the following sections.

### Simple Querying with Lazy Fetching

Let's begin by implementing the `findAll()` method, which simply retrieves all the singers from the database. Listing 7-11 shows the updated code for this functionality.

**Listing 7-11.** `SingerDaoImpl#findAll()` Method

```
package com.apress.prospring6.seven.base.dao;
// import statements omitted

@Transactional
@Repository("singerDao")
public class SingerDaoImpl implements SingerDao{

    private SessionFactory sessionFactory;

    @Transactional(readOnly = true)
    @Override
    public List<Singer> findAll() {
        return sessionFactory.getCurrentSession().createQuery("from Singer s")
            .list();
    }
    // other methods omitted
}
```

The method `SessionFactory.getCurrentSession()` gets hold of Hibernate's `Session` interface. Then, the `Session.createQuery()` method is called, passing in the HQL statement. The statement `from Singer s` simply retrieves all singers from the database. An alternative syntax for the statement is `select s from Singer s`. The `@Transactional(readOnly=true)` annotation means we want the transaction to be set as read-only. Setting that attribute for read-only methods will result in better performance in some cases.

There are two ways to test the `findAll()` method. You can run the `HibernateDemoV1` class that will invoke this method on the MariaDB database available locally or in a container. Or, a test method can be written and executed in a Spring test context using a `Testcontainers MariaDB` datasource. Listing 7-12 shows the contents of the `HibernateDemoV1` class and the results of running the class.

**Listing 7-12.** `HibernateDemoV1` Runnable Class

```
package com.apress.prospring6.seven.base;

import com.apress.prospring6.seven.base.config.HibernateConfig;
import com.apress.prospring6.seven.base.dao.SingerDao;
import org.slf4j.Logger;
```

```

import org.slf4j.LoggerFactory;
import org.springframework.context.annotation.AnnotationConfigApplicationContext;

public class HibernateDemoV1 {
    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateDemoV1.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(HibernateConfig.class);
        var singerDao = ctx.getBean(SingerDao.class);

        LOGGER.info(" ---- Listing singers:");
        singerDao.findAll().forEach(s -> LOGGER.info(s.toString()));
        ctx.close();
    }
}

```

# output

```

---- Listing singers:
Singer - Id: 1, First name: John, Last name: Mayer, Birthday: 1977-10-16
Singer - Id: 3, First name: John, Last name: Butler, Birthday: 1975-04-01
Singer - Id: 2, First name: Eric, Last name: Clapton, Birthday: 1945-03-30

```

Although the singer records were retrieved, what about the albums and instruments? Let's modify the testing class to print the detailed information. In Listing 7-13, you can see the method `singerDao.findAll()` being replaced with `singerDao.findAllWithAlbums()` in the runnable `HibernateDemoV2` class. The listing also shows the output printed when this class is executed.

#### Listing 7-13. HibernateDemoV2 Runnable Class

```

package com.apress.prospring6.seven.base;
// import statements omitted

public class HibernateDemoV2 {
    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateDemoV2.class);

    public static void main(String... args) {
        var ctx = new AnnotationConfigApplicationContext(HibernateConfig.class);
        var singerDao = ctx.getBean(SingerDao.class);
        var singer = singerDao.findById(2L);

        listSingersWithAlbum(singerDao.findAllWithAlbum());
        ctx.close();
    }

    private static void listSingersWithAlbum(List<Singer> singers) {
        LOGGER.info(" ---- Listing singers with instruments:");
        singers.forEach(s -> {
            LOGGER.info(s.toString());
            if (s.getAlbums() != null) {
                s.getAlbums().forEach(a -> LOGGER.info("\t" + a.toString()));
            }
        });
    }
}

```

```

        if (s.getInstruments() != null) {
            s.getInstruments().forEach(i -> LOGGER.info("\tInstrument: " +
                i.getInstrumentId()));
        }
    });
}
}
}

```

# output

```

INFO : HibernateDemoV2 - ---- Listing singers with instruments:
INFO : HibernateDemoV2 - Singer - Id: 1, First name: John, Last name: Mayer, Birthday:
1977-10-16
Exception in thread "main" org.hibernate.LazyInitializationException: failed to lazily
initialize a collection of role: com.apress.prospring6.seven.base.entities.Singer.albums,
could not initialize proxy - no Session
    at org.hibernate.collection.internal.AbstractPersistentCollection.throwLazyInitializatio
nException(AbstractPersistentCollection.java:614)
    at org.hibernate.collection.internal.AbstractPersistentCollection.withTemporarySessionIf
Needed(AbstractPersistentCollection.java:218)
    at org.hibernate.collection.internal.AbstractPersistentCollection.initialize(AbstractPer
sistentCollection.java:591)
    at org.hibernate.collection.internal.AbstractPersistentCollection.read(AbstractPersisten
tCollection.java:149)
    at org.hibernate.collection.internal.PersistentSet.iterator(PersistentSet.java:188)
    at java.base/java.lang.Iterable.forEach(Iterable.java:74)
    at com.apress.prospring6.seven.base.HibernateDemoV2.lambda$listSingersWithAlbum$2(Hiber
nateDemoV2.java:62)

```

You will see Hibernate throw the `LazyInitializationException` when you try to access the associations because, by default, Hibernate will fetch the associations lazily. This means that Hibernate will not join the association tables (that is, `ALBUM` or `INSTRUMENT`) for records. The rationale behind this is for performance; as you can imagine, if a query is retrieving thousands of records and all the associations are retrieved, the massive amount of data transfer will degrade performance.

## Querying with Associations Fetching

To have Hibernate fetch the data from associations, there are two options. The first one is by declaring the Java association with fetch mode `EAGER`: `@ManyToMany(fetch=FetchType.EAGER)`. This tells Hibernate to fetch the associated records in every query. However, as discussed, this will impact data retrieval performance. The second option is to instruct Hibernate to fetch the associated records in the query when required. If you use the `Criteria` query, you can call the function `Criteria.setFetchMode()` to instruct Hibernate to eagerly fetch the association. When using `NamedQuery`, you can use the fetch operator to instruct Hibernate to fetch the association eagerly.

Let's take a look at the implementation of the `findAllWithAlbum()` method, which will retrieve all singer information together with their albums and instruments. This example will use the `jakarta.persistence.NamedQuery` approach. `NamedQuery` can be externalized into an XML file or declared using an annotation on the entity class. In Listing 7-14 you can see the revised `Singer` entity class with the named query defined using annotations.

**Listing 7-14.** Singer Entity Class with NamedQuery Declaration Used in Method SingerDaoImpl.findAllWithAlbum()

```

package com.apress.prospring6.seven.base.entities;

import jakarta.persistence.NamedQueries;
import jakarta.persistence.NamedQuery;
// other import statements omitted

@Entity
@Table(name = "SINGER")
@NamedQueries({
    @NamedQuery(name="Singer.findAllWithAlbum",
        query="select distinct s from Singer s " +
            "left join fetch s.albums a " +
            "left join fetch s.instruments i")
})
public class Singer extends AbstractEntity {
    // content omitted
}

```

In Listing 7-14 we define a NamedQuery instance called `Singer.findAllWithAlbum`. Then we define the query in HQL. Pay attention to the `left join fetch` clause, which instructs Hibernate to fetch the association eagerly. We also need to use `select distinct`; otherwise, Hibernate will return duplicate objects (two `Singer` objects will be returned if a single `Singer` has two `Albums` associated with him).

The implementation of the `SingerDaoImpl.findAllWithAlbum()` method is shown in Listing 7-15.

**Listing 7-15.** `SingerDaoImpl.findAllWithAlbum()` Using the NamedQuery Instance Called `Singer.findAllWithAlbum`, Declared in Listing 7-14

```

package com.apress.prospring6.seven.base.dao;

// import statements omitted

@Transactional
@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    @Transactional(readOnly = true)
    @Override
    public List<Singer> findAllWithAlbum() {
        return sessionFactory.getCurrentSession().getNamedQuery("Singer.findAllWithAlbum").list();
    }

// other code omitted
}

```

This time, when running `HibernateDemoV2`, the `Session.getNamedQuery()` method is called, passing in the name of the NamedQuery instance, which now produces the expected output instead of throwing the `LazyInitializationException`. This output is shown in Listing 7-16.

**Listing 7-16.** Output of `HibernateDemoV2` When `SingerDaoImpl.findAllWithAlbum()` Is Implemented Correctly

```
INFO : HibernateDemoV2 - ---- Listing singers with instruments:
INFO : HibernateDemoV2 - Singer - Id: 1, First name: John, Last name: Mayer, Birthday:
      1977-10-16
INFO : HibernateDemoV2 - Album - Id: 1, Singer id: 1, Title: The Search For Everything,
Release Date: 2017-01-20
INFO : HibernateDemoV2 - Album - Id: 2, Singer id: 1, Title: Battle Studies, Release
Date: 2009-11-17
INFO : HibernateDemoV2 - Instrument: Piano
INFO : HibernateDemoV2 - Instrument: Guitar
INFO : HibernateDemoV2 - Singer - Id: 2, First name: Ben, Last name: Barnes, Birthday:
      1981-08-20
INFO : HibernateDemoV2 - Album - Id: 3, Singer id: 2, Title: 11:11 , Release Date:
      2021-09-18
INFO : HibernateDemoV2 - Instrument: Drums
INFO : HibernateDemoV2 - Instrument: Piano
INFO : HibernateDemoV2 - Instrument: Guitar
INFO : HibernateDemoV2 - Singer - Id: 3, First name: John, Last name: Butler, Birthday:
      1975-04-01
```

Now all the singers with details were retrieved correctly. Let's see another example with `NamedQuery` with parameters. This time, we will implement the `findById()` method that should fetch the associations as well. Listing 7-17 shows the `Singer` class with the new `NamedQuery` instance added.

**Listing 7-17.** `Singer` Entity Class with Two `NamedQuery` Instances

```
package com.apress.prospring6.seven.base.entities;

import jakarta.persistence.NamedQueries;
import jakarta.persistence.NamedQuery;
// other import statements omitted

@Entity
@Table(name = "SINGER")
@NamedQueries({
    @NamedQuery(name="Singer.findById",
        query="select distinct s from Singer s " +
            "left join fetch s.albums a " +
            "left join fetch s.instruments i " +
            "where s.id = :id"),
    @NamedQuery(name="Singer.findAllWithAlbum",
        query="select distinct s from Singer s " +
            "left join fetch s.albums a " +
            "left join fetch s.instruments i")
})
public class Singer extends AbstractEntity {
    // content omitted
}
```

For the `Singer.findById` named query, we declare a named parameter: `id`. When this query is used, the parameter needs to be replaced with a concrete value. You can see the implementation of the `SingerDaoImpl.findById()` method in Listing 7-18.

**Listing 7-18.** `SingerDaoImpl.findById()` Method That Makes Use of the `Singer.findById` NamedQuery Instance

```
package com.apress.prospring6.seven.base.dao;
// import statements omitted

@Transactional
@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    @Transactional(readOnly = true)
    @Override
    public Singer findById(Long id) {
        return (Singer) sessionFactory.getCurrentSession()
            .getNamedQuery("Singer.findById")
            .setParameter("id", id)
            .uniqueResult();
    }

    // other code omitted
}
```

The `getNamedQuery(..)` method returns an instance of a type that implements the `org.hibernate.query.Query` interface. For a Hibernate named query, the concrete type of the instance returned by this method is `org.hibernate.query.internal.QueryImpl`. This is a Hibernate internal type, as its package name makes really obvious. In the same package there are also types specific to native and criteria queries, which are introduced a bit further in the chapter.

Providing the value for the `id` parameter is done by calling the `setParameter(..)` method on this instance. When the named query requires more than one parameter, their values can be provided by calling method `setParameterList()` or `setParameters()`, which are part of the `Query` interface declaration.

Up to this point in the chapter, you have only seen how to test the repository class `SingerDaoImpl` methods by running an executable class. As previously mentioned, a `Testcontainers MariaDB` instance is used for testing in this chapter, so Listing 7-19 introduces the `HibernateTest` class that tests the two named queries introduced in the chapter, on a limited data set that is part of the `testcontainers/create-schema.sql` script for this chapter.

**Listing 7-19.** `HibernateTest` Test Class Using a `Testcontainers MariaDB` Instance

```
package com.apress.prospring6.seven;

import com.apress.prospring6.seven.base.config.HibernateConfig;
import org.testcontainers.containers.MariaDBContainer;
import org.testcontainers.junit.jupiter.Container;
import org.testcontainers.junit.jupiter.Testcontainers;
// other import statements omitted

import static org.junit.jupiter.api.Assertions.assertEquals;
```



```

@Testcontainers
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {HibernateConfig.class})
public class HibernateTest {
    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateTest.class);

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @Autowired
    SingerDao singerDao;

    @Test
    @DisplayName("should return all singers")
    void testFindAll(){
        var singers = singerDao.findAll();
        assertEquals(3, singers.size());
        singers.forEach(singer -> LOGGER.info(singer.toString()));
    }

    @Test
    @DisplayName("should return singer by id")
    void testFindById(){
        var singer = singerDao.findById(2L);
        assertEquals("Ben", singer.getFirstName());
        LOGGER.info(singer.toString());
    }
}

```

One thing you might have noticed since Testcontainers was introduced in **Chapter 6**, is how practical it is to write tests using this library. For most cases, especially for small-scale, demonstrative applications like those in this book, the production-like Spring configuration can be reused without the need to introduce a different profile and extra configurations for testing contexts.

## Inserting Data

Inserting data with Hibernate is simple as well. When using pure JDBC in **Chapter 6**, we needed to explicitly declare that we wanted to retrieve the database-generated primary key, pass in the KeyHolder instance, and get the key back from it after executing the insert statement. With Hibernate, none of those actions are required. Hibernate retrieves the generated key and populates the domain object after the insert operation. Listing 7-20 shows the implementation of the save(..) method using Hibernate's SessionFactory.

**Listing 7-20.** SingerDaoImpl.save(..) Method

```

package com.apress.prospring6.seven.base.dao;
// import statements omitted

import java.util.List;

```

```

@Transactional
@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    // other code omitted

    @Override
    public Singer save(Singer singer) {
        sessionFactory.getCurrentSession().saveOrUpdate(singer);
        LOGGER.debug("Singer saved with id: " + singer.getId());
        return singer;
    }
}

```

The `saveOrUpdate({daoObject})` method can be used for both insert and update operations. A logging statement was added to the implementation to print the `singer.id` field that is populated by Hibernate after the object is persisted. Also note that when we declared our `Singer` entity class, we declared it with a `@OneToMany` association to the `Album` class and a `@ManyToMany` association to the `Instrument` class. What do you think, will a `Singer` instance with the `albums` and `instruments` fields populated be saved together with those associations? Let's test this assumption by creating a new method in the `HibernateTest` class, as shown in Listing 7-21.

**Listing 7-21.** `HibernateTest.testInsert()` Method

```

package com.apress.prospring6.seven;
// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {HibernateTest.TestContainersConfig.class})
public class HibernateTest {
    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateTest.class);

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @Autowired
    SingerDao singerDao;

    // other test methods omitted

    @Test
    @DisplayName("should insert a singer with associations")
    @Sql(statements = {
        "delete from ALBUM where SINGER_ID = (select ID from SINGER where FIRST_NAME
        = 'BB')",
        "delete from SINGER_INSTRUMENT where SINGER_ID = (select ID from SINGER where
        FIRST_NAME = 'BB')",
        "delete from SINGER where FIRST_NAME = 'BB'"
    },
}

```

```

        executionPhase = Sql.ExecutionPhase.AFTER_TEST_METHOD)
void testInsertSinger(){
    var singer = new Singer();
    singer.setFirstName("BB");
    singer.setLastName("King");
    singer.setBirthDate(LocalDate.of(1940, 8, 16));

    var album = new Album();
    album.setTitle("My Kind of Blues");
    album.setReleaseDate(LocalDate.of(1961, 7, 18));
    singer.addAlbum(album);

    album = new Album();
    album.setTitle("A Heart Full of Blues");
    album.setReleaseDate(LocalDate.of(1962, 3, 20));
    singer.addAlbum(album);
    singerDao.save(singer);

    assertNotNull(singer.getId());

    var singers = singerDao.findAllWithAlbum();
    assertEquals(4, singers.size());
    listSingersWithAssociations(singers);
}

```

**@Configuration****@Import(HibernateConfig.class)**

```

public static class TestContainersConfig {
    @Autowired
    Properties hibernateProperties;

    @PostConstruct
    public void initialize() {
        hibernateProperties.put(Environment.FORMAT_SQL, true);
        hibernateProperties.put(Environment.USE_SQL_COMMENTS, true);
        hibernateProperties.put(Environment.SHOW_SQL, true);
    }
}

private static void listSingersWithAssociations(List<Singer> singers) {
    LOGGER.info(" ---- Listing singers with instruments:");
    // code omitted for duplication
}

```

In the `testInsertSinger()` method, a new singer record is inserted in the `SINGER` table, with two child records in the `ALBUM` table, and then the assumption that the insertion succeeded is tested. All singer instances and their associations are logged in the console too, to make it really obvious that the insertion succeeded. To test the insert method in isolation, without dirtying the test context, a few SQL statements to do the cleanup after the test method is executed are configured using the `@Sql` annotation. Another thing done for this test context is to override the `format_sql`, `use_sql_comments` and `show_sql` hibernate properties in a test configuration class and set them to `true`. This will cause all SQL queries generated by

Hibernate to be printed in the log. This means that, when executing the `testInsertSinger()` method, the test is expected to pass, and all the data in the `SINGER`, `ALBUM` and `INSTRUMENTS` tables is printed, together with the SQL queries used to select the data as shown in Listing 7-22.

**Listing 7-22.** `HibernateTest.testInsert()` Method Logs

```

...
INFO : Dialect - HHH000400: Using dialect: org.hibernate.dialect.MariaDB106Dialect
Hibernate:
    /* insert com.apress.prospring6.seven.base.entities.Singer
       */ insert
       into
           SINGER
           (VERSION, BIRTH_DATE, FIRST_NAME, LAST_NAME)
       values
           (?, ?, ?, ?)
Hibernate:
    /* insert com.apress.prospring6.seven.base.entities.Album
       */ insert
       into
           ALBUM
           (VERSION, RELEASE_DATE, SINGER_ID, title)
       values
           (?, ?, ?, ?)
Hibernate:
    /* insert com.apress.prospring6.seven.base.entities.Album
       */ insert
       into
           ALBUM
           (VERSION, RELEASE_DATE, SINGER_ID, title)
       values
           (?, ?, ?, ?)
INFO : SingerDaoImpl - Singer saved with id: 4
...
INFO : HibernateTest - ---- Listing singers with instruments:
INFO : HibernateTest - Singer - Id: 1, First name: John, Last name: Mayer, Birthday:
1977-10-16
INFO : HibernateTest - Album - Id: 2, Singer id: 1, Title: Battle Studies, Release Date:
2009-11-17
INFO : HibernateTest - Album - Id: 1, Singer id: 1, Title: The Search For Everything,
Release Date: 2017-01-20
INFO : HibernateTest - Instrument: Guitar
INFO : HibernateTest - Instrument: Piano
INFO : HibernateTest - Singer - Id: 2, First name: Ben, Last name: Barnes, Birthday:
1981-08-20
INFO : HibernateTest - Album - Id: 3, Singer id: 2, Title: 11:11 , Release Date:
2021-09-18
INFO : HibernateTest - Instrument: Guitar
INFO : HibernateTest - Instrument: Drums
INFO : HibernateTest - Instrument: Piano
INFO : HibernateTest - Singer - Id: 4, First name: BB, Last name: King, Birthday: 1940-08-16

```

```
INFO : HibernateTest - Album - Id: 4, Singer id: 4, Title: A Heart Full of Blues, Release
      Date: 1962-03-20
INFO : HibernateTest - Album - Id: 5, Singer id: 4, Title: My Kind of Blues, Release Date:
      1961-07-18
INFO : HibernateTest - Singer - Id: 3, First name: John, Last name: Butler, Birthday:
      1975-04-01
```

The logging configuration has been modified so that more detailed Hibernate information is printed. From the INFO log record, we can see that the ID of the newly saved contact was populated correctly. Hibernate will also show all the SQL statements being executed against the database, so you know what is happening behind the scenes.

## Updating Data

Updating a record is as easy as inserting data. Suppose for the singer with an ID of 5 we want to update the first name and last name and remove one album. The `testUpdate()` method used to test the update operation is shown Listing 7-23.

**Listing 7-23.** `HibernateTest.testUpdate()` Method

```
package com.apress.prospring6.seven;

// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
      schema.sql" })
@SpringJUnitConfig(classes = {HibernateTest.TestContainersConfig.class})
public class HibernateTest {
    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateTest.class);

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @Autowired
    SingerDao singerDao;

    // other test methods omitted

    @Test
    @SqlGroup({
        @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD),
        @Sql(scripts = {"classpath:testcontainers/remove-nina.sql"},
            executionPhase = Sql.ExecutionPhase.AFTER_TEST_METHOD)
    })
    void testUpdate() {
        void testUpdate() {
            Singer singer = singerDao.findById(5L);
            // making sure such singer exists
```

```

assertNotNull(singer);
// making sure we got expected singer
assertEquals("Simone", singer.getLastName());
// retrieve the album
Album album = singer.getAlbums().stream().filter(
    a -> a.getTitle().equals("I Put a Spell on You")).findFirst().orElse(null);
assertNotNull(album);

singer.setFirstName("Eunice Kathleen");
singer.setLastName("Waymon");
singer.removeAlbum(album);
int version = singer.getVersion();

var nina = singerDao.save(singer);
assertEquals(version +1, nina.getVersion());

// test the update
listSingersWithAssociations(singerDao.findAllWithAlbum());
}

private static void listSingersWithAssociations(List<Singer> singers) {
    LOGGER.info(" ---- Listing singers with instruments:");
    // code omitted for duplication
}
}

```

As shown in this test method, we first retrieve the record with an ID of 5. Next, we change the first name and last name. We then loop through the album objects, retrieve the one with the title *I Put a Spell on You*, and remove it from the singer's albums property. Finally, we call the `singerDao.save()` method and check that the value of the version field of the saved record is incremented. When executed, this test method is expected to pass and print the output shown in Listing 7-24.

**Listing 7-24.** `HibernateTest.testUpdate()` Method Logs

```

Hibernate:
  /* update
    com.apress.prospring6.seven.base.entities.Singer */ update
    SINGER
  set
    VERSION=?,
    BIRTH_DATE=?,
    FIRST_NAME=?,
    LAST_NAME=?
  where
    ID=?
    and VERSION=?
Hibernate:
  /* delete com.apress.prospring6.seven.base.entities.Album */ delete
  from
    ALBUM

```

```

        where
            ID=?
            and VERSION=?
INFO : SingerDaoImpl - Singer saved with id: 5
INFO : HibernateTest - ---- Listing singers with instruments:
...
INFO : HibernateTest - Singer - Id: 5, First name: Eunice Kathleen, Last name: Waymon,
        Birthday: 1933-02-21
INFO : HibernateTest - Album - Id: 4, Singer id: 5, Title: Little Girl Blue, Release Date:
        1959-02-20
INFO : HibernateTest - Album - Id: 5, Singer id: 5, Title: Forbidden Fruit, Release Date:
        1961-08-18
INFO : HibernateTest - Instrument: Voice
INFO : HibernateTest - Instrument: Piano

```

You will see that the first name and last name are updated, and the *I Put a Spell on You* album is removed. The album can be removed because of the `orphanRemoval=true` attribute we pass into the one-to-many association, which instructs Hibernate to remove all orphan records that exist in the database but are no longer found in the object when persisted.

## Deleting Data

Deleting data is simple as well. Just call the `session.delete()` method and pass in the `Singer` object. Listing 7-25 shows the code for deletion.

**Listing 7-25.** `SingerDaoImpl.delete()` Method

```

package com.apress.prospring6.seven.base.dao;
// import statements omitted

@Transactional
@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    private static final Logger LOGGER = LoggerFactory.getLogger(SingerDaoImpl.class);

    private SessionFactory sessionFactory;

    public SingerDaoImpl(SessionFactory sessionFactory) {
        this.sessionFactory = sessionFactory;
    }

    // other methods omitted

    @Override
    public void delete(Singer singer) {
        sessionFactory.getCurrentSession().delete(singer);
        LOGGER.info("Singer deleted with id: " + singer.getId());
    }
}

```

The delete operation will delete the singer record, together with all its associated information, including albums and instruments, as we defined `cascade=CascadeType.ALL` in the mapping. Listing 7-26 shows the code for testing the delete method, `testDelete()`.

**Listing 7-26.** `HibernateTest.testDelete()` Method

```

package com.apress.prospring6.seven;
// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {HibernateTest.TestContainersConfig.class})
public class HibernateTest {
    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateTest.class);

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @Autowired
    SingerDao singerDao;

    @Test
    @Sql(scripts = {"classpath:testcontainers/add-chuck.sql"},
        executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
    void testDelete() {
        Singer singer = singerDao.findById(6L);
        // making sure such singer exists
        assertNotNull(singer);

        singerDao.delete(singer);
        listSingersWithAssociations(singerDao.findAllWithAlbum());
    }

    private static void listSingersWithAssociations(List<Singer> singers) {
        LOGGER.info(" ---- Listing singers with instruments:");
        // code omitted for duplication
    }
}

```

The `testDelete()` method retrieves the singer with an ID of 6 and then calls the `singerDao.delete(..)` method to delete the singer record from the database. Running the program will produce the output shown in Listing 7-27.

**Listing 7-27.** `HibernateTest.testDelete()` Method Output

```

Hibernate:
/* delete com.apress.prospring6.seven.base.entities.Album */ delete
from
    ALBUM

```



```

        where
            ID=?
            and VERSION=?
Hibernate:
  /* delete com.apress.prospring6.seven.base.entities.Singer */ delete
    from
      SINGER
    where
      ID=?
      and VERSION=?
INFO : SingerDaoImpl - Singer deleted with id: 6
INFO : HibernateTest - ---- Listing singers with instruments:
INFO : HibernateTest - Singer - Id: 1, First name: John, Last name: Mayer, Birthday:
      1977-10-16
INFO : HibernateTest - Album - Id: 2, Singer id: 1, Title: Battle Studies, Release Date:
      2009-11-17
INFO : HibernateTest - Album - Id: 1, Singer id: 1, Title: The Search For Everything,
      Release Date: 2017-01-20
INFO : HibernateTest - Instrument: Piano
INFO : HibernateTest - Instrument: Guitar
INFO : HibernateTest - Singer - Id: 2, First name: Ben, Last name: Barnes, Birthday:
      1981-08-20
INFO : HibernateTest - Album - Id: 3, Singer id: 2, Title: 11:11, Release Date: 2021-09-18
INFO : HibernateTest - Instrument: Piano
INFO : HibernateTest - Instrument: Guitar
INFO : HibernateTest - Instrument: Drums
INFO : HibernateTest - Singer - Id: 3, First name: John, Last name: Butler, Birthday:
      1975-04-01

```

You can see that the singer with an ID of 6 was deleted together with its child record in the ALBUM table.

## Executing SQL Native Queries

HQL queries are easy to write, but writing complex queries that span across multiple tables and doing complex calculations (like are often needed in financial domains) is difficult, if not impossible. More often than not, the generated SQL query would not be as efficient as a native query written by a SQL expert. For the examples in the project associated with this book, it is just as easy to write HQL queries as it is to write SQL native queries, but assuming you would need to execute a SQL native query, the Hibernate session allows native SQL query execution as well using the `createNativeQuery(..)` method. An example of using this method with a relatively complex query is shown in Listing 7-28.

**Listing 7-28.** `SingerDaoImpl.findAllDetails()` Method That Executed a Native SQL Query

```

package com.apress.prospring6.seven.base.dao;
// import statements omitted

@Transactional(readOnly = true)
@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    private SessionFactory sessionFactory;

```

```

// other code omitted for duplication

private static final String ALL_SELECT = ""
    SELECT DISTINCT s.first_name, s.last_name, a.title, a.RELEASE_DATE,
    i.INSTRUMENT_ID
    from SINGER s
    inner join ALBUM a on s.id = a.singer_id
    inner join SINGER_INSTRUMENT si on s.ID = si.SINGER_ID
    inner join INSTRUMENT i on si.INSTRUMENT_ID = i.INSTRUMENT_ID
    where s.FIRST_NAME = :firstName and s.LAST_NAME= :lastName
    """;

@Override
public Singer findAllDetails(String firstName, String lastName) {
    List<Object[]> results = sessionFactory.getCurrentSession()
        .createNativeQuery(ALL_SELECT)
        .setParameter("firstName", firstName)
        .setParameter("lastName", lastName)
        .list();

    var singer = new Singer();

    for (Object[] item : results) {
        if (singer.getFirstName() == null && singer.getLastName() == null) {
            singer.setFirstName((String) item[0]);
            singer.setLastName((String) item[1]);
        }
        var album = new Album();
        album.setTitle((String) item[2]);
        album.setReleaseDate(((Date) item[3]).toLocalDate());
        singer.addAlbum(album);

        var instrument = new Instrument();
        instrument.setInstrumentId((String) item[4]);
        singer.getInstruments().add(instrument);
    }

    return singer;
}
}

```

The ALL\_SELECT SQL query uses named parameters. Values for these parameters are provided by calling the `setParameter(..)` method that is called on the `org.hibernate.query.NativeQuery` instance returned by the `createNativeQuery(..)` call. For a Hibernate-native SQL query, the concrete type of the instance returned by this method is `org.hibernate.query.internal.NativeQueryImpl`. Since we are executing a native query, we lose the benefit of automatic mapping of the database records to Java entities, but it is worth it for the benefit of performance.

The returned type of calling this method could be explained as follows. Each `Object[]` in the list contains the values of the columns specified in the query. A `List<E>` is needed in case multiple rows are returned, thus `List<Object[]>` is the suitable returned type.

This is where jOOQ provides better support, but this will be shown later in the chapter, after exploring the other interesting things that Hibernate can be used for.

## Executing Projections with Hibernate

So far in this chapter, all Hibernate operations returned full records, unless the query asked for a specific column value. When querying tables, the return of the full record is not always necessary. The operation of querying only a subset of columns is called a *projection*. Hibernate support projection queries through its `org.hibernate.criterion.Projection` interface and `org.hibernate.Criteria` class.

An example of using Hibernate to create a projection query to extract `firstName` and `lastName` from table `SINGER` is shown in Listing 7-29.

**Listing 7-29.** `SingerDaoImpl.findAllNamesByProjection()` Method Using Hibernate Projections

```
package com.apress.prospring6.seven.base.dao;

import org.hibernate.Criteria;
import org.hibernate.criterion.Projection;
import org.hibernate.criterion.ProjectionList;
import org.hibernate.criterion.Projections;
// import statements omitted

@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    @Transactional(readOnly = true)
    @Override
    public Set<String> findAllNamesByProjection() {
        @SuppressWarnings({"deprecation"})
        Criteria criteria = sessionFactory.getCurrentSession().createCriteria(Singer.class);
        Projection fnProjection = Projections.property("firstName");
        Projection lnProjection = Projections.property("lastName");

        ProjectionList pList = Projections.projectionList();
        pList.add(fnProjection);
        pList.add(lnProjection);
        criteria.setProjection(pList);

        List<Object[]> projResult = criteria.list();
        return projResult.stream().map(o -> o[0] + " " + o[1]).collect(Collectors.toSet());
    }
    // other methods omitted
}
```

Notice that a `Projection` instance is needed for each property being queried.

## Calling Stored Functions with Hibernate

Hibernate provides support for calling stored procedures and functions. This section demonstrates how to use Hibernate to call a simple stored function in a MariaDB database using Hibernate Session's `createSQLQuery(..)` method.

The function being called is the same introduced in **Chapter 6**. The SQL code that creates the function is depicted in a comment on the `SingerDaoImpl.findFirstNameById(..)` method in Listing 7-30.

**Listing 7-30.** `SingerDaoImpl.findFirstNameById()` Method Using Hibernate Session to Call a Stored Function

```

package com.apress.prospring6.seven.base.dao;
// import statements omitted

@Repository("singerDao")
public class SingerDaoImpl implements SingerDao {

    /*
    CREATE FUNCTION IF NOT EXISTS
        getFirstNameById (in_id INT) RETURNS VARCHAR(60)
    RETURN (SELECT first_name FROM SINGER WHERE id = in_id);
    */
    @Transactional(readOnly = true)
    @Override
    public String findFirstNameById(Long id) {
        return sessionFactory.getCurrentSession().createSQLQuery("select
            getfirstnamebyid(?) ")
            .setParameter(1, id).getSingleResult().toString();
    }

    // other methods omitted
}

```

The stored function simply accepts the ID and returns the first name of the singer record with the ID. The `createSQLQuery(...)` method takes a native SQL function call statement as an argument and returns an instance of `org.hibernate.query.NativeQueryImpl`. The function call requires an argument that is provided by calling the `setParameter(...)` method. There is a version of this method that sets parameters using their index and one that does the same using their name. This function is a simple one, thus the Hibernate code to call it is simple as well. Since it returns a single `String` result, retrieving that result is easily done by calling `getSingleResult()`.

## Configuring Hibernate to Generate Tables from Entities

In startup applications using Hibernate, it is common behavior to first write the entity classes and then generate the database tables based on their contents. Usually, a framework like Flyway<sup>6</sup> is added in the mix to manage different versions of the application's database schema reliably and easily, but that topic is beyond the scope of this book.

Generating the database schema from entity classes is done by using the `Environment.HBM2DDL_AUTO/hibernate.hbm2ddl.auto` Hibernate property. When the application is started the first time, this property value is set to `create`; this will make Hibernate scan the entities and generate tables and keys (primary, foreign, unique) according to the relationships defined using JPA and Hibernate annotations.

If the entities are configured correctly and the resulting database objects are exactly as expected, the value of the property should be changed to `update`. This will tell Hibernate to update the existing database with any changes performed later on entities and keep the original database and any data that has been inserted into it.

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<sup>6</sup><https://flywaydb.org>

In production applications, it is practical to write integration tests that run on a pseudo-database that is discarded after all test cases are executed. Usually, the test database is an in-memory database and Hibernate is told to create the database and discard it after the execution of the tests by setting the `Environment.HBM2DDL_AUTO` value to `create-drop`. With the introduction of Testcontainers, this functionality is not necessary, but if, for some reason, you are prohibited from installing Docker on the machine where your tests are running, or the application is so small that Testcontainers is overkill, Hibernate and an embedded in-memory database can come to the rescue. You can find the full list of values for the `hibernate.hbm2ddl.auto` property in the Hibernate official documentation<sup>7</sup>.

Listing 7-31 shows the Java configuration class named `HibernateTestConfig`. As you can see, `Environment.HBM2DDL_AUTO/hibernate.hbm2ddl.auto` is set to `create-drop` and H2 embedded datasource was set up.

**Listing 7-31.** `HibernateTestConfig` Configuration Class

```
package com.apress.prospring6.seven.config;

import org.hibernate.SessionFactory;
import org.hibernate.cfg.Environment;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseBuilder;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseType;
import org.springframework.orm.hibernate5.HibernateTransactionManager;
import org.springframework.orm.hibernate5.LocalSessionFactoryBuilder;
import org.springframework.transaction.PlatformTransactionManager;
// other import statements omitted

@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.seven.base"})
@EnableTransactionManagement
public class HibernateTestConfig {

    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateTestConfig.class);

    @Bean
    public DataSource dataSource() {
        try {
            var dbBuilder = new EmbeddedDatabaseBuilder();
            return dbBuilder.setType(EmbeddedDatabaseType.H2).setName("testdb").build();
        } catch (Exception e) {
            LOGGER.error("Embedded DataSource bean cannot be created!", e);
            return null;
        }
    }

    @Bean
    public Properties hibernateProperties() {
        Properties hibernateProp = new Properties();
        hibernateProp.put(Environment.DIALECT, "org.hibernate.dialect.H2Dialect");
    }
}
```

<sup>7</sup>See Table 3.7 at <https://docs.jboss.org/hibernate/orm/5.0/manual/en-US/html/ch03.html>

```

        hibernateProp.put(Environment.HBM2DDL_AUTO, "create-drop");
        hibernateProp.put(Environment.FORMAT_SQL, true);
        hibernateProp.put(Environment.USE_SQL_COMMENTS, true);
        hibernateProp.put(Environment.SHOW_SQL, true);
        hibernateProp.put(Environment.MAX_FETCH_DEPTH, 3);
        hibernateProp.put(Environment.STATEMENT_BATCH_SIZE, 10);
        hibernateProp.put(Environment.STATEMENT_FETCH_SIZE, 50);
        return hibernateProp;
    }

    @Bean
    public SessionFactory sessionFactory() {
        return new LocalSessionFactoryBuilder(dataSource())
            .scanPackages("com.apress.prospring6.seven.base.entities")
            .addProperties(hibernateProperties())
            .buildSessionFactory();
    }

    @Bean public PlatformTransactionManager transactionManager() {
        return new HibernateTransactionManager(sessionFactory());
    }
}

```

Of course, even if the database schema is created, there is no data, so we cannot run any tests. One solution is to use the `@Sql*` annotation family to set it all up, as done in [Chapter 6](#). Another solution is to write ordered tests, where the first one inserts the data, the second queries it, the third updates it, and the last deletes it. Doing it this way, we validate all CRUD operations in `SingerDaoImpl`. The `H2HibernateTest` class that uses `HibernateTestConfig` to configure its test context is shown in [Listing 7-32](#).

**Listing 7-32.** H2HibernateTest Test Class

```

package com.apress.prospring6.seven;

import com.apress.prospring6.seven.config.HibernateTestConfig;
import org.junit.jupiter.api.MethodOrderer;
import org.junit.jupiter.api.Order;
import org.junit.jupiter.api.TestMethodOrder;
// other import statements omitted

@SpringJUnitConfig(classes = {HibernateTestConfig.class})
@TestMethodOrder(MethodOrderer.OrderAnnotation.class)
public class H2HibernateTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(HibernateTest.class);

    @Autowired
    SingerDao singerDao;

    @Test
    @Order(1)
    @DisplayName("should insert a singer with albums")
    public void testInsert() {

```

```

    var singer = new Singer();
    singer.setFirstName("BB");
    singer.setLastName("King");
    singer.setBirthDate(LocalDate.of(1940, 8, 16));

    var album = new Album();
    album.setTitle("My Kind of Blues");
    album.setReleaseDate(LocalDate.of(1961, 7, 18));
    singer.addAlbum(album);

    album = new Album();
    album.setTitle("A Heart Full of Blues");
    album.setReleaseDate(LocalDate.of(1962, 3, 20));
    singer.addAlbum(album);

    var created = singerDao.save(singer);
    assertNotNull(created.getId());
}

@Test
@Order(2)
@DisplayName("should return all singers")
public void testFindAll() {
    var singers = singerDao.findAll();
    assertEquals(1, singers.size());
    singers.forEach(singer -> LOGGER.info(singer.toString()));
}

@Test
@Order(3)
@DisplayName("should update a singer")
public void testUpdate() {
    var singer = singerDao.findAll().get(0);

    // making sure such singer exists
    assertNotNull(singer);
    singer.setFirstName("Riley B. ");
    int version = singer.getVersion();
    var bb = singerDao.save(singer);

    assertEquals(version + 1, bb.getVersion());
}

```

```

@Test
@Order(4)
@DisplayName("should delete a singer")
void testDelete() {
    Singer singer = singerDao.findAll().get(0);
    // making sure such singer exists
    assertNotNull(singer);

    singerDao.delete(singer);

    assertEquals(0, singerDao.findAll().size());
}
}

```

Notice that the class is annotated with `@TestMethodOrder(MethodOrderer.OrderAnnotation.class)` and each test method is annotated with `@Order({x})`, where `x` represents the numeric order of the test method. The test methods are executed in ascending order, and if all goes well, they should all pass. This obviously introduces a certain dependency between the test methods, and if one fails, all the others that follow might fail too.



Using Hibernate Tools<sup>8</sup>, it is possible to also generate entity classes from an existing schema, but the resulting code is not always the best and might need adjustments.

---

## Annotating Methods or Fields?

In the previous example, the entities had JPA annotations on their getters. But JPA annotations can be used directly on the fields, which has a few advantages:

- Entity configuration is clearer and located in the fields section, instead of being scattered in the whole class content. This is obviously true only if the code was written following clean code recommendations to keep all field declarations in a class in the same continuous section.
- Annotating entity fields does not enforce providing setter/getters. This is useful for the `@Version` annotated field and other audit scope fields, which should never be modified manually; only Hibernate should have access to them.
- Annotating fields allows to do extra processing in setters (for example, encrypting/calculating the value after loading it from the database). The problem with the property access is that the setters are also called when the object is loaded.

There are a lot of discussions on the Internet over which one is better. From a performance point of view, there isn't any difference. The decision is eventually up to the developer because there might be some valid cases when annotating accessors (getters) makes more sense. But keep in mind that in the database,

---

<sup>8</sup><https://github.com/hibernate/hibernate-tools>



the state of the objects is actually saved, and the state of the object is defined by the values of its fields, not the values returned by accessors. This also means that an object can be accurately re-created from the database exactly the way it was persisted. So, in a way, setting the annotations on the getters can be seen as breaking encapsulation.

Listing 7-33 shows the `AbstractEntity` mapped class that was rewritten to annotate the fields common to all Hibernate entity classes in an application.

**Listing 7-33.** `AbstractEntity` Mapped Class with JPA Annotated Fields

```

package com.apress.prospring6.seven.crud.entities;

import jakarta.persistence.*;
import java.io.Serial;
import java.io.Serializable;

@MappedSuperclass
public abstract class AbstractEntity implements Serializable {
    @Serial
    private static final long serialVersionUID = 1L;

    @Id
    @GeneratedValue(strategy = GenerationType.IDENTITY)
    @Column(uptdatable = false)
    protected Long id;

    @Version
    @Column(name = "VERSION")
    private int version;

    // getters and setters omitted
}

```

Listing 7-34 shows the `Singer` entity class that was rewritten to have annotated fields.

**Listing 7-34.** `Singer` Entity Class with JPA Annotated Fields

```

package com.apress.prospring6.seven.crud.entities;

import jakarta.persistence.*;
// other import statements omitted

@Entity
@Table(name = "singer")
@NamedQueries({
    @NamedQuery(name=Singer.FIND_SINGER_BY_ID,
        query="select distinct s from Singer s " +
            "left join fetch s.albums a " +
            "left join fetch s.instruments i " +
            "where s.id = :id"),
}

```

```

        @NamedQuery(name=Singer.FIND_ALL_WITH_ALBUM,
                    query="select distinct s from Singer s " +
                        "left join fetch s.albums a " +
                        "left join fetch s.instruments i")
    })
    public class Singer extends AbstractEntity {

        public static final String FIND_SINGER_BY_ID = "Singer.findById";
        public static final String FIND_ALL_WITH_ALBUM = "Singer.findAllWithAlbum";

        @Column(name = "FIRST_NAME")
        private String firstName;

        @Column(name = "LAST_NAME")
        private String lastName;

        @Column(name = "BIRTH_DATE")
        private LocalDate birthDate;

        @OneToMany(mappedBy = "singer", cascade=CascadeType.ALL,
                   orphanRemoval=true)
        private Set<Album> albums = new HashSet<>();

        @ManyToMany
        @JoinTable(name = "singer_instrument",
                  joinColumns = @JoinColumn(name = "SINGER_ID"),
                  inverseJoinColumns = @JoinColumn(name = "INSTRUMENT_ID"))
        private Set<Instrument> instruments = new HashSet<>();

        // getters and setter omitted
    }

```

## Considerations When Using Hibernate

As shown in the examples of this chapter, once all the object-to-relational mapping, associations, and queries are properly defined, Hibernate can provide an environment for you to focus on programming with the object model, rather than composing SQL statements for each operation. In the past few years, Hibernate has been evolving quickly and has been widely adopted by Java developers as the data access layer library, both in the open source community and in enterprises. However, there are some points you need to bear in mind:

- Since you don't have control over the generated SQL, you should be careful when defining the mappings, especially the associations and their fetching strategy.
- You should observe the SQL statements generated by Hibernate to verify that all perform as you expect.
- SQL is a highly expressive and type-safe language with a rich syntax, so writing SQL queries is not easy and syntax errors are a common occurrence.

- Understanding the internal mechanism of how Hibernate manages its session is important, especially in batch job operations. Hibernate will keep the managed objects in session and will flush and clear them regularly. Poorly designed data access logic may cause Hibernate to flush the session too frequently and greatly impact the performance (in our examples, we flushed it explicitly in the `save(..)` and `delete()` methods).
- If you want absolute control over the query, you can use a native query, as already shown in this chapter. More examples will be shown in the next chapter as well.
- The settings (batch size, fetch size, and so forth) play a significant role in tuning Hibernate's performance. You should define them in your session factory and adjust them while load testing your application to identify the optimal value.

After all, Hibernate, and its excellent JPA support that we discuss in the next chapter, is a natural decision for Java developers looking for an OO way to implement data access logic.



If you are interested in harnessing the full power of Hibernate in a project, you should read Vlad Mihalcea's *High-Performance Java Persistence*<sup>9</sup>.

---

## Introducing jOOQ

jOOQ stands for Java Object Oriented Querying and it is a database-mapping software library written in Java that implements the active record pattern<sup>10</sup>. It is both relational and object-oriented and provides a domain-specific language to construct queries from classes generated from a database schema. jOOQ is SQL-centric and focused on the database. Its capabilities are powerful: it can generate POJO classes that map to database records and DAO classes too, and it supports an extensive number of databases<sup>11</sup>. Also, jOOQ can be integrated with Hibernate: JPA can be kept for modifications, and jOOQ can be used for generating expensive SQL native queries that can be executed with JPA native-queries.

This section will show you how to use jOOQ to generate POJOs and DAOs and how to configure jOOQ in a Spring application to make use of them.



As of jOOQ 3.15, the commercial edition is not published to Maven Central, but available only from the jOOQ website<sup>12</sup>. The distribution can be downloaded as a ZIP file, which contains scripts to publish the artifacts in a local repository (via `mvn install` or `mvn deploy`). Our recommendation is to run the `maven-install` script specific to your operating system. At the moment this chapter is being written, version 3.16.7 is the most recent.

---

<sup>9</sup><https://vladmihalcea.com/books/high-performance-java-persistence>

<sup>10</sup>[https://en.wikipedia.org/wiki/Active\\_record\\_pattern](https://en.wikipedia.org/wiki/Active_record_pattern)

<sup>11</sup><https://www.jooq.org/doc/latest/manual/reference/supported-rdbms>

<sup>12</sup><https://www.jooq.org/download/versions>



Since using jOOQ requires you to manually install it first on your computer, we created the project `chapter07-jooq`, which is not part of the full build for the book. To add it to the full build, remove the commented configuration snippet from the main `pom.xml` or `settings.gradle`, depending on the build tool you chose to use.

Assuming you managed to install the jOOQ libraries in your local Maven repository, the next step is to add the necessary libraries to your Maven/Gradle configuration. Luckily for us, the `jooq-codegen.jar` file that needs to be used for code generation depends on the main `jooq.jar` and `jooq-meta.jar` files that will be added to the project as its transitive dependencies.

After this, we need to generate the jOOQ classes. There is more than one way to do it:

- Programmatic way using the `org.jooq.codegen.GenerationTool` and XML configuration
- Programmatic way using the `org.jooq.codegen.GenerationTool` and explicit configuration in the Java code
- The `jooq-codegen-maven` plug-in
- The `nu.studer.jooq` plug-in

In `chapter07-jooq`, both of the plug-ins are configured, which you can take a look at after cloning the repository. In Listing 7-35, however, the `GenerateJOOQSources` class is depicted, an executable class that contains the two programmatic code-generation versions.

**Listing 7-35.** Programmatic jOOQ Code-Generation Class

```
package com.apress.prospring6.seven.util;

import org.jooq.codegen.GenerationTool;
import org.jooq.meta.jaxb.Configuration;
import org.jooq.meta.jaxb.Database;
import org.jooq.meta.jaxb.Generate;
import org.jooq.meta.jaxb.Generator;
import org.jooq.meta.jaxb.Jdbc;
import org.jooq.meta.jaxb.Target;
// other import statements omitted

public class GenerateJOOQSources {
    private static final Logger LOGGER = LoggerFactory.getLogger(GenerateJOOQSources.class);

    public static void main(String... args) throws Exception {
        if (args.length > 0) { // run with any argument to run this one
            // programmatic version 1
            LOGGER.info("... Generating jOOQ using programmatic version 1 with XML
            configuration ...");
            URL resource = GenerateJOOQSources.class.getResource("/jooq-config.xml");
            assert resource != null;
            final File jooqCfg = Paths.get(resource.toURI()).toFile();
```

```

        GenerationType.generate(
            Files.readString(jooqCfg.toPath())
        );
    } else {
        // programmatic version 2
        LOGGER.info("... Generating jOOQ using programmatic version 2 with programmatic
        configuration ...");
        GenerationType.generate(new Configuration()
            .withJdbc(new Jdbc()
                .withDriver("org.mariadb.jdbc.Driver")
                .withUrl("jdbc:mariadb://localhost:3306/musicdb")
                .withUser("prospring6")
                .withPassword("prospring6"))
            .withGenerator(new Generator()
                .withDatabase(new Database()
                    .withName("org.jooq.meta.mariadb.MariaDBDatabase")
                    .withInputSchema("musicdb")
                    .withIncludes(".*"))
                .withGenerate(
                    new Generate()
                        .withPojos(true)
                        .withPojosToString(true)
                        .withDaos(true)
                .withTarget(new Target()
                    .withPackageName("com.apress.prospring6.seven.jooq.
                    generated")
                    .withDirectory("./chapter07-jooq/src/main/generated"))));
    }
}
}
}

```

To run the second version, just execute the class with an argument (any argument). The `jooq-config.xml` file is located in the resources directory, and it contains the same information shown in the full programmatic version in version2, but in XML format.



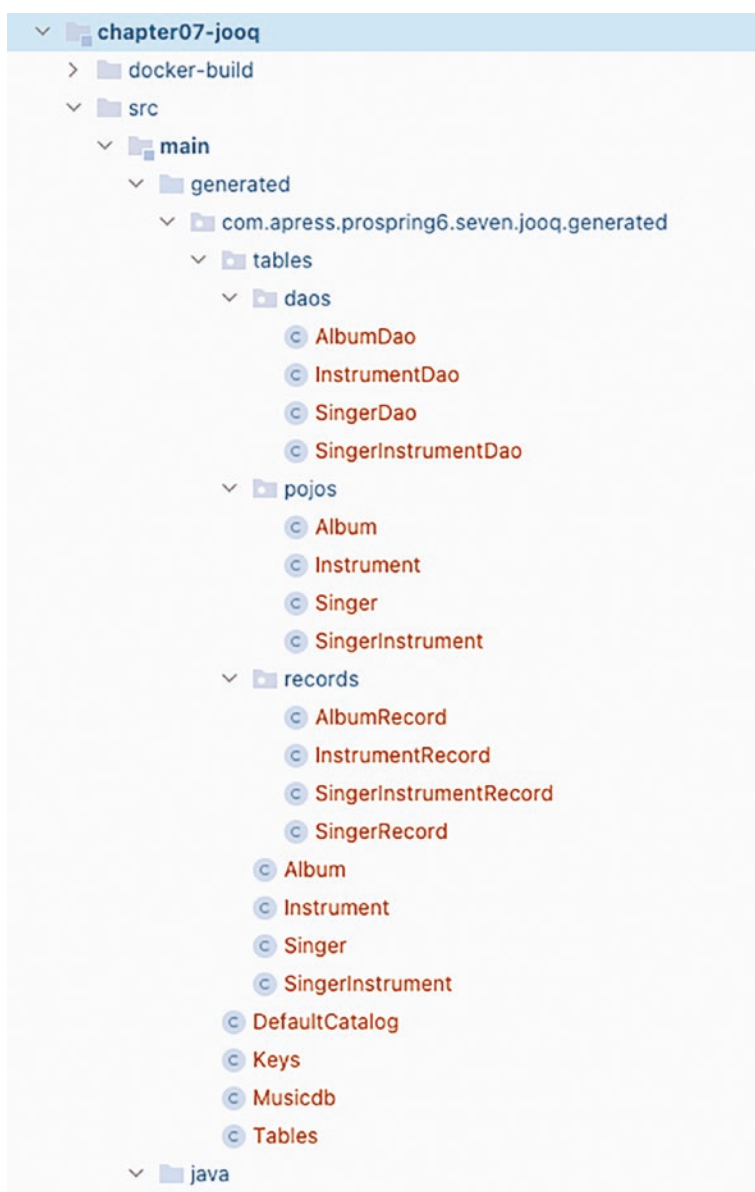
Notice that the generated sources are saved in a directory named `generated`, saved at the same level with the `java` directory, the one that Maven and Gradle know contains the project sources. A small configuration is necessary for Maven and Gradle to tell them that the generated directory also contains sources for the project.

Separating the generated sources from the concrete project sources is a good practice for clarity reasons and avoiding the risk of overriding concrete classes with generated ones in case of misconfiguration.

---

If the `withDirectory` property is not set, the generated sources are put into the `target/generated-sources` directory. For easy access and visibility, we decided to put them in a more obvious location.

Once the `GenerateJOOQSources` is executed, the generated directory should be populated with a lot of classes, as shown in Figure 7-3.



**Figure 7-3.** Classes generated by jOOQ

The reason there are so many classes in the generated directory is that the configuration shown in Listing 7-35 requested them through this snippet: `withPojos(true).withPojosToString(true).withDaos(true)`. There are a lot more possible options, and you can find them all in the official documentation. For the example in this book, we just configured for POJO classes to be generated for the tables in the MariaDB schema, `toString()` methods for them, for logging purposes, and DAO classes to manage data. The generated POJO classes look like the Hibernate entity classes but without the annotations. The classes under package `daos` look very similar to the DAO classes we've been writing so far, only the instances returned are of the types declared in the `pojos` package.

Now that we have the classes, let's use them. The first step is to configure jOOQ support in the Spring application, which is quite easy. At the core of jOOQ is a class named `org.jooq.DSLContext`. An instance of this class is the main entry point for client code to access jOOQ classes and functionality that are related to `org.jooq.Query` execution. To configure a `org.jooq.DSLContext` bean a connection to the database, a few details regarding the syntax being used when generating queries, and other such little things are needed. The most important piece is the database connection. Earlier this chapter presented the `BasicDataSourceCfg` configuration class that configured a MariaDB `DataSource`; this class can be reused, because the database connection can be retrieved from it. Listing 7-36 shows the `JOOQConfig` class that contains a single `DSLContext` declaration.

**Listing 7-36.** Spring Configuration Class to Enable Support for jOOQ

```
package com.apress.prospring6.seven.jooq.config;

import org.jooq.DSLContext;
import org.jooq.conf.RenderNameCase;
import org.jooq.conf.RenderQuotedNames;
import org.jooq.conf.Settings;
import org.jooq.impl.DSL;
import javax.sql.DataSource;
import java.sql.SQLException;
// other import statements omitted

@Configuration
public class JOOQConfig {

    private static Logger LOGGER = LoggerFactory.getLogger(JOOQConfig.class);

    @Autowired
    DataSource dataSource;

    @Bean
    DSLContext dslContext() {
        try {
            return DSL.using(dataSource.getConnection(),
                new Settings()
                    .withRenderNameCase(RenderNameCase.UPPER)
                    .withRenderQuotedNames(RenderQuotedNames.NEVER)
                    .withRenderSchema(false)
                    .withRenderGroupConcatMaxLenSessionVariable(false));
        } catch (SQLException ex) {
            LOGGER.error("Problem initializing jOOQ.DSLContext!", ex);
        }
        return null;
    }
}
```

Notice how the `BasicDataSourceCfg` configuration class is not imported using `@Import`. This is because we want to keep the jOOQ configuration detached and only introduce it to the configuration when a context is created.

Now we'll use our new configuration class. The easiest way to keep the project compiling even when the generated classes are not there is to write tests. Another great thing about jOOQ is that it integrates nicely with Spring Test components and `Testcontainers`, which makes writing tests easier too. We just had to copy

the `HibernateTest` class and replace the test context annotation configuration and the body of each method and, *voilà*, we had a class testing SQL native queries generated by jOOQ's `DSLContext`. Listing 7-37 shows a few test methods from the `JOOQDslTest`, because you don't have to use the jOOQ-generated DAOs if you don't want to.

**Listing 7-37.** Testing jOOQ's `DSLContext`

```

package com.apress.prospring6.seven;

import com.apress.prospring6.seven.base.config.BasicDataSourceCfg;
import com.apress.prospring6.seven.jooq.config.JOOQConfig;
import com.apress.prospring6.seven.jooq.generated.tables.records.SingerRecord;
import org.jooq.DSLContext;
import static com.apress.prospring6.seven.jooq.generated.tables.Singer.SINGER;
// other import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {BasicDataSourceCfg.class, JOOQConfig.class})
public class JOOQDslTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(JOOQDslTest.class);

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @Autowired
    DSLContext dslContext;

    @Test
    @DisplayName("should return all singers")
    void findAll(){
        Result<SingerRecord> singers = dslContext.selectFrom(SINGER).fetch();
        assertEquals(3, singers.size());
    }

    @Test
    @DisplayName("should return singer by id")
    void testFindById(){
        SingerRecord singerRecord = dslContext.selectFrom(SINGER).where(SINGER.ID.eq(2)).
fetchOne();

        assertNotNull(singerRecord);
        assertEquals("Ben", singerRecord.getFirstName());
    }
    // other code omitted
}

```



Notice that the jOOQ syntax looks a lot like SQL. Also, if logging for `org.jooq` is configured to `DEBUG`, when the `JOOQDslTest` class is run, the generated SQL queries are dumped in the console, but also the results. A log sample is shown in Listing 7-38.

**Listing 7-38.** Log Snippets for the Execution of the `JOOQDslTest` Class

```

DEBUG: JooqLogger - Executing query      : select SINGER.ID, SINGER.VERSION, SINGER.
                                         FIRST_NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE
                                         from SINGER
DEBUG: JooqLogger - Fetched result       : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                      : | ID|VERSION|FIRST_NAME|LAST_NAME|BIRTH_DATE|
DEBUG: JooqLogger -                      : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                      : |  1|      0|John      |Mayer   |1977-10-16|
DEBUG: JooqLogger -                      : |  2|      0|Ben       |Barnes  |1981-08-20|
DEBUG: JooqLogger -                      : |  3|      0|John      |Butler  |1975-04-01|
DEBUG: JooqLogger -                      : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger - Fetched row(s)       : 3
...
DEBUG: JooqLogger - Executing query      : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_
                                         NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE from
                                         SINGER where SINGER.ID = ?
DEBUG: JooqLogger --> with bind values   : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_
                                         NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE from
                                         SINGER where SINGER.ID = 2
DEBUG: JooqLogger - Fetched result       : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                      : | ID|VERSION|FIRST_NAME|LAST_NAME|BIRTH_DATE|
DEBUG: JooqLogger -                      : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                      : |  2|      0|Ben       |Barnes  |1981-08-20|
DEBUG: JooqLogger -                      : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger - Fetched row(s)       : 1
    
```

Neat, right? What about retrieving singers with albums? This obviously requires a join. This can be done as well, but a little manual work is required. The advantage is that we can design the classes to store the data and simplify them to hold only the necessary data. For example, we created a record named `SingerWithAlbums` that only contains the `firstName`, `lastName`, and `List<AlbumRecord>`. As the name indicates, `AlbumRecord` is also a record and only declares two fields, `title` and `releaseDate`. Listing 7-39 shows these two records and the test method loading the information using `DSLContext`.

**Listing 7-39.** jOOQ Way to Execute a Join Query

```

// -----
// SingerWithAlbums.java
public record SingerWithAlbums(String firstName,
                               String lastName,
                               LocalDate birthDate,
                               List<AlbumRecord> albums) {

}
// -----
// AlbumRecord.java
public record AlbumRecord( String title, LocalDate releaseDate) {}
    
```

```
// -----
// JooQDslTest.java
import com.apress.prospring6.seven.jooq.records.SingerWithAlbums;
import com.apress.prospring6.seven.jooq.records.AlbumRecord;

import static com.apress.prospring6.seven.jooq.generated.tables.Singer.SINGER;
import static com.apress.prospring6.seven.jooq.generated.tables.Album.ALBUM;

import static org.jooq.Records.mapping;
import static org.jooq.impl.DSL.multisetAgg;

@Test
@DisplayName("should return all singers with albums as records")
void findAllWithAlbumsAsRecords(){
    List<SingerWithAlbums> singerWithAlbums =
        dslContext.select(SINGER.FIRST_NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE,
            multisetAgg(ALBUM.TITLE, ALBUM.RELEASE_DATE).convertFrom
                (r -> r.map(mapping(AlbumRecord::new))))
            .from(SINGER)
            .innerJoin(ALBUM).on(ALBUM.SINGER_ID.eq(SINGER.ID))
            .groupBy(SINGER.FIRST_NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE)
            .fetch(mapping(SingerWithAlbums::new));
    assertEquals(2, singerWithAlbums.size());
}

```

To make sure we only get the singers that have albums in the databases, we use the `innerJoin(..)` method. The `multisetAgg(..)` method is used to aggregate the column of an album into an `AlbumRecord`. Since we do not want duplicate entries, a `groupBy(..)` call is also necessary. As you might have noticed, the Java code here looks a lot like its SQL equivalent as well, which makes it very easy to write and enables you to ensure that only the data you are interested in is extracted. The `SINGER` instance is of type `com.apress.prospring6.seven.jooq.generated.tables.Singer` that encapsulates all the metadata supporting writing jOOQ queries involving the `SINGER` table. The same goes for `ALBUM` and `INSTRUMENT`, which are not used in this example.



A version of the generated classes is part of the repository, in case you are not interested in generating them yourself.

---

Listing 7-40 shows a snippet of the `findAllWithAlbumsAsRecords()` log, showing the generated query and the retrieved data.

**Listing 7-40.** `findAllWithAlbumsAsRecords()` Log Snippet Showing the jOOQ-Generated Query

```
DEBUG: JooqLogger - Executing query           : select SINGER.FIRST_NAME, SINGER.LAST_NAME,
SINGER.BIRTH_DATE,
JSON_MERGE_PRESERVE(['[]', CONCAT(['', GROUP_CONCAT(JSON_ARRAY(ALBUM.TITLE, ALBUM.RELEASE_
DATE) separator ','), '']')])
from SINGER
join ALBUM on ALBUM.SINGER_ID = SINGER.ID

```

```

group by SINGER.FIRST_NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE
DEBUG: JooqLogger - Fetched result: +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -           : |FIRST_NAME|LAST_NAME|BIRTH_DATE|multiset_agg          |
DEBUG: JooqLogger -           : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -           : |Ben      |Barnes  |1981-08-20|[AlbumRecord[title=11:11, releaseDate=..]]|
DEBUG: JooqLogger -           : |John    |Mayer   |1977-10-16|[AlbumRecord[title=The Search For .., r...]|
DEBUG: JooqLogger -           : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger - Fetched row(s) : 2

```

In this example, because we wanted to keep our objects compact, we used some simplified records to represent singer and albums. Here is where Hibernate might meet jOOQ. Instead of mapping the jOOQ retrieved data to records, we could have mapped it to JPA entities.

Writing insert, update, and delete statements is just as easy; feel free to look at the examples provided with the book on your own, because now it's time to cover jOOQ DAO classes. The DAO classes generated by jOOQ are grouped under the `daos` package, and all of them extend `org.jooq.impl.DAOImpl<R extends UpdatableRecord<R>, P, T>`. This means that for the `SINGER` table, a class named `SingerDao` was created that extends `DAOImpl<SingerRecord, com.apress.prospring6.seven.jooq.generated.tables.pojos.Singer, Integer>`. This type of class is very similar in concept to the repository implementations generated by Spring Data, which will be introduced later in the book. The `SingerRecord` is generated by jOOQ, and its purpose is to represent a `Singer` instance holding a primary key that maps to a database record. This type of class is designed to be used internally by jOOQ, so you should never need to use them directly. The `com.apress.prospring6.seven.jooq.generated.tables.pojos.Singer` is a view on top of it that you can use in your code to interact with jOOQ DAO classes.

With the previous rather abstract way of looking at things in mind, let's see how we can test jOOQ DAO classes. Listing 7-41 shows two very simple test methods testing the `SingerDao` class.

**Listing 7-41.** JooQDaoTest Class

```

package com.apress.prospring6.seven;

import com.apress.prospring6.seven.base.config.BasicDataSourceCfg;
import com.apress.prospring6.seven.jooq.config.JooQConfig;
import com.apress.prospring6.seven.jooq.generated.tables.daos.SingerDao;
import org.jooq.DSLContext;
// other import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnit4Config(classes = {BasicDataSourceCfg.class, JooQConfig.class})
public class JooQDaoTest {

    @Container
    static MariaDBContainer<> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

```

```

@Autowired
DSLContext dslContext;

@Test
@DisplayName("should return all singers")
void findAll(){
    var dao = new SingerDao(dslContext.configuration());

    var singers = dao.findAll();
    assertEquals(3, singers.size());
}

@Test
@DisplayName("should return singer by id")
void testFindById(){
    var dao = new SingerDao(dslContext.configuration());

    var singer = dao.findById(2);

    assertNotNull(singer);
    assertEquals("Ben", singer.getFirstName());
}

@Test
@SqlGroup({
    @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
        executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD),
    @Sql(scripts = {"classpath:testcontainers/remove-nina.sql"},
        executionPhase = Sql.ExecutionPhase.AFTER_TEST_METHOD)
})
@DisplayName("should update a singer")
void testUpdate() {
    var dao = new SingerDao(dslContext.configuration());
    var nina = dao.findById(5);
    assertNotNull(nina);

    nina.setFirstName("Eunice Kathleen");
    nina.setLastName("Waymon");
    dao.update(nina);

    var updatedNina = dao.findById(5);

    assertNotNull(updatedNina);
    assertEquals("Eunice Kathleen", updatedNina.getFirstName());
    assertEquals("Waymon", updatedNina.getLastName());
}
}

```

Listing 7-42 depicts some snippets of the `JOOQDaoTest` execution log, showing the generated SQL queries and the data.

**Listing 7-42.** JooQDaoTest Class Log Snippets

```

DEBUG: JooqLogger - Executing query           : select SINGER.ID, SINGER.VERSION, SINGER.
FIRST_NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE
from SINGER
DEBUG: JooqLogger - Fetched result           : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                          : | ID|VERSION|FIRST_NAME|LAST_NAME|BIRTH_DATE|
DEBUG: JooqLogger -                          : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                          : |  1|      0|John      |Mayer   |1977-10-16|
DEBUG: JooqLogger -                          : |  2|      0|Ben        |Barnes  |1981-08-20|
DEBUG: JooqLogger -                          : |  3|      0|John      |Butler  |1975-04-01|
DEBUG: JooqLogger -                          : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger - Fetched row(s)           : 3
...
DEBUG: JooqLogger - Executing query           : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_
NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE from
SINGER where SINGER.ID = ?
DEBUG: JooqLogger --> with bind values        : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_NAME,
SINGER.LAST_NAME, SINGER.BIRTH_DATE from SINGER
where SINGER.ID = 2
DEBUG: JooqLogger - Fetched result           : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                          : | ID|VERSION|FIRST_NAME|LAST_NAME|BIRTH_DATE|
DEBUG: JooqLogger -                          : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                          : |  2|      0|Ben        |Barnes  |1981-08-20|
DEBUG: JooqLogger -                          : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger - Fetched row(s)           : 1
...
DEBUG: JooqLogger - Executing query           : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_
NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE from
SINGER where SINGER.ID = ?
DEBUG: JooqLogger --> with bind values        : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_
NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE from
SINGER where SINGER.ID = 5
DEBUG: JooqLogger - Fetched result           : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                          : | ID|VERSION|FIRST_NAME|LAST_NAME|BIRTH_DATE|
DEBUG: JooqLogger -                          : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger -                          : |  5|      0|Nina      |Simone  |1933-02-21|
DEBUG: JooqLogger -                          : +-----+-----+-----+-----+-----+
DEBUG: JooqLogger - Fetched row(s)           : 1
DEBUG: JooqLogger - Executing query           : update SINGER set SINGER.VERSION = ?,
SINGER.FIRST_NAME = ?, SINGER.LAST_NAME = ?,
SINGER.BIRTH_DATE = ? where SINGER.ID = ?
DEBUG: JooqLogger --> with bind values        : update SINGER set SINGER.VERSION = 0, SINGER.FIRST_
NAME = 'Eunice Kathleen', SINGER.LAST_NAME = 'Waymon', SINGER.BIRTH_DATE = date '1933-02-21' where
SINGER.ID = 5
DEBUG: JooqLogger - Affected row(s)         : 1
DEBUG: JooqLogger - Executing query           : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_
NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE from
SINGER where SINGER.ID = ?

```

```

DEBUG: JooqLogger --> with bind values      : select SINGER.ID, SINGER.VERSION, SINGER.FIRST_
                                           : NAME, SINGER.LAST_NAME, SINGER.BIRTH_DATE
                                           : from SINGER where SINGER.ID = 5
DEBUG: JooqLogger - Fetched result         : +---+-----+-----+-----+-----+
DEBUG: JooqLogger -                       : | ID|VERSION|FIRST_NAME   |LAST_NAME|BIRTH_DATE|
DEBUG: JooqLogger -                       : +---+-----+-----+-----+-----+
DEBUG: JooqLogger -                       : | 5|      0|Eunice Kathleen|Waymon   |1933-02-21|
DEBUG: JooqLogger -                       : +---+-----+-----+-----+-----+
DEBUG: JooqLogger - Fetched row(s)        : 1

```

The jOOQ-generated POJO classes map completely to the tables they model, which means that when using the DAO classes, we always work with a fully populated object. So if performance is an issue and you need only a small set of columns, using the `DSLContext` is the better approach.

This section showed you how to configure jOOQ in a Spring application and gave a few usage examples to try to underline a few of the following benefits of using this framework:

- It allows the developer to think in terms of objects, rather than sets of objects.
- It saves you from writing SQL queries but allows you to write clear and concise Java code representing the query logic.
- It generates very good, working SQL code and the Java code provides type safety—there is no way to have a typo in your SQL query if you don't write the SQL query.
- It supports a ridiculous number of databases, so if you want to use a relational database in a project, there's a 99% chance you can use jOOQ too.
- It is a very good integration with Spring.

Using the jOOQ framework also has disadvantages, of course, and this list is just a sampling of what was noticed while writing this section:

- You have to install jOOQ manually on your Maven repo, because it was pulled from Maven Central, starting with version 3.16.6.
- Even if you don't have to write SQL queries, the Java syntax for interacting with a database is a language itself. Luckily the compiler helps here, so usually compiling Java code results in a valid SQL script.
- Currently there is some confusion regarding which version works with which JDK. For example, the community trial version was supposed to work with JDK 17+, but it didn't at the time of writing.
- Complex SQL queries will be represented by complex Java queries, and traversing large object graphs can become very inefficient, so in the end it is the developer's responsibility to design the database schema properly.

This section was just meant to introduce you to jOOQ as a possible alternative for Hibernate. Its capabilities are very vast and covering them would require an entire book. If jOOQ looks interesting to you, you can advance your knowledge by reading more about it on its official page.

Spring Boot makes things even easier with jOOQ and Hibernate. Since the same library `spring-boot-starter-data-jpa` is used in **Chapter 8** and the code is pretty much the same as the code for classic non-Boot Spring application, we'll end this chapter here.

## Summary

In this chapter, we first discussed the basic concepts of Hibernate and how to configure it within a Spring application. Then we covered common techniques for defining ORM mappings; associations; and how to use the `HibernateTemplate` class to perform various database operations. With regard to Hibernate, we covered only a small piece of its functionality and features. If you are interested in using Hibernate with Spring, we highly recommend you study Hibernate's standard documentation.

Also, numerous books discuss Hibernate in detail. We recommend *Beginning Hibernate 6* by Joseph Ottinger, Jeff Linwood, and Dave Minter (Apress, 2022)<sup>13</sup>, as well as *Pro JPA 2* by Mike Keith and Merrick Schincariol (Apress, 2013)<sup>14</sup>.

We also introduced you to jOOQ, a cool framework for generating SQL queries using Java code; jOOQ can be used together with Hibernate, or could replace it altogether, it all depends on your development needs.

**Chapter 8** will introduce you to JPA and how to use it when using Spring. Hibernate provides excellent support for JPA, and we will continue to use Hibernate as the persistence provider for the examples in **Chapter 8**. For query and update operations, JPA act likes Hibernate. We'll also discuss advanced topics including native and criteria query and how we can use Hibernate as well as its JPA support.

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<sup>13</sup> <https://link.springer.com/book/10.1007/978-1-4842-7337-1>

<sup>14</sup> <https://link.springer.com/book/10.1007/978-1-4302-4927-6>

## CHAPTER 8



# Spring with JPA

In **Chapter 7**, we discussed how to use Hibernate with Spring when implementing data access logic with the ORM approach. We demonstrated how to configure Hibernate's `SessionFactory` in Spring's configuration and how to use the `Session` interface for various data access operations. However, that is just one way Hibernate can be used. Another way of adopting Hibernate in a Spring application is to use Hibernate as a persistence provider of the standard Java Persistence API (JPA), now renamed to Jakarta Persistence API.

Hibernate's POJO mapping and its powerful query language (HQL) have gained great success and also influenced the development of data access technology standards in the Java world. After Hibernate, the Java Community Process members developed the Java Data Objects (JDO) standard and then JPA.

At the time of this writing JPA has reached version 3.1 and provides concepts that were standardized such as `PersistenceContext`, `EntityManager`, and the Java Persistence Query Language (JPQL). These standardizations provide a way for developers to switch between JPA persistence providers such as Hibernate, EclipseLink, Oracle TopLink, and Apache OpenJPA. As a result, most new JEE applications are adopting JPA as the data access layer.

Spring also provides excellent support for JPA. For example, the Spring container creates and manages an `EntityManager` instance, injecting it in the respective JPA components, based on a `EntityManagerFactoryBean` bean.

The Spring Data project also provides a subproject called Spring Data JPA, which provides advanced support for using JPA in Spring applications. The main features of the Spring Data JPA project include concepts of a repository and specification and support for the Query Domain-Specific Language (Querydsl).

This chapter covers how to use JPA 3.1, recently outsourced by Oracle and thus renamed to Jakarta Persistence API<sup>1</sup>, with Spring, using Hibernate as the underlying persistence provider. You will learn how to implement various database operations by using JPA's `EntityManager` interface and JPQL. Then you will see how Spring Data JPA can further help simplify JPA development. Finally, we present advanced topics related to ORM, including native queries and criteria queries.

Specifically, we discuss the following topics:

- *Core concepts of Jakarta Persistence API (JPA):* We cover major concepts of JPA.
- *Configuring the JPA entity manager:* We discuss the types of `EntityManagerFactory` that Spring supports and how to configure the most commonly used one, `LocalContainerEntityManagerFactoryBean`.
- *Data operations:* We show how to implement basic database operations in JPA, which is much like the concept when using Hibernate on its own.

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<sup>1</sup><https://github.com/eclipse-ee4j/jpa-api>



- *Advanced query operations:* We discuss how to use native queries in JPA and the strongly typed Criteria API in JPA for more flexible query operations.



Like Hibernate, JPA supports the definition of mappings either in XML or in Java annotations. This chapter focuses on the annotation type of mapping because its usage tends to be much more popular than the XML style.

---

## Introducing JPA 3.1

Like other Java Specification Requests (JSRs), the objective of the JPA 2.1 specification as defined by JSR-338<sup>2</sup> is to standardize the ORM programming model in both the JSE and JEE environments. It defines a common set of concepts, annotations, interfaces, and other services that a JPA persistence provider should implement. When programming to the JPA standard, developers have the option of switching the underlying provider at will, just like switching to another JEE-compliant application server for applications developed on the JEE standards. Since Oracle is no longer in charge of JPA development, there will be no other JSRs for it in the future, but you can read about the latest releases on its Jakarta EE official site. The version used in this project is JPA version 3.1.<sup>3</sup>

The core concept of JPA is the `EntityManager` interface, which comes from factories of the type `EntityManagerFactory`. The main job of `EntityManager` is to maintain a persistence context, in which all the entity instances managed by it will be stored. The configuration of `EntityManager` is defined as a *persistence unit*, and there can be more than one persistence unit in an application. If you are using Hibernate, you can think of the persistence context in the same way as the `Session` interface, while `EntityManagerFactory` is the same as `SessionFactory`. In Hibernate, the managed entities are stored in the session, which you can directly interact with via Hibernate's `SessionFactory` or `Session` interface. In JPA, however, you can't interact with the persistence context directly. Instead, you need to rely on `EntityManager` to do the work for you.

JPQL is similar to HQL, so if you have used HQL before, JPQL should be easy to pick up. However, in JPA 2, a strongly typed Criteria API was introduced, which relies on the mapped entities' metadata to construct the query. Given this, any errors will be discovered at compile time rather than runtime.

For a detailed discussion of JPA 2, since JPA 3 is identical except the package name (jakarta), we recommend the book *Pro JPA 2*<sup>4</sup> by Mike Keith and Merrick Schincariol (Apress, 2013). In this section, we discuss the basic concepts of JPA, the sample data model that will be used in this chapter, and how to configure Spring's `ApplicationContext` to support JPA.

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<sup>2</sup><https://jcp.org/aboutJava/communityprocess/final/jsr338/index.html>

<sup>3</sup><https://jakarta.ee/specifications/persistence/3.1>

<sup>4</sup><https://link.springer.com/book/10.1007/978-1-4302-1957-6>

## Sample Data Model for Example Code

In this chapter, we use the same data model as used in **Chapter 7**. To get started, we will begin with the same database creation scripts used in the previous chapter. If you skipped **Chapter 7**, take a look at the data model presented in that chapter’s “Sample Data Model for Example Code” section, which can help you understand the sample code in this chapter.

## Configuring JPA’s EntityManagerFactory

As mentioned earlier in this chapter, to use JPA in Spring, we need to configure `EntityManagerFactory`, just like `SessionFactory` used in Hibernate. Spring supports three types of `EntityManagerFactory` configurations.

The first option uses the `LocalEntityManagerFactoryBean` class. It’s the simplest one, which requires only the persistence unit name. However, since it doesn’t support the injection of `DataSource` and hence isn’t able to participate in global transactions, it’s suitable only for simple development purposes.

The second option is to use a JEE-compliant container, in which the application server bootstraps the JPA persistence unit based on the information in the deployment descriptors. This allows Spring to look up the entity manager via the JNDI JEE namespace. This obviously means that XML configuration is needed for this. Listing 8-1 depicts the element needed to look up an entity manager via JNDI.

**Listing 8-1.** Spring XML Configuration Snippet Using JNDI JEE Namespace for Lookup

```
<beans ...>
  <jee:jndi-lookup id="prospring6Emf"
    jndi-name="persistence/prospring6PersistenceUnit"/>
</beans>
```

In the JPA specification, a persistence unit should be defined in the configuration file `META-INF/persistence.xml`. However, as of Spring 3.1, a new feature has been added that eliminates this need; we show you how to use it later in this chapter.

Luckily, there are various Java configuration alternatives that can be used in a `Spring@Configuration` class. The configuration depicted in Listing 8-2 is the most compact of them.

**Listing 8-2.** Spring Annotated Configuration Snippet Using JNDI JEE Namespace for Lookup

```
package com.apress.prospring6.eight.config;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.jdbc.datasource.lookup.JndiDataSourceLookup;
import javax.sql.DataSource;

@Configuration
public class JndiDataSourceCfg {

    @Bean
    public DataSource dataSource() {
        final JndiDataSourceLookup dsLookup = new JndiDataSourceLookup();
        dsLookup.setResourceRef(true);
        return dsLookup.getDataSource("persistence/prospring6PersistenceUnit");
    }
}
```

The third option, which is the most common and is used in this chapter, is the `LocalContainerEntityManagerFactoryBean` class that supports the injection of `DataSource` and can participate in both local and global transactions. Listing 8-3 depicts the configuration snippet.

**Listing 8-3.** Spring Annotated Configuration Using `LocalContainerEntityManagerFactoryBean`

```

package com.apress.prospring6.eight.config;

import org.hibernate.cfg.Environment;
import org.hibernate.jpa.HibernatePersistenceProvider;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.orm.jpa.JpaTransactionManager;
import org.springframework.orm.jpa.JpaVendorAdapter;
import org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean;
import org.springframework.orm.jpa.vendor.HibernateJpaVendorAdapter;
import org.springframework.transaction.PlatformTransactionManager;
import org.springframework.transaction.annotation.EnableTransactionManagement;
// other import statements omitted

@Import(BasicDataSourceCfg.class)
@Configuration
@EnableTransactionManagement
@ComponentScan(basePackages = {"com.apress.prospring6.eight.service"})
public class JpaConfig {

    private static Logger LOGGER = LoggerFactory.getLogger(JpaConfig.class);

    @Autowired
    DataSource dataSource;

    @Bean
    public PlatformTransactionManager transactionManager() {
        JpaTransactionManager transactionManager=new JpaTransactionManager();
        transactionManager.setEntityManagerFactory(entityManagerFactory().getObject());
        return transactionManager;
    }

    @Bean
    public JpaVendorAdapter jpaVendorAdapter() {
        return new HibernateJpaVendorAdapter();
    }

    @Bean
    public Properties jpaProperties() {
        Properties jpaProps = new Properties();
        jpaProps.put(Environment.HBM2DDL_AUTO, "none");
        jpaProps.put(Environment.FORMAT_SQL, false);
        jpaProps.put(Environment.USE_SQL_COMMENTS, false);
        jpaProps.put(Environment.SHOW_SQL, false);
        return jpaProps;
    }
}

```

```

@Bean
public LocalContainerEntityManagerFactoryBean entityManagerFactory() {
    var factory = new LocalContainerEntityManagerFactoryBean();
    factory.setDataSource(dataSource);
    factory.setJpaVendorAdapter(jpaVendorAdapter());
    //factory.setPersistenceProviderClass(HibernatePersistenceProvider.class);
    factory.setPackagesToScan("com.apress.prospring6.eight.entities");
    factory.setJpaProperties(jpaProperties());
    return factory;
}
}

```

In this configuration, several beans are declared in order to be able to support the configuration of `LocalContainerEntityManagerFactoryBean` with Hibernate as the persistence provider. The purpose for each bean and other configuration details are described next:

- *Component scan*: The tag should be familiar to you. We instruct Spring to scan the components under the package `com.apress.prospring6.eight.service`.
- `dataSource`: This bean is injected and it is declared in a separate configuration class that contains only database-specific beans and properties (e.g., `BasicDataSourceCfg` introduced in [Chapter 7](#)).
- `transactionManager`: `EntityManagerFactory` requires a transaction manager for transactional data access. Spring provides a transaction manager specifically for JPA (`org.springframework.orm.jpa.JpaTransactionManager`). The bean is declared with an ID of `transactionManager` assigned. We discuss transactions in detail in [Chapter 9](#). The `@EnableTransactionManagement` annotation is needed to support a declaration of the transaction demarcation requirements using annotations, but for now notice that this bean needs an `EntityManagerFactory` instance to be created that is provided by the `EntityManagerFactoryBean`, by calling `getObject()`.
- `JpaVendorAdapter`: This bean allows us to plug in vendor-specific behavior into Spring's `EntityManagerFactory` creators. In this case we are using Hibernate, and thus the type of the bean is `HibernateJpaVendorAdapter`.
- `EntityManagerFactoryBean`: The JPA `EntityManagerFactory` bean is the most important part of this configuration. However, it is not part of it directly, but instead a `LocalContainerEntityManagerFactoryBean` bean is declared, which will configure and create it. To configure the `LocalContainerEntityManagerFactoryBean` bean the following are needed:
  - a `DataSource` bean.
  - a `HibernateJpaVendorAdapter` bean.
  - Third, although commented, it deserves a mention. Calling the `setPersistenceProviderClass(..)` method sets the `PersistenceProvider` implementation class to use for creating the `EntityManagerFactory`. If not specified, the persistence provider will be taken from the `JpaVendorAdapter` (if any) or retrieved through scanning (as far as possible). This also means, when specified, the `JpaVendorAdapter` bean is no longer necessary.

- Forth, we instruct the `LocalContainerEntityManagerFactoryBean` bean to scan for the domain objects with ORM annotations under the package `com.apress.prospring6.eight.entities` by setting the `packagesToScan` property to this value.



Note that this feature has been available only since Spring 3.1. In the same version support for domain class scanning was added, that allows ditching the definition of the persistence unit from the `META-INF/persistence.xml` file.

- Finally, the `jpaProperties` property provides configuration details for the Hibernate persistence provider. The configuration options are the same as those introduced in [Chapter 7](#).

## Using JPA Annotations for ORM Mapping

If you read [Chapter 7](#) you might have noticed that the annotations used to configure entity classes were JPA annotations. Hibernate used to have a set of its own, but when JPA was developed the team behind it decided to keep things simple and adopt the new specification. This is the reason why, if you take a look at the domain classes' source code in [Chapter 7](#), you will see that same mapping annotations are used.

Once `EntityManagerFactory` has been properly configured, injecting it into your classes is simple. Let's start with a simple service class.



In a multilayered application, service classes depend on repository classes and service beans are the ones that are usually annotated with `@Transactional`, so that related repository calls can be grouped in the same transaction. Since the service classes in this project do nothing but call repository classes, we decided to combine the two, and thus a service class is annotated with `@Repository` and `@Transactional`.

The purpose of doing this is for simplicity, and except for academic purposes, you might never need to write code like this.



The `@Transactional` annotations are shown in the code of this chapter, because executing database operations outside of a transaction is not something you might ever want to do, unless you are using a database as a service (e.g., DynamoDB). Transactions are discussed in detail in [Chapter 9](#).

The `SingerService` interface depicted in [Listing 8-4](#) declares the methods expected for the bean type to implement.

**Listing 8-4.** SingerService Interface

```

package com.apress.prospring6.eight.service;

import com.apress.prospring6.eight.entities.Singer;
import java.util.Optional;
import java.util.stream.Stream;

public interface SingerService {

    String ALL_SINGER_NATIVE_QUERY =
        "select ID, FIRST_NAME, LAST_NAME, BIRTH_DATE, VERSION from
        SINGER";

    Stream<Singer> findAll();
    Stream<Singer> findAllWithAlbum();
    Optional<Singer> findById(Long id);
    Optional<Singer> save(Singer singer);
    void delete(Singer singer);
    Stream<Singer> findAllByNativeQuery();
}

```

The interface is very simple; it has just three finder methods, one save method, and one delete method. The save method will serve both the insert and update operations. To keep things interesting and a little different, we've also changed the type returned by the methods from `Set<T>` to `Stream<T>`.

Listing 8-5 shows the code for the `SingerServiceImpl` class that implements the `SingerService` interface, which we will use as the sample for performing database operations using JPA.

**Listing 8-5.** SingerServiceImpl Bean Type

```

package com.apress.prospring6.eight.service;

import jakarta.persistence.EntityManager;
import jakarta.persistence.TypedQuery;
import jakarta.persistence.PersistenceContext;
// other import statements omitted

@Service("jpaSingerService")
@Repository
@Transactional
public class SingerServiceImpl implements SingerService {
    private static final Logger LOGGER = LoggerFactory.getLogger(SingerServiceImpl.class);

    @PersistenceContext
    private EntityManager em;

    @Transactional(readOnly=true)
    @Override
    public Stream<Singer> findAllWithAlbum() {
        throw new NotImplementedException("findAllWithAlbum");
    }
}

```

```

@Transactional(readOnly=true)
@Override
public Stream<Singer> findAll() {
    throw new NotImplementedException("findAll");
}

@Transactional(readOnly=true)
@Override
public Optional<Singer> findById(Long id) {
    throw new NotImplementedException("findById");
}

@Override
public Optional<Singer> save(Singer singer) {
    throw new NotImplementedException("save");
}

@Override
public void delete(Singer singer) {
    throw new NotImplementedException("delete");
}

@Override
public Stream<Singer> findAllByNativeQuery() {
    throw new NotImplementedException("findAllByNativeQuery");
}
}

```

Several annotations are applied to the class:

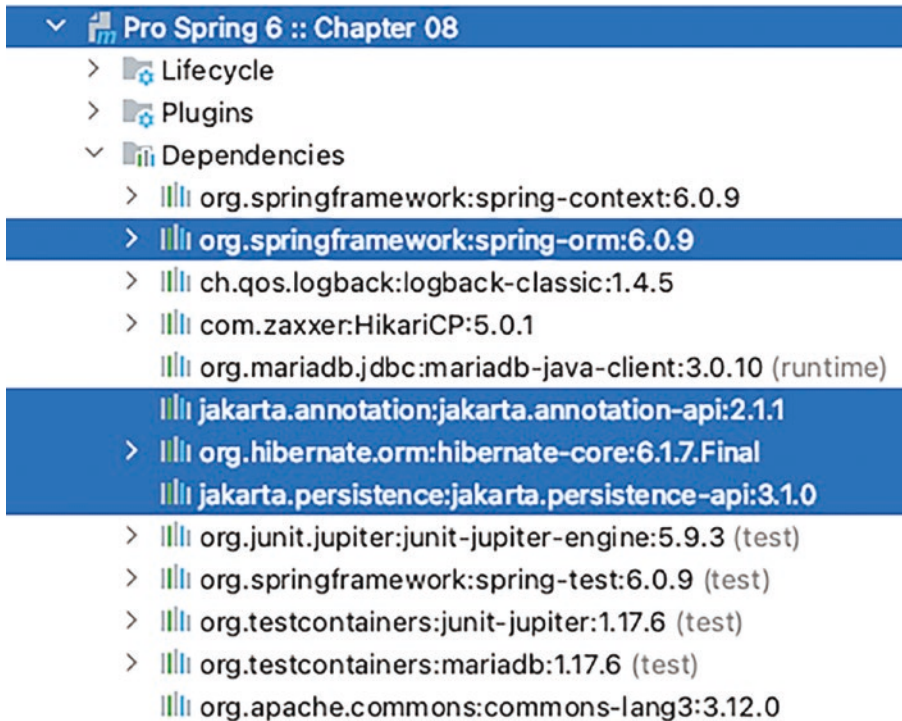
- The `@Service` annotation is used to identify the class as being a Spring component that provides business services to another layer and assigns the Spring bean the name `jpaSingerService`.
- The `@Repository` annotation indicates that the class contains data access logic and instructs Spring to translate the vendor-specific exceptions to Spring's `DataAccessException` hierarchy.
- The `@Transactional` annotation is used for defining transaction requirements.

To inject `EntityManager`, we use the `@PersistenceContext` annotation, which is the standard JPA annotation for entity manager injection. It may be questionable as to why we're using the name `@PersistenceContext` to inject an entity manager, but if you consider that the persistence context itself is managed by `EntityManager`, the annotation naming makes perfect sense. If you have multiple persistence units in your application, you can also add the `unitName` attribute to the annotation to specify which persistence unit you want to be injected. Typically, a persistence unit represents an individual back-end `DataSource`.

## Performing Database Operations with JPA

Executing queries and managing data with `EntityManager` is similar to using Hibernate's `SessionFactory`, the only difference being that there is no session involved.

The syntax for JPQL and HQL is so similar that all the HQL queries that we used in **Chapter 7** are reusable to implement the finder methods within the `SingerService` interface. To use JPA and Hibernate, the exact set of dependencies from **Chapter 7** are required; the most important are `spring-orm` and `hibernate-core-jakarta`. The latter is the one that depends on Jakarta's `persistence-api.jar` and adds it to the classpath as a transitive dependency. The dependencies of this project as shown in the Gradle View of IntelliJ IDEA in **Figure 8-1**.



**Figure 8-1.** Spring with Hibernate JPA project dependencies

## Using the Java Persistence Query Language to Query Data

**Listing 8-6** recaps the important bits of code for the `Singer` domain object model class introduced **Chapter 7**. (The other classes won't be depicted.)

**Listing 8-6.** Singer Domain Object

```
package com.apress.prospring6.eight.entities;

import jakarta.persistence.*;
import java.io.Serializable;
// other import statements omitted
```



```

@Entity
@Table(name = "SINGER")
@NamedQueries({
    @NamedQuery(name=Singer.FIND_ALL, query="select s from Singer s"),
    @NamedQuery(name=Singer.FIND_SINGER_BY_ID,
        query=""
        select distinct s from Singer s
        left join fetch s.albums a
        left join fetch s.instruments i
        where s.id = :id
        """),
    @NamedQuery(name=Singer.FIND_ALL_WITH_ALBUM,
        query=""
        select distinct s from Singer s
        left join fetch s.albums a
        left join fetch s.instruments i
        """)
})
public class Singer extends AbstractEntity {
    @Serial
    private static final long serialVersionUID = 2L;

    public static final String FIND_ALL = "Singer.findAll";
    public static final String FIND_SINGER_BY_ID = "Singer.findById";
    public static final String FIND_ALL_WITH_ALBUM = "Singer.findAllWithAlbum";

    private String firstName;
    private String lastName;
    private LocalDate birthDate;
    private Set<Album> albums = new HashSet<>();
    private Set<Instrument> instruments = new HashSet<>();

    @Column(name = "FIRST_NAME")
    public String getFirstName() {
        return this.firstName;
    }

    @Column(name = "LAST_NAME")
    public String getLastName() {
        return this.lastName;
    }

    @Column(name = "BIRTH_DATE")
    public LocalDate getBirthDate() {
        return birthDate;
    }

    @OneToMany(mappedBy = "singer", cascade=CascadeType.ALL, orphanRemoval=true)
    public Set<Album> getAlbums() {
        return albums;
    }
}

```

```

@ManyToMany
@JoinTable(name = "SINGER_INSTRUMENT",
           joinColumns = @JoinColumn(name = "SINGER_ID"),
           inverseJoinColumns = @JoinColumn(name = "INSTRUMENT_ID"))
public Set<Instrument> getInstruments() {
    return instruments;
}
// other methods omitted
}

```

If you analyze the queries defined using `@NamedQuery`, you will see that there seems to be no difference between HQL and JPQL, at least not for the simple queries anyway. Now that we have entity classes and configuration, we can start implementing the methods to interact with the database. Let's begin by writing the `findAll()` method, which simply retrieves all the singers from the database. The method implementation is depicted in Listing 8-7.

**Listing 8-7.** `findAll()` Method Implemented Using `EntityManager`

```

package com.apress.prospring6.eight.service;
// import statements omitted

@Service("jpaSingerService")
@Repository
@Transactional
public class SingerServiceImpl implements SingerService {
    private static final Logger LOGGER = LoggerFactory.getLogger(SingerServiceImpl.class);

    @PersistenceContext
    private EntityManager em;

    @Transactional(readOnly=true)
    @Override
    public Stream<Singer> findAll() {
        return em.createNamedQuery(Singer.FIND_ALL, Singer.class)
                .getResultList()
                .stream();
    }
// other methods omitted
}

```

As shown in Listing 8-7, we use the `EntityManager.createNamedQuery()` method, passing in the name of the query and the expected return type. The method returns an instance of `TypedQuery<X>`. The method `getResultList()` is then called to retrieve the singers, which are then returned as a stream. To test the implementation of the method, a test class is built that uses `Testcontainers` to spin up a MariaDB test container to run the queries on. The test method used to test `SingerServiceImpl.findAll()` and the `Testcontainers` setup are shown in Listing 8-8 (the latter will be omitted from future test examples).

**Listing 8-8.** Testing the findAll() Method

```

package com.apress.prospring6.eight;

import org.testcontainers.containers.MariaDBContainer;
import org.testcontainers.junit.jupiter.Container;
import org.testcontainers.junit.jupiter.Testcontainers;
import static org.junit.jupiter.api.Assertions.assertEquals;
// other import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {SingerServiceTest.TestContainersConfig.class})
public class SingerServiceTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(SingerServiceTest.class);

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @Autowired
    SingerService singerService;

    @Test
    @DisplayName("should return all singers")
    void testFindAll(){
        var singers = singerService.findAll().toList();
        assertEquals(3, singers.size());
        singers.forEach(singer -> LOGGER.info(singer.toString()));
    }

    @Configuration
    @Import(JpaConfig.class)
    public static class TestContainersConfig {
        @Autowired
        Properties jpaProperties;

        @PostConstruct
        public void initialize() {
            jpaProperties.put(Environment.FORMAT_SQL, true);
            jpaProperties.put(Environment.USE_SQL_COMMENTS, true);
            jpaProperties.put(Environment.SHOW_SQL, true);
        }
    }
}

```

The TestContainersConfig class is introduced to override the Hibernate variables that control showing the generated SQL queries. If assertEquals() does not throw an exception (the test fails), running the testFindAll() test method produces the output shown in Listing 8-9.

**Listing 8-9.** Snippets of the Console Output When Running the `testFindAll()` Test Method

```

/* 1 */ DEBUG: LocalContainerEntityManagerFactoryBean - Building JPA container
EntityManagerFactory for persistence unit 'default'
DEBUG: LogHelper - PersistenceUnitInfo [
    name: default
    persistence provider classname: null
    classloader: jdk.internal.loader.ClassLoaders$AppClassLoader@5fffd2b7
    excludeUnlistedClasses: true
    JTA datasource: null
    Non JTA datasource: org.apache.tomcat.dbcp.dbcp2.BasicDataSource@40247d48
    Transaction type: RESOURCE_LOCAL
    PU root URL: file:/Users/iulianacosmina/apress/workspace/pro-spring-6/chapter08/build/
    classes/java/test/
    Shared Cache Mode: UNSPECIFIED
    Validation Mode: AUTO
    Jar files URLs []
    Managed classes names [
        com.apress.prospring6.eight.entities.AbstractEntity
        com.apress.prospring6.eight.entities.Album
        com.apress.prospring6.eight.entities.Instrument
        com.apress.prospring6.eight.entities.Singer]
    Mapping files names []
    Properties []
...
/* 2 */ DEBUG: JdbcEnvironmentInitiator - Database ->
    name : MariaDB
    version : 10.7.4-MariaDB-1:10.7.4+maria~focal
    major : 10
    minor : 7
...
/* 3 */ DEBUG: SqlStatementLogger - select singer0_.ID as id1_2_,
    singer0_.VERSION as version2_2_,
    singer0_.BIRTH_DATE as birth_da3_2_,
    singer0_.FIRST_NAME as first_na4_2_,
    singer0_.LAST_NAME as last_nam5_2_
    from SINGER singer0_
...
/* 4 */ INFO : SingerServiceTest - Singer - Id: 1, First name: John, Last name: Mayer,
    Birthday: 1977-10-16
INFO : SingerServiceTest - Singer - Id: 2, First name: Ben, Last name: Barnes, Birthday:
    1981-08-20
INFO : SingerServiceTest - Singer - Id: 3, First name: John, Last name: Butler, Birthday:
    1975-04-01

```

The output sample is made of four different snippets:

- `/* 1 */` is the `EntityManager` configuration used in this test context.
- `/* 2 */` includes the properties of the container used to run the tests.
- `/* 3 */` is the SQL native query generated for the `Singer.findAll` query.
- `/* 4 */` includes the results returned by the execution of the `Singer.findAll` query.



For associations, the JPA specification states that, by default, the persistence providers must fetch the association eagerly. However, for Hibernate's JPA implementation, the default fetching strategy is still lazy. So, when using Hibernate's JPA implementation, you don't need to explicitly define an association as lazy fetching. The default fetching strategy of Hibernate is different from the JPA specification.

Now let's implement the `findAllWithAlbum()` method, which will fetch the associated albums and instruments. The implementation is shown in Listing 8-10.

**Listing 8-10.** The `findAllWithAlbum()` Method

```
package com.apress.prospring6.eight.service;
// all import statements omitted

/*
Annotation from Singer.java, to show the JQL query
@NamedQuery(name=Singer.FIND_ALL_WITH_ALBUM,
    query="select distinct s from Singer s " +
        "left join fetch s.albums a " +
        "left join fetch s.instruments i")
*/
@Service("jpaSingerService")
@Repository
@Transactional
public class SingerServiceImpl implements SingerService {

    @Transactional(readOnly=true)
    @Override
    public Stream<Singer> findAllWithAlbum() {
        return em.createNamedQuery(Singer.FIND_ALL_WITH_ALBUM, Singer.class).
            getResultList().stream();
    }

    // other methods and set up omitted
}
```

The `findAllWithAlbum()` method is the same as the `findAll()` method, but it uses a different named query with inner `join fetch` statements that are used to link records from different tables. The method used to test it and print the entries is shown in Listing 8-11.

**Listing 8-11.** Testing the `findAllWithAlbum()` Method

```
package com.apress.prospring6.eight;
// all import statements omitted

//annotation omitted
public class SingerServiceTest {

    @Test
```

```

@DisplayName("should return all singers")
void testFindAllWithAlbum(){
    var singers = singerService.findAllWithAlbum().toList();
    assertEquals(3, singers.size());
    singers.forEach(s -> {
        LOGGER.info(s.toString());
        if (s.getAlbums() != null) {
            s.getAlbums().forEach(a -> LOGGER.info("\tAlbum:" + a.toString()));
        }
        if (s.getInstruments() != null) {
            s.getInstruments().forEach(i -> LOGGER.info("\tInstrument: " +
                i.getInstrumentId()));
        }
    });
}
// other methods and setup omitted
}

```

The JQL query is simple, but the generated SQL query is not so simple, as shown by the output of this method execution depicted in Listing 8-12.

**Listing 8-12.** Snippets of the Console Output When Running the `testFindAllWithAlbum()` Test Method

```

DEBUG: SqlStatementLogger - select distinct singer0_.ID as id1_2_0_,
    albums1_.ID as id1_0_1_,
    instrument3_.INSTRUMENT_ID as instrume1_1_2_,
    singer0_.VERSION as version2_2_0_,
    singer0_.BIRTH_DATE as birth_da3_2_0_,
    singer0_.FIRST_NAME as first_na4_2_0_,
    singer0_.LAST_NAME as last_nam5_2_0_,
    albums1_.VERSION as version2_0_1_,
    albums1_.RELEASE_DATE as release_3_0_1_,
    albums1_.SINGER_ID as singer_i5_0_1_,
    albums1_.title as title4_0_1_,
    albums1_.SINGER_ID as singer_i5_0_0_,
    albums1_.ID as id1_0_0_,
    instrument2_.SINGER_ID as singer_i1_3_1_,
    instrument2_.INSTRUMENT_ID as instrume2_3_1_
from SINGER singer0_
left outer join ALBUM albums1_ on singer0_.ID=albums1_.SINGER_ID
left outer join SINGER_INSTRUMENT instrument2_ on singer0_.ID=instrument2_.SINGER_ID
left outer join INSTRUMENT instrument3_ on instrument2_.INSTRUMENT_ID=instrument3_.
INSTRUMENT_ID
...
INFO : SingerServiceTest - Singer - Id: 1, First name: John, Last name: Mayer, Birthday:
    1977-10-16
INFO : SingerServiceTest - Album:Album - Id: 1, Singer id: 1, Title: The Search For
    Everything, Release Date: 2017-01-20
INFO : SingerServiceTest - Album:Album - Id: 2, Singer id: 1, Title: Battle Studies,
    Release Date: 2009-11-17
INFO : SingerServiceTest - Instrument: Piano
INFO : SingerServiceTest - Instrument: Guitar

```

```
INFO : SingerServiceTest - Singer - Id: 2, First name: Ben, Last name: Barnes, Birthday:
      1981-08-20
INFO : SingerServiceTest - Album:Album - Id: 3, Singer id: 2, Title: 11:11, Release Date:
      2021-09-18
INFO : SingerServiceTest - Instrument: Piano
INFO : SingerServiceTest - Instrument: Drums
INFO : SingerServiceTest - Instrument: Guitar
INFO : SingerServiceTest - Singer - Id: 3, First name: John, Last name: Butler, Birthday:
      1975-04-01
```

Now let's see the `findById()` method, which demonstrates how to use a named query with named parameters in JPA. The associations will be fetched as well. Listing 8-13 shows the implementation.

**Listing 8-13.** The `findById()` Method

```
package com.apress.prospring6.eight.service;

import jakarta.persistence.NoResultException;
// all import statements omitted

/*
Annotation from Singer.java, to show the JQL query
@NamedQuery(name=Singer.FIND_SINGER_BY_ID,
            query=""
                select distinct s from Singer s
                left join fetch s.albums a
                left join fetch s.instruments i
                where s.id = :id
                """)
*/
@Service("jpaSingerService")
@Repository
@Transactional
public class SingerServiceImpl implements SingerService {

    @Transactional(readOnly=true)
    @Override
    public Optional<Singer> findById(Long id) {
        TypedQuery<Singer> query = em.createNamedQuery(Singer.FIND_SINGER_BY_ID,
            Singer.class);
        query.setParameter("id", id);
        try {
            return Optional.of(query.getSingleResult());
        } catch (NoResultException nre) {
            return Optional.empty();
        }
    }

    // other methods and set up omitted
}
```

`EntityManager.createNamedQuery(java.lang.String name, java.lang.Class<T> resultClass)` was called to get an instance of the `TypedQuery<T>` interface, which ensures that the result of the query must be of type `Singer`. Then the `TypedQuery<T>.setParameter()` method was used to set the values of the named parameters within the query and to invoke the `getSingleResult()` method, since the result should contain only a single `Singer` object with the specified ID. Testing it is very easy, and similar to what was done in **Chapter 7** for similar methods, so it won't be repeated here.

## Querying with Untyped Results

In many cases, you want to submit a query to the database and manipulate the results at will, instead of storing them in a mapped entity class. After all, why use entity classes when you could use records, right? Also, records can be designed to store only a subset of columns, and thus this results in behavior identical to a projection query.

One typical example is a web-based report that lists only a certain number of columns across multiple tables. For example, say you have a web page that shows the singer information and their most recently released album title. The summary information contains the complete name of the singer and their most recently released album title. Singers without albums will not be listed. In this case, we can implement this use case with a query and then manually manipulate the `ResultSet` object.

Let's create a new class called `SingerSummaryServiceImpl` and name the method `findAllAsRecord()`. Listing 8-14 shows a typical implementation of the method and the `SingerSummaryRecord` record class.

**Listing 8-14.** The `SingerSummaryServiceImpl.findAllAsRecord()` Method

```
package com.apress.prospring6.eight.view;

public record SingerSummaryRecord(String firstName,
                                String lastName,
                                String latestAlbum) {
}
// -----
package com.apress.prospring6.eight.service;

import com.apress.prospring6.eight.view.SingerSummary;
import com.apress.prospring6.eight.view.SingerSummaryRecord;
// other import statements

@Service("singerSummaryService")
@Repository
@Transactional(readOnly = true)
public class SingerSummaryServiceImpl implements SingerSummaryService {

    @PersistenceContext
    private EntityManager em;

    public static final String ALL_SINGER_SUMMARY_RECORD_JPQL_QUERY = ""
        select s.firstName, s.lastName, a.title from Singer s
        left join s.albums a
        where a.releaseDate=(select max(a2.releaseDate) from Album a2 where a2.singer.
        id = s.id)
        "";
```



```

@SuppressWarnings({"unchecked"})
@Override
public Stream< SingerSummaryRecord > findAllAsRecord() {
    return em.createQuery(ALL_SINGER_SUMMARY_RECORD_JPQL_QUERY).getResultList().
        stream().
            map(obj -> {
                Object[] values = (Object[]) obj;
                return new SingerSummaryRecord((String) values[0],(String) values[1],
                    (String) values[2]);
            });
}
}

```

SingerSummaryService is just the interface declaring the method to be implemented by SingerSummaryServiceImpl.

As shown in Listing 8-14, we use the EntityManager.createQuery() method to create Query, passing in the JPQL statement, and then get the result list. When we explicitly specify the columns to be selected within JPQL, JPA will return an iterator, and each item within the iterator is an array of objects. We loop through the iterator, and for each array object a SingerSummaryRecord instance is created. Each object array corresponds to a record within the ResultSet object.

Listing 8-15 shows the test method.

**Listing 8-15.** Testing the SingerSummaryServiceImpl.findAllAsRecord() Method

```

package com.apress.prospring6.eight;
// import statements omitted

// annotations omitted
public class SingerServiceTest {

    @Autowired
    SingerSummaryService singerSummaryService;

    @Test
    @DisplayName("should return all singers and their most recent album as records")
    void testFindAllWithAlbumAsRecords(){
        var singers =
            singerSummaryService.findAllAsRecord()
                .peek(s -> LOGGER.info(s.toString()))
                .toList();
        assertEquals(2, singers.size());
    }
    // other methods and setup omitted
}

```

Executing this test method produces similar output to that of other methods in this chapter, but the results are converted to String using the record toString() generated method, as shown in Listing 8-16.

**Listing 8-16.** Output Snippets Printed During Testing of the `SingerSummaryServiceImpl.findAllAsRecord()` Method

```
DEBUG: SqlStatementLogger - select singer0_.FIRST_NAME as col_0_0_,
    singer0_.LAST_NAME as col_1_0_,
    albums1_.title as col_2_0_ from SINGER singer0_
left outer join ALBUM albums1_ on singer0_.ID=albums1_.SINGER_ID
where
    albums1_.RELEASE_DATE=(select max(album2_.RELEASE_DATE) from ALBUM album2_
    where album2_.SINGER_ID=singer0_.ID)
...
INFO : SingerServiceTest - SingerSummaryRecord[firstName=John, lastName=Mayer,
latestAlbum=The Search For Everything]
INFO : SingerServiceTest - SingerSummaryRecord[firstName=Ben, lastName=Barnes,
latestAlbum=11:11]
```

In JPA, there is a more elegant solution than playing around with the `ResultSet` object array returned from the query, as discussed in the next section.

## Querying for a Custom Result Type with a Constructor Expression

In JPA, when querying for a custom result like the one in the previous section, you can instruct JPA to directly construct a POJO from each record for you. This POJO is also called a *view* because it contains data from multiple tables. For the example in the previous section, a record called `SingerSummaryRecord` was created. For this example, a POJO called `SingerSummary` is used, which is equivalent to the record class. The `SingerSummary` class has the properties for each singer summary, with a constructor method that accepts all the properties. Using this class we can write a `findAll()` method and use a constructor expression within the query to instruct the JPA provider to map the `ResultSet` to the `SingerSummary` class. In Listing 8-17 you can see this method and the query it executes.

**Listing 8-17.** The `SingerSummaryServiceImpl.findAll()` Method

```
package com.apress.prospring6.eight.service;
// all import statements omitted

@Service("singerSummaryService")
@Repository
@Transactional(readOnly = true)
public class SingerSummaryServiceImpl implements SingerSummaryService {

    @PersistenceContext
    private EntityManager em;

    public static final String ALL_SINGER_SUMMARY_JPQL_QUERY = """
        select new com.apress.prospring6.eight.view.SingerSummary(
            s.firstName, s.lastName, a.title) from Singer s
        left join s.albums a
        where a.releaseDate=(select max(a2.releaseDate) from Album a2 where a2.singer.
            id = s.id)
        """;
```

```

@Override
public Stream<SingerSummary> findAll() {
    return em.createQuery(ALL_SINGER_SUMMARY_JPQL_QUERY, SingerSummary.class).
        getResultList().stream();
}
// other method omitted
}

```

In the JPQL query, the new keyword is specified, together with the fully qualified name of the POJO class that will store the results and pass in the selected attributes as the constructor argument of each `SingerSummary` class. Finally, the `SingerSummary` class is passed into the `createQuery()` method to indicate the result type. Testing this method is no different than what we did for the `findAllAsRecord()`, but the returned results are of type `SingerSummary` instead of `SingerSummaryRecord`, as you can see in Listing 8-18.

**Listing 8-18.** Testing the `SingerSummaryServiceImpl.findAll()` Method

```

package com.apress.prospring6.eight;
// import statements omitted

// annotations omitted
public class SingerServiceTest {

    @Autowired
    SingerSummaryService singerSummaryService;

    @Test
    @DisplayName("should return all singers and their most recent album as POJOs")
    void testFindAllAsPojos(){
        var singers =
            singerSummaryService.findAll()
                .peek(s -> LOGGER.info(s.toString())).toList();
        assertEquals(2, singers.size());
    }
    // other methods and setup omitted
}

```

Executing this method produces the result in Listing 8-19.

**Listing 8-19.** Output Snippets Printed During Testing of the `SingerSummaryServiceImpl.testFindAllAsPojos()` Method

```

DEBUG: QueryTranslatorImpl - HQL: select new com.apress.prospring6.eight.view.
SingerSummary(s.firstName, s.lastName, a.title)
    from com.apress.prospring6.eight.entities.Singer s
    left join s.albums a where a.releaseDate=
        (select max(a2.releaseDate)
         from com.apress.prospring6.eight.entities.Album a2
         where a2.singer.id = s.id)
DEBUG: QueryTranslatorImpl - SQL: select singer0_.FIRST_NAME as col_0_0_,
    singer0_.LAST_NAME as col_1_0_,
    albums1_.title as col_2_0_ from SINGER singer0_
    left outer join ALBUM albums1_ on singer0_.ID=albums1_.SINGER_ID

```

```

where albums1_.RELEASE_DATE=
    (select max(album2_.RELEASE_DATE)
     from ALBUM album2_
     where album2_.SINGER_ID=singer0_.ID)
...
INFO : SingerServiceTest - First name: John, Last Name: Mayer, Most Recent Album: The Search
For Everything
INFO : SingerServiceTest - First name: Ben, Last Name: Barnes, Most Recent Album: 11:11

```

Notice that the JPQL query is represented in Java by an `org.hibernate.query.internal.QueryImpl` instance; this is because Hibernate is the JPA provider for this application. Also notice in the native SQL generated query that there is no trace of the `SingerSummary` constructor.

## Inserting Data

Inserting data by using JPA is simple. Like Hibernate, JPA also supports retrieving a database-generated primary key. Listing 8-20 shows the `save(..)` method.

**Listing 8-20.** The `SingerServiceImpl.save(..)` Method

```

package com.apress.prospring6.eight.service;
// import statements omitted

@Service("jpaSingerService")
@Repository
@Transactional
public class SingerServiceImpl implements SingerService {
    private static final Logger LOGGER = LoggerFactory.getLogger(SingerServiceImpl.class);

    @PersistenceContext
    private EntityManager em;

    @Override
    public void save(Singer singer) {
        if (singer.getId() == null) {
            LOGGER.info("Inserting new singer");
            em.persist(singer);
        } else {
            em.merge(singer);
            LOGGER.info("Updating existing singer");
        }

        LOGGER.info("Singer saved with id: " + singer.getId());
    }

    // other methods omitted
}

```

As shown here, the `save(..)` method first checks whether the object is a new entity instance, by checking the `id` value. If `id` is null (that is, not yet assigned), the object is a new entity instance, and the `EntityManager.persist(..)` method will be invoked. When calling the `persist(..)` method, `EntityManager` persists the entity and makes it a managed instance within the current persistence context. If the `id` value exists, then we're carrying out an update, and the `EntityManager.merge(..)` method will be called instead. When the `merge(..)` method is called, the `EntityManager` merges the state of the entity into the current persistence context.

Listing 8-21 shows the code to insert a new `Singer` record. It's all done in a test method because we want to test that the insert succeeds.

**Listing 8-21.** Testing the `SingerServiceImpl.save(..)` Method

```

package com.apress.prospring6.eight;
// import statements omitted

// annotations omitted
public class SingerServiceTest {

    @Test
    @DisplayName("should insert a singer with associations")
    @Sql(statements = { // avoid dirtying up the test context
        "delete from ALBUM where SINGER_ID = (select ID from SINGER where
        FIRST_NAME = 'BB')",
        "delete from SINGER_INSTRUMENT where SINGER_ID = (select ID from SINGER where
        FIRST_NAME = 'BB')",
        "delete from SINGER where FIRST_NAME = 'BB'"
    },
        executionPhase = Sql.ExecutionPhase.AFTER_TEST_METHOD)
    public void testInsert(){
        var singer = new Singer();
        singer.setFirstName("BB");
        singer.setLastName("King");
        singer.setBirthDate(LocalDate.of(1940, 8, 16));

        var album = new Album();
        album.setTitle("My Kind of Blues");
        album.setReleaseDate(LocalDate.of(1961, 7, 18));
        singer.addAlbum(album);

        album = new Album();
        album.setTitle("A Heart Full of Blues");
        album.setReleaseDate(LocalDate.of(1962, 3, 20));
        singer.addAlbum(album);
        singerService.save(singer);

        Assertions.assertNotNull(singer.getId());

        var singers = singerService.findAllWithAlbum().peek(
            s -> {
                LOGGER.info(s.toString());
                if (s.getAlbums() != null) {
                    s.getAlbums().forEach(a -> LOGGER.info("\tAlbum:" + a.toString()));
                }
            }
        );
    }
}

```

```

    }
    if (s.getInstruments() != null) {
        s.getInstruments().forEach(i -> LOGGER.info("\tInstrument: " +
            i.getInstrumentId()));
    }
    }).toList();
    assertEquals(4, singers.size());
}
// other methods and setup omitted
}

```

As shown here, we create a new singer, add two albums, and save the object. The success of this operation is tested by verifying the size of the result set returned by the `findAllWithAlbum()` method.

The `@Sql` annotation is used to clean up the database to avoid accidentally failing other tests run on the initial test data set.

## Updating Data

Updating data is as easy as inserting data, and as you've seen, a single method was created for the insert and update operation. There are two ways we can test an update operation: by updating the name or other properties of a singer record, or by removing related associations, such as an album. Listing 8-22 shows two ways to test the `SingerServiceImpl.save(..)` method for performing updates.

**Listing 8-22.** Testing the `SingerServiceImpl.save(..)` Method for Two Forms of the Update Operation

```

package com.apress.prospring6.eight;
// import statements omitted

// annotations omitted
public class SingerServiceTest {

    @Test
    @SqlGroup({
        @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD),
        @Sql(scripts = {"classpath:testcontainers/remove-nina.sql"},
            executionPhase = Sql.ExecutionPhase.AFTER_TEST_METHOD)
    })
    @DisplayName("should update a singer")
    void testUpdate() {
        var singer = singerService.findById(5L).orElse(null);
        // making sure such singer exists
        assertNotNull(singer);
        // making sure we got expected singer
        assertEquals("Simone", singer.getLastName());
        // retrieve the album
        var album = singer.getAlbums().stream().filter(
            a -> a.getTitle().equals("I Put a Spell on You")).findFirst().orElse(null);
        Assertions.assertNotNull(album);
    }
}

```

```

    singer.setFirstName("Eunice Kathleen");
    singer.setLastName("Waymon");
    singer.removeAlbum(album);
    int version = singer.getVersion();

    singerService.save(singer);

    var nina = singerService.findById(5L).orElse(null);
    assertAll( "nina was updated" ,
        () -> Assertions.assertNotNull(nina),
        () -> Assertions.assertEquals(version + 1, nina.getVersion())
    );
}

@Test
@DisplayName("should update album set")
public void testUpdateAlbumSet() {
    var singer = singerService.findById(1L).orElse(null);
    // making sure such singer exists
    assertNotNull(singer);
    // making sure we got expected record
    assertEquals("Mayer", singer.getLastName());
    // retrieve the album
    var album = singer.getAlbums().stream().filter(a -> a.getTitle().equals("Battle
    Studies")).findAny().orElse(null);

    singer.setFirstName("John Clayton");
    singer.removeAlbum(album);
    singerService.save(singer);

    var singers = singerService.findAllWithAlbum().peek(
        s -> {
            LOGGER.info(s.toString());
            if (s.getAlbums() != null) {
                s.getAlbums().forEach(a -> LOGGER.info("\tAlbum:" + a.toString()));
            }
            if (s.getInstruments() != null) {
                s.getInstruments().forEach(i -> LOGGER.info("\tInstrument: " +
                    i.getInstrumentId()));
            }
        }
    ).toList();
    assertEquals(3, singers.size());
}
// other methods and setup omitted
}

```

In the `testUpdate()` method, we first retrieve the record with an ID of 5, and we change the first and last name. We call the `SingerService.save(..)` method and then retrieve the saved item from the database. The success of the update operation is confirmed by the incrementing of its version field.

In the `testUpdateAlbumSet()` method, we first retrieve the record with an ID of 1 and we change the first name. Then we loop through its Album associations and retrieve the one with title *Battle Studies* and remove it from the singer's albums property. Finally, we call the `SingerService.save(..)` method again. When you execute this method, you can check that the update operation succeeded by looking in the console log and checking that the *Battle Studies* album is not displayed.



The album can be removed because of the `orphanRemoval=true` attribute that was defined in the one-to-many association, which instructs the JPA provider (Hibernate) to remove all orphan records that exist in the database but are no longer found in the object when persisted: `@OneToMany(mappedBy = "singer", cascade=CascadeType.ALL, orphanRemoval=true)`.

---

## Deleting Data

Deleting data is just as simple. Simply call the `EntityManager.remove()` method and pass in the `Singer` object. Listing 8-23 shows the updated code to delete a singer.

**Listing 8-23.** The `SingerServiceImpl.delete(..)` Method

```
package com.apress.prospring6.eight.service;
// import statements omitted

@Service("jpaSingerService")
@Repository
@Transactional
public class SingerServiceImpl implements SingerService {

    @Override
    public void delete(Singer singer) {
        var mergedContact = em.merge(singer);
        em.remove(mergedContact);

        LOGGER.info("Singer with id: " + singer.getId() + " deleted successfully");
    }
    // other methods and setup omitted
}
```

First the `EntityManager.merge(..)` method is invoked to merge the state of the entity into the current persistence context. The `merge(..)` method returns the managed entity instance. Then `EntityManager.remove()` method is called, passing in the managed singer entity instance. The remove operation deletes the singer record, together with all its associated information, including albums and instruments, as we defined the `cascade=CascadeType.ALL` in the mapping. To test the delete operation, the `testDelete()` method can be used, which is depicted in Listing 8-24.



**Listing 8-24.** Testing the `SingerServiceImpl.delete(..)` Method

```

package com.apress.prospring6.eight;
// import statements omitted

// annotations omitted
public class SingerServiceTest {

    @Test
    @Sql(scripts = {"classpath:testcontainers/add-chuck.sql"},
        executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
    @DisplayName("should delete a singer")
    public void testDelete() {
        var singer = singerService.findById(6L).orElse(null);
        //making sure such singer exists
        assertNotNull(singer);
        singerService.delete(singer);

        var deleted = singerService.findById(6L);
        assertTrue(deleted.isEmpty());
    }
    // other methods and setup omitted
}

```

Listing 8-24 retrieves the singer with an ID of 6 and then calls the `delete(..)` method to delete the singer information.

## Using a Native Query

Having discussed performing trivial database operations by using JPA, now let's move on to some more advanced topics. Sometimes you may want to have absolute control over the query that will be submitted to the database. One example is using a hierarchical query in an Oracle database. This kind of query is database-specific and referred to as a *native query*.

JPA supports the execution of native queries; `EntityManager` will submit the query to the database as is, without any mapping or transformation performed. One main benefit of using JPA native queries is the mapping of `ResultSet` back to the ORM-mapped entity classes. The following two sections discuss how to use a native query to retrieve all singers and directly map `ResultSet` back to the `Singer` objects.

## Using a Simple Native Query

To demonstrate how to use a native query, let's implement a new method to retrieve all the singers from the database. This method is shown in Listing 8-25.

**Listing 8-25.** The `SingerServiceImpl.findAllByNativeQuery(..)` Method

```

package com.apress.prospring6.eight.service;
// import statements omitted

@Service("jpaSingerService")
@Repository

```

```

@Transactional
public class SingerServiceImpl implements SingerService {

    public static final String ALL_SINGER_NATIVE_QUERY =
        "select ID, FIRST_NAME, LAST_NAME, BIRTH_DATE, VERSION from SINGER";

    @Override
    public Stream<Singer> findAllByNativeQuery() {
        return em.createNativeQuery(ALL_SINGER_NATIVE_QUERY)
            .getResultList().stream();
    }
    // other methods and setup omitted
}

```

You can see that the native query is just a simple SQL statement to retrieve all the columns from the SINGER table. To create and execute the query, `EntityManager.createNativeQuery(..)` was first called, passing in the query string as well as the result type. The result type should be a mapped entity class (in this case the `Singer` class). The `createNativeQuery(..)` method returns a `Query` instance, which provides the `getResultList()` operation to get the result list. The JPA provider will execute the query and transform the `ResultSet` object into the entity instances, based on the JPA mappings defined in the entity class. Executing the previous method produces the same result as the `findAll()` method.

## Native Querying with SQL ResultSet Mapping

Aside from the mapped domain object, you can pass in a string representing the name of a SQL `ResultSet` mapping. A SQL `ResultSet` mapping is defined at the entity class level by using the `@SqlResultSetMapping` annotation. A SQL `ResultSet` mapping can have one or more entity and column mappings. A SQL `ResultSet` mapping called `singerResult` is defined for the entity class, with the `entityClass` attribute in the `Singer` class itself. JPA supports more complex mapping for multiple entities and supports mapping down to column-level mapping.

After the SQL `ResultSet` mapping is defined, the `findAllByNativeQuery()` method can be invoked using the `ResultSet` mapping's name. Listing 8-26 shows the updated `findAllByNativeQuery()` method.

**Listing 8-26.** The `@SqlResultSetMapping` Mapping Results of the `ALL_SINGER_NATIVE_QUERY` Native Query

```

package com.apress.prospring6.eight.entities;

import jakarta.persistence.EntityResult;
import jakarta.persistence.SqlResultSetMapping;
// other import statements omitted

@Entity
@Table(name = "SINGER")

@SqlResultSetMapping(
    name="singerResult",
    entities=@EntityResult(entityClass=Singer.class)
)
public class Singer extends AbstractEntity {
    // code omitted
}

```

```
// -----
// other details omitted
public class SingerServiceImpl implements SingerService {

    @Override
    public Stream<Singer> findAllByNativeQuery() {
        return em.createNativeQuery(ALL_SINGER_NATIVE_QUERY, "singerResult").
            getResultList().stream();
    }
    // other methods omitted
}
```

As you can see, JPA also provides strong support for executing native queries, with a flexible SQL ResultSet mapping facility provided.

## Executing Stored Functions and Procedures

There is more than one way to configure support for SQL functions and procedures execution, but the easiest is to use native queries. To do so, write the SQL to declare your stored SQL function or procedure, use `@NamedNativeQuery` from the `jakarta.persistence` package to map its SQL invocation to a query name, and then use `EntityManager.createNamedQuery(..)` to create a native query and retrieve the result using `getSingleResult()` or `getResultList()` or any other method available.

Listing 8-27 shows a very simple SQL stored function that returns the first name for a singer with a given id.

**Listing 8-27.** The `getFirstNameById` SQL Stored Function

```
CREATE FUNCTION IF NOT EXISTS getFirstNameById (in_id INT) RETURNS VARCHAR(60)
RETURN (SELECT first_name FROM SINGER WHERE id = in_id);
```

The `getFirstNameById(..)` stored function invocation can be mapped to a name using `@NamedNativeQuery`. This annotation can be included in `@NamedNativeQueries` when there is more than one native query declared for an entity type. These annotations are declared on the entity class, in this case the `Singer` class, as shown in Listing 8-28.

**Listing 8-28.** The `getFirstNameById` SQL Stored Function Invocation Being Mapped to Named Query `Singer.getFirstNameById(?)`

```
package com.apress.prospring6.eight.entities;
// other class details omitted
import jakarta.persistence.NamedNativeQueries;
import jakarta.persistence.NamedNativeQuery;

@NamedNativeQueries({
    @NamedNativeQuery(
        name = "Singer.getFirstNameById(?)",
        query = "select getfirstnamebyid(?)")
})
public class Singer extends AbstractEntity {
    // body omitted
}
```

The SQL stored function or procedure is nothing else than a native query, and thus it is allowed to map it to a named native query. The name is quite flexible, and in this scenario the chosen name is `Singer.getFirstNameById(?)` because it makes it quite obvious that the query is specific to `Singer` instances and that it requires a parameter.

Since the query is named, the `EntityManager.createNamedQuery(..)` is used to create the query and retrieve the result, as shown in Listing 8-29.

**Listing 8-29.** Invoking a SQL Stored Function Using `EntityManager`

```
package com.apress.prospring6.eight.service;
// other class details omitted

public class SingerServiceImpl implements SingerService {

    @Override
    public String findFirstNameById(Long id) {
        return em.createNamedQuery("Singer.getFirstNameById(?)")
            .setParameter(1, id).getSingleResult().toString();
    }
}
```

Testing this method is done by a method identical to the one introduced for testing SQL functions and procedures in **Chapter 7**.

You should know that in the `jakarta.persistence` package there is an annotation named `@NamedStoredProcedureQueries` used to declare an array of SQL stored procedures, each of them configured using `@NamedStoredProcedureQuery`. When declared using these annotations, a stored function or procedure can be invoked from an `EntityManager` using the `createNamedStoredProcedureQuery(..)` method. Since these annotations are a bit misleading (their names imply that only SQL stored procedures are supported), we prefer to use named native queries instead.

## Using the JPA Criteria API for a Criteria Query

Most applications provide a front end for users to search for information. Typically, many searchable fields are displayed, and the users enter information in only some of them and do the search. It's difficult to prepare many queries, with each possible combination of parameters that users may choose to enter. In this situation, the Criteria API query feature comes to the rescue.

In JPA 2, one major new feature introduced was a strongly typed Criteria API query. In this new Criteria API, the criteria being passed into the query is based on the mapped entity classes' metamodel. As a result, each criteria specified is strongly typed, and errors will be discovered at compile time, rather than runtime.

In the JPA Criteria API, an entity class metamodel is represented by the entity class name with a suffix of an underscore (`_`). For example, the metamodel class for the `Singer` entity class is `Singer_`. Listing 8-30 shows the `Singer_` class.

**Listing 8-30.** The Metamodel for the `Singer` Entity

```
package com.apress.prospring6.eight.entities;

import jakarta.persistence.metamodel.SetAttribute;
import jakarta.persistence.metamodel.SingularAttribute;
import jakarta.persistence.metamodel.StaticMetamodel;
```

```

import java.time.LocalDate;
import javax.annotation.processing.Generated;

@Generated(value = "org.hibernate.jpamodelgen.JPAMetaModelEntityProcessor")
@StaticMetamodel(Singer.class)
public abstract class Singer_ extends com.apsed.prospring6.eight.entities.AbstractEntity_ {

    public static volatile SingularAttribute<Singer, String> firstName;
    public static volatile SingularAttribute<Singer, String> lastName;
    public static volatile SetAttribute<Singer, Album> albums;
    public static volatile SetAttribute<Singer, Instrument> instruments;
    public static volatile SingularAttribute<Singer, LocalDate> birthDate;

    public static final String FIRST_NAME = "firstName";
    public static final String LAST_NAME = "lastName";
    public static final String ALBUMS = "albums";
    public static final String INSTRUMENTS = "instruments";
    public static final String BIRTH_DATE = "birthDate";
}

```

The metamodel class is annotated with `@StaticMetamodel`, and the attribute is the mapped entity class. Within the class are the declaration of each attribute and its related types. It would be tedious to code and maintain those metamodel classes. However, tools can help generate those metamodel classes automatically based on the JPA mappings within the entity classes. The one provided by Hibernate is called Hibernate Metamodel Generator<sup>5</sup>.

The way you go about generating your metamodel classes depends on what tools you are using to develop and build your project. We recommend reading the “Usage” section of the documentation<sup>6</sup> for specific details.

The required dependency for metamodel class generation is the `hibernate-jpamodelgen` library. Configuration for Maven and Gradle is included in the project for this chapter, and metamodel classes are generated during the default build.

With the class generation strategy set up, let’s define a query that accepts both the first name and last name for searching singers. For this we will add a method `findByCriteriaQuery()` in the `SingerService` interface and its implementation in `SingerServiceImpl`, as shown in Listing 8-31.

*Listing 8-31.* `SingerServiceImpl.findByCriteriaQuery()` Using JPA Criteria API

```

package com.apsed.prospring6.eight.service;

import com.apsed.prospring6.eight.entities.Singer_;
import org.apache.commons.lang3.StringUtils;
import jakarta.persistence.criteria.CriteriaBuilder;
import jakarta.persistence.criteria.CriteriaQuery;
import jakarta.persistence.criteria.JoinType;
import jakarta.persistence.criteria.Predicate;
import jakarta.persistence.criteria.Root;
//other import statements omitted

```

<sup>5</sup><https://hibernate.org/orm/tooling>

<sup>6</sup>[https://docs.jboss.org/hibernate/stable/jpamodelgen/reference/en-US/html\\_single](https://docs.jboss.org/hibernate/stable/jpamodelgen/reference/en-US/html_single)

```

@Service("jpaSingerService")
@Repository
@Transactional
public class SingerServiceImpl implements SingerService {
    private static final Logger LOGGER = LoggerFactory.getLogger(SingerServiceImpl.class);

    @PersistenceContext
    private EntityManager em;

    @Override
    public Stream<Singer> findByCriteriaQuery(String firstName, String lastName) {
        LOGGER.info("Finding singer for firstName: " + firstName + " and lastName: " +
            lastName);

        CriteriaBuilder cb = em.getCriteriaBuilder();
        CriteriaQuery<Singer> criteriaQuery = cb.createQuery(Singer.class);

        Root<Singer> singerRoot = criteriaQuery.from(Singer.class);
        singerRoot.fetch(Singer_.albums, JoinType.LEFT);
        singerRoot.fetch(Singer_.instruments, JoinType.LEFT);
        criteriaQuery.select(singerRoot).distinct(true);

        Predicate criteria = cb.conjunction();
        if (StringUtils.isNotBlank(firstName)) {
            Predicate firstNamePredicate = cb.equal(singerRoot.get(Singer_.firstName),
                firstName);
            criteria = cb.and(criteria, firstNamePredicate);
        }

        if (StringUtils.isNotBlank(lastName)) {
            Predicate lastNamePredicate = cb.equal(singerRoot.get(Singer_.lastName),
                lastName);
            criteria = cb.and(criteria, lastNamePredicate);
        }
        criteriaQuery.where(criteria);
        return em.createQuery(criteriaQuery).getResultList().stream();
    }

    // other methods and setup omitted
}

```

Let's break down the Criteria API usage:

- `EntityManager.getCriteriaBuilder()` is called to retrieve an instance of `jakarta.persistence.criteria.CriteriaBuilder`.
- A typed query is created by calling `CriteriaBuilder.createQuery()` and passing in `Singer` as the result type. The resulting instance is of type `jakarta.persistence.criteria.CriteriaQueryImpl<Singer>` that implements `jakarta.persistence.criteria.CriteriaQuery<Singer>`.

- The two `Root<..>.fetch(..)` method calls enforce the eager fetching of the associations relating to albums and instruments. The `JoinType.LEFT` argument specifies an outer join. Calling the `Root<..>.fetch(..)` method with `JoinType.LEFT` as the second argument is equivalent to specifying the left join fetch join operation in JPQL.
- The `CriteriaQuery.select(..)` method is invoked and with the root query object. The `distinct(..)` method called with argument `true` means that duplicate records should be eliminated.
- A `jakarta.persistence.criteria.Predicate` instance is obtained by calling the `CriteriaBuilder.conjunction()` method, which means that a conjunction of one or more restrictions is made. A `Predicate` can be a simple or compound predicate, and a predicate is a restriction that indicates the selection criteria defined by an expression.
- The `firstName` and `lastName` arguments are checked. For each not `null` argument, a new `Predicate` is constructed using the `CriteriaBuilder` instance (that is, the `CriteriaBuilder.and(..)` method). The method `equal()` is to specify an equal restriction, within which `Root<..>.get()` is called, passing in the corresponding attribute of the entity class metamodel to which the restriction applies. The constructed predicate is then “conjunct” with the existing predicate (stored by the variable `criteria`) by calling the `CriteriaBuilder.and()` method.
- The `Predicate` is constructed with all the criteria and restrictions and passed as the `where` clause to the query by calling the `CriteriaQuery.where(..)` method.
- Finally, `CriteriaQuery` is passed to `EntityManager`. `EntityManager` then constructs the query based on the `CriteriaQuery` value passed in, executes the query, and returns the result.

To test the criteria query operation, a new test method is added to the `SingerServiceTest` test class and is depicted in Listing 8-32.

**Listing 8-32.** Testing the `SingerServiceImpl.findByCriteriaQuery()` Method

```

package com.apress.prospring6.eight;
// import statements omitted

// annotations omitted
public class SingerServiceTest {

    @Test
    public void testFindByCriteriaQuery(){
        var singers = singerService.findByCriteriaQuery("John", "Mayer").peek(
            s -> {
                LOGGER.info(s.toString());
                if (s.getAlbums() != null) {
                    s.getAlbums().forEach(a -> LOGGER.info("\tAlbum:" + a.toString()));
                }
                if (s.getInstruments() != null) {
                    s.getInstruments().forEach(i -> LOGGER.info("\tInstrument: " +
                        i.getInstrumentId()));
                }
            }
        );
    }
}

```

```

        }).toList();
        assertEquals(1, singers.size());
    }
    // other methods and setup omitted
}

```

The test is not that different from the previous tests written in this chapter, and neither is the output, as depicted in Listing 8-33.

**Listing 8-33.** Console Output Snippets for the Execution of the `testFindByCriteriaQuery()` Test Method.

```

INFO : SingerServiceImpl - Finding singer for firstName: John and lastName: Mayer
DEBUG: CriteriaQueryImpl - Rendered criteria query ->
    select distinct generatedAlias0 from Singer as generatedAlias0
    left join fetch generatedAlias0.albums as generatedAlias1
    left join fetch generatedAlias0.instruments as generatedAlias2
    where ( ( 1=1 )
        and ( generatedAlias0.firstName=:param0 ) )
        and ( generatedAlias0.lastName=:param1 )
...
DEBUG: QueryTranslatorImpl - parse() - HQL:
    select distinct generatedAlias0
    from com.apres.prospring6.eight.entities.Singer as generatedAlias0
    left join fetch generatedAlias0.albums as generatedAlias1
    left join fetch generatedAlias0.instruments as generatedAlias2
    where ( ( 1=1 )
        and ( generatedAlias0.firstName=:param0 ) )
        and ( generatedAlias0.lastName=:param1 )
...
DEBUG: QueryTranslatorImpl - SQL:
    select
        distinct singer0_ID as id1_2_0_,
        albums1_ID as id1_0_1_,
        instrument3_INSTRUMENT_ID as instrume1_1_2_,
        singer0_VERSION as version2_2_0_,
        singer0_BIRTH_DATE as birth_da3_2_0_,
        singer0_FIRST_NAME as first_na4_2_0_,
        singer0_LAST_NAME as last_nam5_2_0_,
        albums1_VERSION as version2_0_1_,
        albums1_RELEASE_DATE as release_3_0_1_,
        albums1_SINGER_ID as singer_i5_0_1_,
        albums1_title as title4_0_1_,
        albums1_SINGER_ID as singer_i5_0_0_,
        albums1_ID as id1_0_0_,
        instrument2_SINGER_ID as singer_i1_3_1_,
        instrument2_INSTRUMENT_ID as instrume2_3_1_
    from SINGER singer0
    left outer join ALBUM albums1_ on singer0_ID=albums1_SINGER_ID
    left outer join SINGER_INSTRUMENT instrument2_ on singer0_ID=instrument2_SINGER_ID
    left outer join INSTRUMENT instrument3_ on instrument2_INSTRUMENT_ID=instrument3_
    INSTRUMENT_ID

```



```

    where 1=1
           and singer0_.FIRST_NAME=?
           and singer0_.LAST_NAME=?
...
INFO : SingerServiceTest - Singer - Id: 1, First name: John, Last name: Mayer, Birthday:
1977-10-16
INFO : SingerServiceTest - Album:Album - Id: 1, Singer id: 1, Title: The Search For
Everything, Release Date: 2017-01-20
INFO : SingerServiceTest - Album:Album - Id: 2, Singer id: 1, Title: Battle Studies,
Release Date: 2009-11-17
INFO : SingerServiceTest - Instrument: Guitar
INFO : SingerServiceTest - Instrument: Piano

```

This output is consistent, but it will show you exactly what is happening under the hood. It starts with a criteria query that gets transformed in HQL, which is then transformed in SQL and finally executed on the database. This seems a little too much, right? Is the performance cost worth having strongly typed queries and having errors discovered at compile time rather than at runtime? It depends on the application profile and the query complexity. We already mentioned `jOOQ` in Chapter 7, which provides roughly the same benefits but without two levels of conversion and with a friendlier syntax.

## Summary

In this chapter, we covered the basic concepts of JPA and how to configure JPA's `EntityManagerFactory` in Spring by using Hibernate as the persistence service provider. Then we discussed using JPA to perform basic database operations. Advanced topics included native queries and the strongly typed JPA Criteria API.

The purpose of this chapter was to introduce you to JPA's `EntityManagerFactory`, because from an architectural point of view, Hibernate's `SessionFactory` is an extension of it. Thus, the `SessionFactory` is also a JPA `EntityManagerFactory`, which means both contain the entity mapping metadata and allow you to create a Hibernate `Session` or a `EntityManager`.

However, the `EntityManagerFactory` is the standard implementation, and it is the same across all the implementations. This means that, although not very likely, if you would like to change your JPA provider, in this case Hibernate, to some other persistence implementation (let's say Oracle TopLink), doing so is way easier when your code is not tied to your provider.

This being said, in **Chapter 9** we'll complete the whole picture of working with SQL databases in Spring by exploring transactions.



# Spring Transaction Management

Managing transactions is one of the most critical parts of building a reliable enterprise application. The most common type of transaction is a database operation. In a typical database update operation, a database transaction begins, data is updated, and then the transaction is committed or rolled back, depending on the result of the database operation. However, in many cases, depending on the application requirements and the back-end resources that the application needs to interact with (such as an RDBMS, message-oriented middleware, an ERP system, and so on), transaction management can be much more complicated.

In the early days of Java application development (after JDBC was created but before the JEE standard or an application framework like Spring was available), developers programmatically controlled and managed transactions within application code. When JEE and, more specifically, the EJB standard became available, developers were able to use container-managed transactions (CMTs) to manage transactions in a declarative way. But the complicated transaction declaration in the EJB deployment descriptor was difficult to maintain and introduced unnecessary complexity for transaction processing. Some developers favored having more control over the transaction and chose bean-managed transactions (BMTs) to manage transactions in a programmatic way. However, the complexity of programming with the Java Transaction API (JTA) also hindered developers' productivity.

As discussed in **Chapter 5**, transaction management is a crosscutting concern and should not be coded within the business logic. The most appropriate way to implement transaction management is to allow developers to define transaction requirements in a declarative way and have frameworks such as Spring, JEE, or AOP weave in the transaction processing logic on our behalf. In this chapter, we discuss how Spring helps simplify the implementation of transaction-processing logic. Spring provides support for both declarative and programmatic transaction management.

Spring offers excellent support for declarative transactions, which means you do not need to clutter your business logic with transaction management code. All you have to do is declare those methods (within classes or layers) that must participate in a transaction, together with the details of the transaction configuration, and Spring will take care of handling the transaction management. To be more specific, this chapter covers the following:

- *Spring transaction abstraction layer*: We discuss the base components of Spring transaction abstraction classes and explain how to use these classes to control the properties of the transactions.
- *Declarative transaction management*: We show you how to use Spring and just plain Java objects to implement declarative transactional management. We offer examples for declarative transaction management using the XML configuration files as well as Java annotations.

- *Programmatic transaction management*: Even though programmatic transaction management is not used very often, we explain how to use the Spring-provided `TransactionTemplate` class, which gives you full control over the transaction management code.

## Exploring the Spring Transaction Abstraction Layer

When developing your applications, no matter whether you choose to use Spring or not, you have to make a fundamental choice when using transactions about whether to use global transactions or local transactions. *Local transactions* are specific to a single transactional resource (a JDBC connection, for example), whereas *global transactions* are managed by the container and can span multiple transactional resources.

### Transaction Types

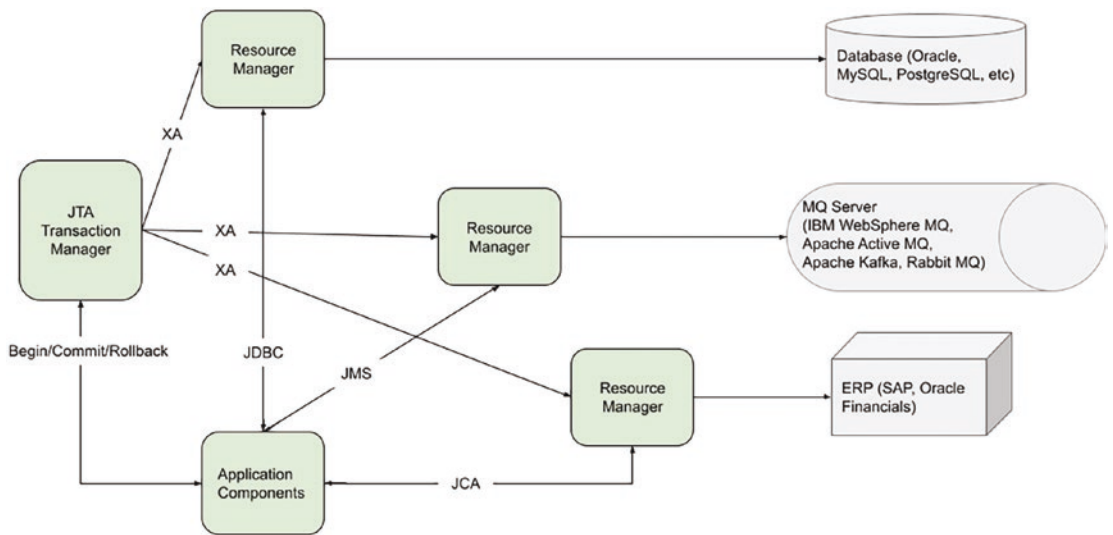
Local transactions are easy to manage, and if all operations in your application need to interact with just one transactional resource (such as a JDBC transaction), using local transactions will be sufficient. However, if you are not using an application framework such as Spring, you have a lot of transaction management code to write, and if in the future the scope of the transaction needs to be extended across multiple transactional resources, you have to drop the local transaction management code and rewrite it to use global transactions.

In the Java world, global transactions are implemented with the JTA (Java/Jakarta Transaction API). In this scenario, a JTA-compatible transaction manager connects to multiple transactional resources via respective resource managers, which are capable of communicating with the transaction manager over the XA (Exchange Access) protocol (an open standard defining distributed transactions). The 2-Phase Commit (2PC) mechanism is used to ensure that all back-end data sources were updated or rolled back altogether. If either of the back-end resources fails, the entire transaction is rolled back, and hence the updates to all resources are rolled back too. The global transaction is an implementation of `UserTransaction` and normally needs to be sourced from JNDI. Since JNDI is specific to a server environment, this limits the potential reuse of application code. In the past there were some libraries that did not require a server, such as Atomikos<sup>1</sup>, which was used in the previous edition of this book, but is not used this edition because the current version has not been adapted to Jakarta Transaction API and thus is unusable with the most recent Spring version.

Figure 9-1 shows a high-level view of global transactions with JTA. As you can see, four main parties participate in a global transaction (also generally referred to as a distributed transaction). The first party is the back-end resource, such as an RDBMS, messaging middleware, an enterprise resource planning (ERP) system, and so on.

---

<sup>1</sup><https://www.atomikos.com>



**Figure 9-1.** Overview of global transactions with JTA

The second party is the resource manager, which is generally provided by the back-end resource vendor and is responsible for interacting with the back-end resource. For example, when connecting to a MySQL database, we need to interact with the `MySQLXADataSource` class provided by MySQL's Java connector. Equivalent implementations exist for MariaDB as well. Other back-end resources (for example, MQ, ERP, and so on) provide their resource managers too.

The third party is the JTA transaction manager, which is responsible for managing, coordinating, and synchronizing the transaction status with all resource managers that are participating in the transaction. The previously mentioned XA protocol is used, which is an open standard widely used for distributed transaction processing. The JTA transaction manager also supports 2PC so that all changes will be committed together, and if any resource update fails, the entire transaction will be rolled back, resulting in none of the resources being updated. The entire mechanism was specified by the Java Transaction Service (JTS) specification.

The final component is the application. Either the application itself or the underlying container or Spring Framework that the application runs on manages the transaction (begin, commit, roll back a transaction, and so on). At the same time, the application interacts with the underlying back-end resources via various standards defined by JEE. As shown in Figure 9-1, the application connects to the RDBMS via JDBC, MQ via JMS, and an ERP system via Java EE Connector Architecture (JCA). JTA is supported by all full-blown JEE-compliant application servers (for example, JBoss, WebSphere, WebLogic, and GlassFish), within which the transaction is available via JNDI lookup. As for stand-alone applications or web containers (for example, Tomcat and Jetty), open source and commercial solutions exist that provide support for JTA/XA in those environments. The one favored by the Spring community used to be Atomikos, for which there was even a Spring Boot starter library. Unfortunately, the latest version of Atomikos as this chapter is being written (5.0.9) is not based on Jakarta JTA, which means building a Spring JTA application with the latest Spring version is not possible. The other alternative, Bitronix<sup>2</sup>, is already archived on GitHub and no update has been done in the last 6 years. The last update on Java Open Transaction Manager (JOTM)<sup>3</sup> was done in 2009.

<sup>2</sup><https://github.com/bitronix/btm>

<sup>3</sup><https://jotm.ow2.org>

It looks like JTA is slowly becoming obsolete with the increasing interest in microservices, event-driven systems built using Apache Kafka, RabbitMQ, and Azure Event Hub (and more), and the rise of DBaaS (database as a service) like Amazon’s DynamoDB and MariaDB SkySQL, all of which make transactions not particularly necessary. Of course, if you need to use global transactions, there is always the option to use an application EE server.

At the time of writing, Spring 6 JTA support with stand-alone implementations is unclear. Spring’s components are based on Jakarta API, which means the stand-alone implementation must be based on it too. For example, a stand-alone implementation must provide an implementation for `jakarta.transaction.UserTransaction` to be compatible with Spring 6 JTA, and none of them do yet. Using a Jakarta 10-compatible server is not an option either. Jakarta EE 10<sup>4</sup> is the first major release of Jakarta EE since the “jakarta” namespace update, and a lot of application servers are not compatible with it.

By the end of the year there might be compatible stand-alone implementations available, or Jakarta 10-compatible servers like Apache TomEE, Open Liberty, Eclipse Glassfish, and others<sup>5</sup>. If you are interested in global transactions with Spring 5 and Atomikos, feel free to check out the previous edition of this book and the sample project in its associated repo<sup>6</sup>.

## Implementations of the PlatformTransactionManager

In Spring, the `PlatformTransactionManager` interface uses the `TransactionDefinition` and `TransactionStatus` interfaces to create and manage transactions. The concrete implementations of these interfaces must have detailed knowledge of the transaction manager.

Spring provides a rich set of implementations for the `PlatformTransactionManager` interface.

Figure 9-2 shows a few of them.

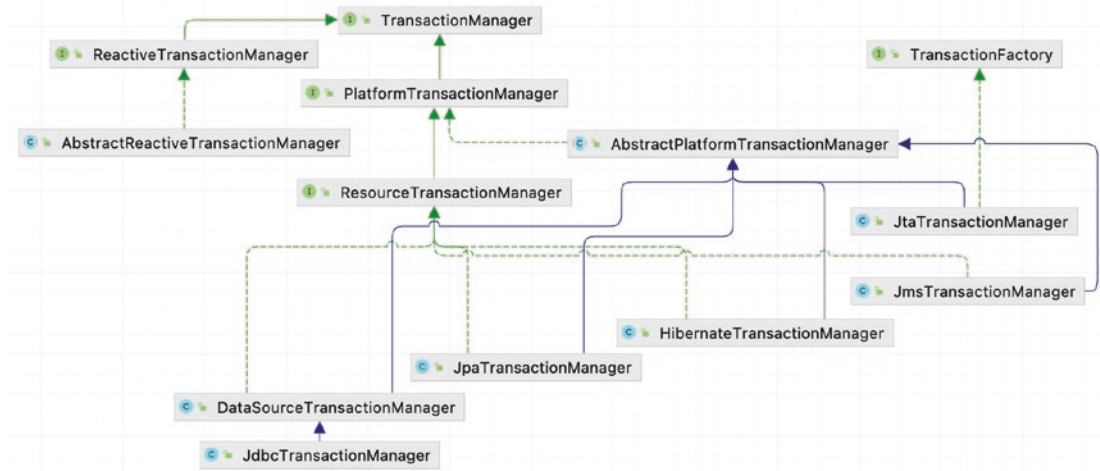


Figure 9-2. PlatformTransactionManager implementations

<sup>4</sup><https://eclipse-ee4j.github.io/jakartaee-platform/jakartaee10/JakartaEE10ReleasePlan>

<sup>5</sup><https://jakarta.ee/compatibility>

<sup>6</sup><https://github.com/Apress/pro-spring-5/tree/master/chapter09>

The `DataSourceTransactionManager` class, from package `org.springframework.jdbc.datasource`, is for generic JDBC connections. For the ORM side, there are a few implementations, including JPA - the `JpaTransactionManager` class, and Hibernate 5 `HibernateTransactionManager` class. There will probably be a new version for Hibernate 6 in the future. Currently the only `HibernateTransactionManager` class available is the one from package `org.springframework.orm.hibernate5`. Since support for Hibernate 5 will probably not be dropped, expect a package named `org.springframework.orm.hibernate6` to appear in Spring ORM 6. For JMS, the implementations support JMS 2.0 through the `JmsTransactionManager` class. For JTA, the generic implementation class is `JtaTransactionManager`. For reactive servers, Spring provides `AbstractReactiveTransactionManager`, an abstract base class that implements Spring's standard reactive transaction workflow, serving as a basis for concrete platform transaction managers (like the `R2dbcTransactionManager` implementation for a single `R2DBC ConnectionFactory`).

Spring also provides several JTA transaction manager classes (not depicted here in Figure 9-2) that are specific to particular application servers. Those classes provide native support for WebSphere (the `WebSphereUowTransactionManager` class) and BEA WebLogic 9.0 and higher (the `WebLogicJtaTransactionManager` class).



JDO support was dropped in Spring 5, thus `JdoTransactionManager` is missing from the class diagram in Figure 9-2. Starting with Spring 5, only Hibernate 5 is supported; implementations for Hibernate 3 and Hibernate 4 have been dropped. Support for JMS 1.1 was dropped in Spring 5. The `CciLocalTransactionManager` class that supports JEE, JCA, and the Common Client Interface (CCI) is currently deprecated.

---

## Analyzing Transaction Properties

In this section, we discuss the transaction properties that Spring supports, focusing on interacting with RDBMS as the back-end resource.

Transactions have the four well-known ACID properties (atomicity, consistency, isolation, and durability), and it is up to the transactional resources to maintain these aspects of a transaction. You cannot control the atomicity, consistency, and durability of a transaction. However, you can control the transaction propagation and timeout, as well as configure whether the transaction should be read-only and specify the isolation level.

Spring encapsulates all these settings in a `TransactionDefinition` interface. This interface is used in the core interface of the transaction support in Spring, which is the `PlatformTransactionManager` interface, whose implementations perform transaction management on a specific platform, such as JDBC or JTA. The core method, `PlatformTransactionManager.getTransaction()`, takes a `TransactionDefinition` interface as an argument and returns a `TransactionStatus` interface. The `TransactionStatus` interface is used to control the transaction execution, more specifically to set the transaction result and to check whether the transaction is completed or whether it is a new transaction.

## The TransactionDefinition Interface

As we mentioned earlier, the `TransactionDefinition` interface controls the properties of a transaction. Let's take a more detailed look at the `TransactionDefinition` interface<sup>7</sup>, shown in Listing 9-1, and describe its methods.

**Listing 9-1.** Essential `TransactionDefinition` Source Code

```

package org.springframework.transaction;

import org.springframework.lang.Nullable;

public interface TransactionDefinition {
    // Variable declarations and comments omitted

    default int getPropagationBehavior() {
        return PROPAGATION_REQUIRED; // 0
    }

    default int getIsolationLevel() {
        return ISOLATION_DEFAULT; // -1
    }

    default int getTimeout() {
        return TIMEOUT_DEFAULT; // -1
    }

    default boolean isReadOnly() {
        return false;
    }

    @Nullable
    default String getName() {
        return null;
    }

    // Return an unmodifiable {@code TransactionDefinition} with defaults.
    static TransactionDefinition withDefaults() {
        return StaticTransactionDefinition.INSTANCE;
    }
}

```

The simple and obvious methods of this interface are `getTimeout()`, which returns the time (in seconds) in which the transaction must complete, and `isReadOnly()`, which indicates whether the transaction is read-only. The transaction manager implementation can use this value to optimize the execution and check to make sure that the transaction is performing only read operations. The `getName()` method returns the name of the transaction.

<sup>7</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-tx/src/main/java/org/springframework/transaction/TransactionDefinition.java>

The other two methods, `getPropagationBehavior()` and `getIsolationLevel()`, need to be discussed in more detail. We begin with `getIsolationLevel()`, which controls what changes to the data other transactions see. Table 9-1 lists the transaction isolation levels you can use and explains which changes made in the current transaction other transactions can access. The isolation levels are represented as static values defined in the `TransactionDefinition` interface.

**Table 9-1.** *Transaction Isolation Levels*

Isolation Level	Description
<code>ISOLATION_DEFAULT</code>	Default isolation level of the underlying data store.
<code>ISOLATION_READ_UNCOMMITTED</code>	Lowest level of isolation; it is barely a transaction at all because it allows this transaction to see data modified by other uncommitted transactions.
<code>ISOLATION_READ_COMMITTED</code>	Default level in most databases; it ensures that other transactions are not able to read data that has not been committed by other transactions. However, the data that was read by one transaction can be updated by other transactions.
<code>ISOLATION_REPEATABLE_READ</code>	Stricter than <code>ISOLATION_READ_COMMITTED</code> ; it ensures that once you select data, you can select at least the same set again. However, if other transactions insert new data, you can still select the newly inserted data.
<code>ISOLATION_SERIALIZABLE</code>	The most expensive and reliable isolation level; all transactions are treated as if they were executed one after another.

Choosing the appropriate isolation level is important for the consistency of the data, but making these choices can have a great impact on performance. The highest isolation level, `ISOLATION_SERIALIZABLE`, is particularly expensive to maintain.

The `getPropagationBehavior()` method specifies what happens to a transactional call, depending on whether there is an active transaction. Table 9-2 describes the values for this method. The propagation types are represented as static values defined in the `TransactionDefinition` interface.

**Table 9-2.** *Transaction Propagation Modes*

Propagation Mode	Value	Description
<code>PROPAGATION_REQUIRED</code>	0	Supports a transaction if one already exists. If there is no transaction, starts one. Default propagation mode in Spring.
<code>PROPAGATION_SUPPORTS</code>	1	Supports a current transaction; executes non-transactionally if no current transaction exists.
<code>PROPAGATION_MANDATORY</code>	2	Supports a current transaction; throws an exception if no current transaction exists.
<code>PROPAGATION_REQUIRES_NEW</code>	3	Creates a new transaction, suspending the current transaction if one exists.
<code>PROPAGATION_NOT_SUPPORTED</code>	4	Does not support execution with an active transaction. Always executes non-transactionally and suspends any existing transaction.
<code>PROPAGATION_NEVER</code>	5	Always executes non-transactionally even if an active transaction exists. Throws an exception if an active transaction exists.
<code>PROPAGATION_NESTED</code>	6	Runs in a nested transaction if an active transaction exists. If there is no active transaction, behaves as if <code>PROPAGATION_REQUIRED</code> is set.



## The TransactionStatus Interface

The `TransactionStatus` interface<sup>8</sup> allows a transaction manager to control the transaction execution. The code can check whether the transaction is a new one or whether it is a read-only transaction, and it can initiate a rollback. The behavior described by the `TransactionStatus` interface is split between two interfaces: `TransactionExecution`, which declares basic transaction operations, and `SavepointManager`, which declares methods related to savepoints. All are shown in Listing 9-2.

**Listing 9-2.** Essential `TransactionStatus` Source Code

```
// TransactionStatus.java
package org.springframework.transaction;

import java.io.Flushable;

public interface TransactionStatus extends TransactionExecution, SavepointManager,
Flushable {

    boolean hasSavepoint();

    @Override
    void flush();

}

// TransactionExecution.java
package org.springframework.transaction;

public interface TransactionExecution {
    boolean isNewTransaction();
    void setRollbackOnly();
    boolean isRollbackOnly();
    boolean isCompleted();
}

// SavepointManager.java
package org.springframework.transaction;

public interface SavepointManager {
    Object createSavepoint() throws TransactionException;
    void rollbackToSavepoint(Object savepoint) throws TransactionException;
    void releaseSavepoint(Object savepoint) throws TransactionException;
}
```

The methods in the `TransactionExecution` interface are fairly self-explanatory; the most notable one is `setRollbackOnly()`, which causes a rollback and ends the active transaction. The `hasSavePoint()` method from `TransactionStatus` returns whether the transaction internally carries a savepoint (that is, the transaction was created as a nested transaction based on a savepoint). The `flush()` method, also from

<sup>8</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-tx/src/main/java/org/springframework/transaction/TransactionStatus.java>

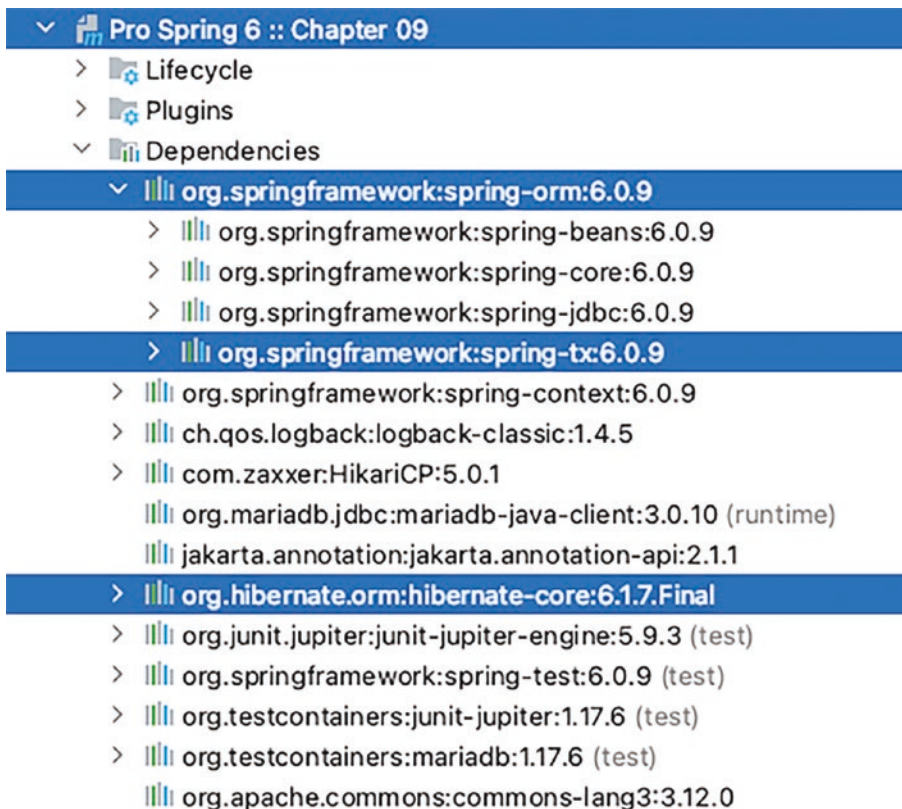
TransactionStatus, flushes the underlying session to a data store if applicable (for example, when using with Hibernate). The isCompleted() method from the TransactionExecution interface method returns whether the transaction has ended (that is, committed or rolled back).

## Sample Data Model and Infrastructure for Example Code

This section uses the same data model introduced in **Chapter 7**. There are two main tables, namely SINGER and ALBUM, that we have used throughout the chapters about data access. Feel free to set up the container as instructed in chapter09/README.adoc or ignore that altogether and just run the tests that are set up to use a MariaDB container set up by Testcontainers. JPA with Hibernate is used as the persistence layer for implementing data access logic.

The main project dependencies are Spring ORM and Hibernate. The Spring ORM library introduces the spring-tx transitive dependency that contains all the Spring components that provide transaction support.

Figure 9-3 shows the list of dependencies for the chapter09 project.



**Figure 9-3.** Project chapter09 dependencies as shown in the Gradle View

There are two main JPA entity classes, Singer and Album, that map to those tables that will be used in most examples in this chapter. These two classes should be familiar to you if you've read the previous data access chapters, but to keep things simple, their core parts are shown in Listing 9-3.

**Listing 9-3.** Singer and Album JPA Entity Classes

```

// Singer.java
package com.apress.prospring6.nine.entities;

import jakarta.persistence.*;
// other import statements omitted

@Entity
@Table(name = "SINGER")
@NamedQueries({
    @NamedQuery(name=Singer.FIND_ALL, query="select s from Singer s"),
    @NamedQuery(name=Singer.COUNT_ALL, query="select count(s) from Singer s")
})
public class Singer extends AbstractEntity {
    @Serial
    private static final long serialVersionUID = 2L;

    public static final String FIND_ALL = "Singer.findAll";
    public static final String COUNT_ALL = "Singer.countAll";

    @Column(name = "FIRST_NAME")
    private String firstName;

    @Column(name = "LAST_NAME")
    private String lastName;
    @Column(name = "BIRTH_DATE")
    private LocalDate birthDate;
    @OneToMany(mappedBy = "singer")
    private Set<Album> albums = new HashSet<>();

    @ManyToMany
    @JoinTable(name = "SINGER_INSTRUMENT",
        joinColumns = @JoinColumn(name = "SINGER_ID"),
        inverseJoinColumns = @JoinColumn(name = "INSTRUMENT_ID"))
    private Set<Instrument> instruments = new HashSet<>();

    // setters, getter, etc. omitted
}
// -----
// Album.java
package com.apress.prospring6.nine.entities;

import jakarta.persistence.*;
// other import statements omitted

@Entity
@Table(name = "ALBUM")
@NamedQueries({
    @NamedQuery(name=Album.FIND_ALL, query="select a from Album a where a.singer=
:singer")
})

```

```

public class Album extends AbstractEntity {
    @Serial
    private static final long serialVersionUID = 3L;

    public static final String FIND_ALL = "Album.findAll";

    @Column
    private String title;
    @Column(name = "RELEASE_DATE")
    private LocalDate releaseDate;

    @ManyToOne
    @JoinColumn(name = "SINGER_ID")
    private Singer singer;

    // setters, getter, etc. omitted
}

```

We use JPA with Hibernate as the persistence layer for implementing data access logic, which means the configuration will too be identical to the one in **Chapter 7**. Listing 9-4 shows only the piece of configuration that is relevant to transaction management.

**Listing 9-4.** Transaction Management Configuration Class

```

package com.apress.prospring6.nine.config;

import org.springframework.orm.jpa.JpaTransactionManager;
import org.springframework.orm.jpa.JpaVendorAdapter;
import org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean;
import org.springframework.orm.jpa.vendor.HibernateJpaVendorAdapter;
import org.springframework.transaction.PlatformTransactionManager;
import org.springframework.transaction.annotation.EnableTransactionManagement;
// other import statements omitted

@Import(BasicDataSourceCfg.class)
@Configuration
@EnableTransactionManagement
@ComponentScan(basePackages = {"com.apress.prospring6.nine.services"})
public class TransactionCfg {
    private static Logger LOGGER = LoggerFactory.getLogger(TransactionCfg.class);

    @Autowired
    DataSource dataSource;

    @Bean
    public PlatformTransactionManager transactionManager() {
        JpaTransactionManager transactionManager=new JpaTransactionManager();
        transactionManager.setEntityManagerFactory(entityManagerFactory().getObject());
        return transactionManager;
    }
}

```

```

@Bean
public JpaVendorAdapter jpaVendorAdapter() {
    return new HibernateJpaVendorAdapter();
}

@Bean
public LocalContainerEntityManagerFactoryBean entityManagerFactory() {
    var factory = new LocalContainerEntityManagerFactoryBean();
    factory.setPersistenceProviderClass(HibernatePersistenceProvider.class);
    factory.setPackagesToScan("com.apress.prospring6.nine.entities");
    factory.setDataSource(dataSource);
    factory.setJpaProperties(jpaProperties());
    factory.setJpaVendorAdapter(jpaVendorAdapter());
    return factory;
}

@Bean
public Properties jpaProperties() {
    Properties jpaProps = new Properties();
    jpaProps.put(Environment.HBM2DDL_AUTO, "none");
    jpaProps.put(Environment.FORMAT_SQL, false);
    jpaProps.put(Environment.USE_SQL_COMMENTS, false);
    jpaProps.put(Environment.SHOW_SQL, false);
    return jpaProps;
}
}

```

Currently, using annotations is the most common way to define transaction requirements in Spring. The main benefit is that the transaction requirement together with the detail transaction properties (timeout, isolation level, propagation behavior, and so on) are defined within the code itself, which makes the application easier to trace and maintain. The configuration for the `transactionManager` bean, the core component ensuring those requirements are met, is done using Java configuration. Because we are using JPA, our `transactionManager` is a `JpaTransactionManager` instance that implements Spring's standard transaction workflow in applications that use a single JPA `EntityManagerFactory` for transactional data access.

The `@EnableTransactionManagement` annotation is the one that completes this configuration, because it is responsible for enabling annotation-driven transaction capability. This annotation is used on Spring configuration classes to configure traditional, imperative transaction management or reactive transaction management. `@EnableTransactionManagement` is responsible for registering all infrastructure Spring beans that support transaction management, such as `TransactionInterceptor` and the proxy- or AspectJ-based advice that weaves the interceptor into the call stack when methods annotated with `@Transactional` are called.

There is no change in how the `EntityManagerFactory` bean is then configured.

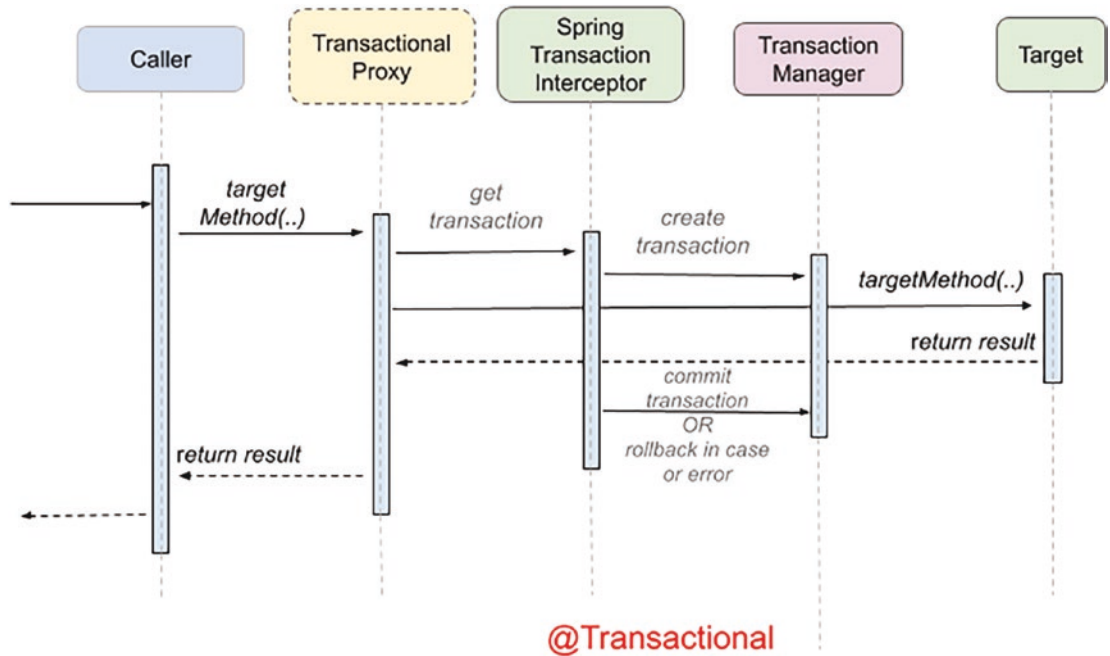
With this configuration in place, any method interacting with the data layer can be annotated with `@Transactional` and the Spring IoC container will open a transaction before the method execution and close it right after.

## Using Declarative Transactions

Configuring transactional behavior using annotations is referred to as *declarative* because the desired behavior is declared using annotations on the targeted methods. There is no code to be written to create, start, and end a transaction. The Spring `transactionManager` bean picks up the `@Transactional` annotations

and wraps the method within the desired transactional behavior. This is done using something introduced in **Chapter 5**: proxying. The bean declaration annotated with `@Transactional`, or that contains methods annotated with `@Transactional`, is transformed at runtime into a bean that is wrapped into a proxy that injects transactional behavior for every targeted method.

Figure 9-4 shows what happens under the hood every time a method of a transactional bean is invoked.



**Figure 9-4.** Diagram showing how transactional behavior is injected in Spring

In multilayered implementations, where service classes are calling repository classes to exchange data with the database, service methods are configured to be executed in transactions, providing the opportunity to provide atomic behavior for methods that involve multiple database operations. For this reason, in the examples in this section, the albums are not eagerly loaded for a singer, nor are they loaded through a named query, since they will be loaded through a repo method in the same method where singers are extracted as well, as shown in the `AllServiceImpl` class shown in Listing 9-5.

**Listing 9-5.** `AllServiceImpl` Method Showing Loading of Singers and Albums Through Repository Methods Executed in the Same Transaction

```
package com.apress.prospring6.nine.services;

import org.springframework.stereotype.Service;
import org.springframework.transaction.annotation.Transactional;
// other import statements omitted

@Service
@Transactional
public class AllServiceImpl implements AllService{
```

```

private final SingerRepo singerRepo;

private final AlbumRepo albumRepo;

public AllServiceImpl(SingerRepo singerRepo, AlbumRepo albumRepo) {
    this.singerRepo = singerRepo;
    this.albumRepo = albumRepo;
}

@Transactional(readOnly = true)
@Override
public Stream<Singer> findAllWithAlbums() {
    var singers = singerRepo.findAll();
    return singers.peek(s -> s.setAlbums(albumRepo.findBySinger(s).collect(Collectors.
        toSet())));
}
}

```

When using annotation-based transaction management, the only annotation that we need to deal with is Spring's `@Transactional`. The `@Transactional` annotation can be applied at the class level, which means that, by default, Spring will ensure that a transaction is present before the execution of each method within the class. Starting with Spring 5, `@Transactional` is supported on interfaces and default methods in interfaces as well.



It is recommended to use Spring's `@Transactional` annotation only on non-private methods, since the transactional behavior is injected using AOP proxying.

---



The implementation for the `SingerRepo` and `AlbumRepo` is not important for this chapter, but if you are curious, feel free to check the repository sources. Their methods are implemented using `EntityManager`, as shown in **Chapter 8**.

---

The `@Transactional` annotation supports a number of attributes that you can provide to override the default behavior. Table 9-3 shows the available attributes, together with the default values and possible values.

**Table 9-3.** *@Transactional* annotation attributes

Attribute Name	Default Value	Possible Values
propagation	Propagation.REQUIRED	Propagation.REQUIRED Propagation.SUPPORTS Propagation.MANDATORY Propagation.REQUIRES_NEW Propagation.NOT_SUPPORTED Propagation.NEVER Propagation.NESTED
isolation	Isolation.DEFAULT (default isolation level of the underlying resource)	Isolation.DEFAULT Isolation.READ_UNCOMMITTED Isolation.READ_COMMITTED Isolation.REPEATABLE_READ Isolation.SERIALIZABLE
timeout	TransactionDefinition.TIMEOUT_DEFAULT (default transaction timeout in seconds of the underlying resource)	An integer value larger than zero; indicates the number in seconds for timeout
readOnly	false	{true, false}
rollbackFor	Exception classes for which the transaction will be rolled back	N/A
rollbackForClassName	Exception class names for which the transaction will be rolled back	N/A
noRollbackFor	Exception classes for which the transaction will not be rolled back	N/A
noRollbackForClassName	Exception class names for which the transaction will not be rolled back	N/A
value	""	A qualifier value for the specified transaction; may be used to determine the target transaction manager, matching the qualifier value (or the bean name) of a specific transactionManager bean

As a result, based on Table 9-3, the `@Transactional` annotation without any attribute means that the transaction propagation mode is required, the isolation is the default isolation level of the underlying data store, the timeout is the default timeout of the underlying transaction system, and the mode is read-write.

The `@Transactional` annotation can be applied at the method level as well, and this allows overriding of the transactional configuration at the class level. For example, use `@Transactional(readOnly = true)` when transaction is effectively read-only, which allows for corresponding optimizations at runtime. All attributes remain unchanged.



The `readOnly` flag configuration is just a hint for the underlying persistence system, and Hibernate is very good at taking hints, so don't use `readOnly = true` on a method designed to update an existing entry, for example, or you'll have to flush the changes explicitly.



Now that we have a service method, it is time to test it. Listing 9-6 shows the `AllServiceTest` class, which uses a MariaDB container managed by Testcontainers for database operations.

**Listing 9-6.** AllServiceTest Test Class

```

package com.apress.prospring6.nine;
// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {AllServiceTest.TestContainersConfig.class})
public class AllServiceTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(AllServiceTest.class);

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:10.7.4-focal");

    @DynamicPropertySource
    static void setUp(DynamicPropertyRegistry registry) {
        registry.add("jdbc.driverClassName", mariaDB::getDriverClassName);
        registry.add("jdbc.url", mariaDB::getJdbcUrl);
        registry.add("jdbc.username", mariaDB::getUsername);
        registry.add("jdbc.password", mariaDB::getPassword);
    }

    @Autowired
    AllService service;

    @Test
    @DisplayName("should return all singers and albums")
    void testFindAll(){
        var singers = service.findAllWithAlbums().peek(s -> {
            LOGGER.info(s.toString());
            if (s.getAlbums() != null) {
                s.getAlbums().forEach(a -> LOGGER.info("\tAlbum:" + a.toString()));
            }
        }).toList();
        assertEquals(3, singers.size());
    }

    @Configuration
    @Import(TransactionCfg.class)
    public static class TestContainersConfig {
        @Autowired
        Properties jpaProperties;

        @PostConstruct
        public void initialize() {
            jpaProperties.put(Environment.FORMAT_SQL, true);
        }
    }
}

```

```

        jpaProperties.put(Environment.USE_SQL_COMMENTS, true);
        jpaProperties.put(Environment.SHOW_SQL, true);
    }
}
}

```

Testing methods designed to run in a transaction is no different from what was done in the previous chapters. The focus in this chapter won't be on the SQL queries being generated, but on the transactions being used to execute those queries in. Take a look at the logging statements in Listing 9-7.

**Listing 9-7.** AllServiceTest.testFindAll() Execution Log Snippet Showing Transaction Management

```

DEBUG: AbstractPlatformTransactionManager - Creating new transaction with name
      [com.apress.prospring6.nine.services.AllServiceImpl.findAllWithAlbums]:
      PROPAGATION_REQUIRED,ISOLATION_DEFAULT,readOnly
DEBUG: JpaTransactionManager - Opened new EntityManager [SessionImpl(1958757239<open>)] for
JPA transaction
DEBUG: DataSourceUtils - Setting JDBC Connection [HikariProxyConnection@282368256 wrapping
org.mariadb.jdbc.Connection@7327a447] read-only
DEBUG: TransactionImpl - On TransactionImpl creation, JpaCompliance#isJpaTransactionComplianceEnabled == false
DEBUG: TransactionImpl - begin
DEBUG: JpaTransactionManager - Exposing JPA transaction as JDBC [org.springframework.orm.
jpa.vendor.HibernateJpaDialect$HibernateConnectionHandle@e645600]
TRACE: TransactionAspectSupport - Getting transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.findAllWithAlbums]
DEBUG: SqlStatementLogger - select singer0_.... from SINGER singer0_
...
DEBUG: TwoPhaseLoad - Done materializing entity [com.apress.prospring6.nine.entities.
Singer#3]
TRACE: TransactionAspectSupport - Completing transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.findAllWithAlbums]
DEBUG: AbstractPlatformTransactionManager - Initiating transaction commit
DEBUG: JpaTransactionManager - Committing JPA transaction on EntityManager [SessionImpl
(1958757239<open>)]
DEBUG: TransactionImpl - committing
DEBUG: DataSourceUtils - Resetting read-only flag of JDBC Connection
[HikariProxyConnection@282368256 wrapping org.mariadb.jdbc.Connection@7327a447]
DEBUG: JpaTransactionManager - Closing JPA EntityManager [SessionImpl(1958757239<open>)]
after transaction
DEBUG: SharedEntityManagerCreator$SharedEntityManagerInvocationHandler - Creating new
EntityManager for shared EntityManager invocation
DEBUG: SqlStatementLogger - select album0_... from ALBUM album0_ where album0_.SINGER_ID=?
...
INFO : AbstractEntityManagerFactoryBean - Closing JPA EntityManagerFactory for persistence
unit 'default'
...
INFO : AllServiceTest - Singer - Id: 1, First name: John, Last name: Mayer, Birthday:
1977-10-16
INFO : AllServiceTest - Album:Album - Id: 1, Singer id: 1, Title: The Search For
Everything, Release Date: 2017-01-20

```

```
INFO : AllServiceTest - Album:Album - Id: 2, Singer id: 1, Title: Battle Studies,
Release Date: 2009-11-17
INFO : AllServiceTest - Singer - Id: 2, First name: Ben, Last name: Barnes, Birthday:
1981-08-20
INFO : AllServiceTest - Album:Album - Id: 3, Singer id: 2, Title: 11:11, Release Date:
2021-09-1
INFO : AllServiceTest - Singer - Id: 3, First name: John, Last name: Butler, Birthday:
1975-04-01
```

This log snippet contains relevant logging statements for classes in packages `org.springframework.orm.jpa` and `org.springframework.transaction`. The `JpaTransactionManager` handles the creation and commit operations of the transaction. Notice how before the execution of the `findAllWithAlbums()` method, Spring's `AbstractPlatformTransactionManager` (`JpaTransactionManager`'s superclass) creates a new transaction. Its name is equal to the fully qualified class name concatenated with the method name. Next to the transaction name are the transaction attributes: `PROPAGATION_REQUIRED`, `ISOLATION_DEFAULT`, `readOnly`. The transaction is represented by an instance of Hibernate's `TransactionImpl` from its internal package `org.hibernate.engine.transaction.internal`. This class implements (indirectly) the `jakarta.persistence.EntityTransaction` interface, which is used to control transactions on resource-local entity managers. The transaction is thus being obtained by the `EntityManager`, then the query is submitted, and upon completion and without any errors, the transaction is committed.

From the log you might think that the transaction is committed before the albums are retrieved from the database, but it is only logging timing. In fact, all queries are executed within the same transaction.

The next method we want to look at is the update operation. To check the result of an update operation, the `findById()` method is useful too. Listing 9-8 shows the implementation of the two methods.

**Listing 9-8.** `AllServiceImpl` in the Same Transaction

```
package com.apress.prospring6.nine.services;
// import statements omitted

@Service
@Transactional
public class AllServiceImpl implements AllService{
    // constructor and fields omitted

    @Transactional(readOnly = true)
    @Override
    public Optional<Singer> findByIdWithAlbums(Long id) {
        var singerOpt = singerRepo.findById(id);
        singerOpt.ifPresent(s -> s.setAlbums(albumRepo.findById(singer(s).collect(Collectors.
        toSet()))));
        return singerOpt;
    }

    @Transactional(propagation = Propagation.REQUIRES_NEW)
    @Override
    public void update(Singer singer) {
        singerRepo.save(singer);
    }
}
```

The `findByIdWithAlbums(..)` method is also annotated with `@Transactional(readOnly=true)`. Generally, the `readOnly=true` attribute should be applied to all finder methods. The main reason is that most persistence providers will perform a certain level of optimization on read-only transactions. For example, Hibernate will not maintain the snapshots of the managed instances retrieved from the database with read-only turned on.

In the `AllServiceImpl.update(..)` method, we simply invoke the `SingerRepoImpl.save(..)` method and annotate the method with `@Transactional(propagation = Propagation.REQUIRES_NEW)`. This means the class-level annotation is overridden and a new transaction is to be created and used to perform the update operation. The method to test the `AllServiceImpl.update(..)` operation first calls the `findByIdWithAlbums(..)` method to retrieve the record to be updated, as shown in Listing 9-9.

**Listing 9-9.** `AllServiceTest` Method Testing the `AllServiceImpl.update(..)` Method

```
package com.apress.prospring6.nine;
// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {AllServiceTest.TestContainersConfig.class})
public class AllServiceTest {

    @Test
    @SqlGroup({
        @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
    })
    @DisplayName("should update a singer")
    void testUpdate() {
        var singer = service.findByIdWithAlbums(5L).orElse(null);
        // making sure such singer exists
        assertNotNull(singer);

        // retrieve the album
        var album = singer.getAlbums().stream().filter(
            a -> a.getTitle().equals("I Put a Spell on You")).findFirst().orElse(null);
        assertNotNull(album);

        singer.setFirstName("Eunice Kathleen");
        singer.setLastName("Waymon");
        singer.removeAlbum(album);
        int version = singer.getVersion();

        service.update(singer);

        var nina = service.findByIdWithAlbums(5L).orElse(null);
        assertAll( "nina was updated" ,
            () -> assertNotNull(nina),
```

```

        () -> assertEquals(version +1, nina.getVersion()),
        () -> assertEquals(2, nina.getAlbums().size())
    });
}

// test setup and other test methods omitted
}

```

There are three things being updated for the `Singer` instance: its `firstName`, `lastName`, and `album` collection. This method is executed in its own transaction, separate from `AllServiceImpl.findByIdWithAlbums(..)`, as it is revealed by the test execution log. The log in Listing 9-10 shows only the statements creating transactions relevant for the test method; the actual execution log is quite verbose and includes the transactions necessary to populate the database with the entries necessary for the test methods to be run.

**Listing 9-10.** `AllServiceTest` Method Testing the `AllServiceImpl.update(..)` Method Execution Log Snippet

```

DEBUG: AbstractPlatformTransactionManager - Creating new transaction with name
      [com.apress.prospring6.nine.services.AllServiceImpl.findByIdWithAlbums]:
      PROPAGATION_REQUIRED,ISOLATION_DEFAULT,readOnly
TRACE: TransactionAspectSupport - Getting transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.findByIdWithAlbums]
DEBUG: TransactionImpl - begin
...
TRACE: TransactionAspectSupport - Completing transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.findByIdWithAlbums]
....
DEBUG: AbstractPlatformTransactionManager - Creating new transaction with name
      [com.apress.prospring6.nine.services.AllServiceImpl.update]:
      PROPAGATION_REQUIRES_NEW,ISOLATION_DEFAULT
TRACE: TransactionAspectSupport - Getting transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.update]
DEBUG: TransactionImpl - begin
...
TRACE: TransactionAspectSupport - Completing transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.update]
...
DEBUG: AbstractPlatformTransactionManager - Creating new transaction with name
      [com.apress.prospring6.nine.services.AllServiceImpl.findByIdWithAlbums]:
      PROPAGATION_REQUIRED,ISOLATION_DEFAULT,readOnly
TRACE: TransactionAspectSupport - Getting transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.findByIdWithAlbums]
DEBUG: TransactionImpl - begin
...
TRACE: TransactionAspectSupport - Completing transaction for
      [com.apress.prospring6.nine.services.AllServiceImpl.findByIdWithAlbums]
....

```

Here's the fun part: because the update operation requires a non-read-only transaction, even without the `@Transactional(propagation = Propagation.REQUIRES_NEW)` configuration, the update operation would have been executed in its own newly created transaction anyway. The only thing

important here is that creating this new transaction suspends the existing one, and thus the next time `findByIdWithAlbums(..)` is executed to retrieve the updated item from the database, it requires creating a new transaction, as shown by the last section of the log.

Let's design an example that shows an existing transaction being reused. Although pretty basic, a method returning the total number of singers in the database can be configured to run in an existing read-only transaction, since it does not modify the database. To make it execute in an existing transaction, the method is annotated with `@Transactional(propagation = Propagation.SUPPORTS)`, as shown in Listing 9-11.

**Listing 9-11.** `AllServiceImpl.countSingers(..)` Method

```

package com.apress.prospring6.nine.services;
// import statements omitted

@Service
@Transactional
public class AllServiceImpl implements AllService {
    // constructor and fields omitted

    @Transactional(readOnly = true, propagation = Propagation.SUPPORTS)
    @Override
    public Long countSingers() {
        return singerRepo.countAllSingers();
    }
}

```

To make sure that this method is executed in an existing transaction, a test method can be written to compare the result of the `AllServiceImpl.countSingers()` method with the size of the collection returned by `AllServiceImpl.findAllWithAlbums()`, as shown in Listing 9-12.

**Listing 9-12.** `AllServiceImplTest.testCount(..)` Method

```

package com.apress.prospring6.nine;
// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {AllServiceTest.TestContainersConfig.class})
public class AllServiceTest {

    @Test
    void testCount() {
        var singers = service.findAllWithAlbums().collect(Collectors.toSet());
        var count = service.countSingers();

        assertEquals(count, singers.size() );
    }

    // test setup and other test methods omitted
}

```

The expectation is that a transaction is created to execute `service.findAllWithAlbums()` and this transaction is reused to execute `service.countSingers()`. The test execution log makes it pretty clear that a new transaction is not created for `service.countSingers()`, as shown in the log snippet in Listing 9-13.

**Listing 9-13.** AllServiceTest Method Testing the AllServiceImpl.countSingers(..) Method Execution Log Snippet

```
DEBUG: AbstractPlatformTransactionManager - Creating new transaction with name
[com.apress.prospring6.nine.services.AllServiceImpl.findAllWithAlbums]:
PROPAGATION_REQUIRED,ISOLATION_DEFAULT,readonly
DEBUG: JpaTransactionManager - Opened new EntityManager [SessionImpl(1674995553<open>)] for
JPA transaction
DEBUG: TransactionImpl - begin
TRACE: TransactionAspectSupport - Getting transaction for [com.apress.prospring6.nine.
services.AllServiceImpl.findAllWithAlbums]
DEBUG: SqlStatementLogger - select singer0_.... from SINGER singer0_
...
TRACE: TransactionAspectSupport - Getting transaction for [com.apress.prospring6.nine.
services.AllServiceImpl.countSingers]
DEBUG: EntityManagerFactoryUtils - Opening JPA EntityManager
DEBUG: SqlStatementLogger - select count(singer0_.ID) as col_0_0_ from SINGER singer0_
```

Notice that there is no log message saying `Creating new transaction with name[com.apress.prospring6.nine.services.AllServiceImpl.countSingers]`, and the reason is that no transaction is created to execute this method. Because of the transaction propagation mode being set to `PROPAGATION_SUPPORTS`, the method is executed within an existing transaction, or non-transactionally if none exists.

This section covered a few transaction configurations that you might find useful when writing transactional applications. For special cases, you may need to configure the timeout, isolation level, rollback (or not) for specific exceptions, and so on.

Configuring transactional behavior using annotations is practical since transactional behavior can be customized up to the method level. Just make sure to not mix up Spring's `@Transactional` with Jakarta's `@Transactional`, since Jakarta's version does not support as many options as Spring's version does.

## Rolling Back Transactions

In database technologies, a *rollback* is an operation that returns the database to some previous state. Rollbacks are important for database integrity, because they restore a clean copy of the database even after erroneous operations are performed.

At the beginning of this section, when listing the `@Transactional` attributes, there were four of them related to rollback behavior: `rollbackFor`, `rollbackForClassName`, `noRollbackFor`, and `noRollbackForClassName`. Their names are quite relevant to the behavior they configure. Rollback is important for methods that perform more than one database operation within the same transaction. For example, let's assume we have a `save(..)` method that inserts a singer to the database, then retrieves the saved record to link it to a set of albums being saved to the database. Although not realistic, let's assume one of the albums cannot be saved, and we want to undo the entire process, an all-or-nothing approach.

By default, a transaction will be rolled back on `RuntimeException` and `Error` but not on checked exceptions (business exceptions). This means that if we try to insert an album twice, the transaction is automatically rolled back, since the exception thrown is of type `jakarta.persistence.PersistenceException` that is a subclass of `RuntimeException`.

However, if we introduce a limitation of 50 characters for the title length, when we try to save a record with a title length bigger than 50, a checked exception is thrown, but the transaction is not automatically rolled back. The rollback has to be explicitly configured using the `rollbackFor` attribute.

To test this, let's introduce the checked exception class shown in Listing 9-14.

**Listing 9-14.** TitleTooLongException Checked Exception Class

```
package com.apress.prospring6.nine.ex;

public class TitleTooLongException extends Exception {
    public TitleTooLongException(String message) {
        super(message);
    }

    public TitleTooLongException(String message, Throwable cause) {
        super(message, cause);
    }
}
```

This exception is thrown by the `save(..)` method in the `AlbumRepoImpl`. Since we know we want to save a set of albums, we can also add a version of `save(..)` that takes a `Set<Album>` argument. This method can also be used to implement something that wasn't covered until this chapter: *batch writing*, the grouping of multiple save requests into one method call. The two methods are shown in Listing 9-15.

**Listing 9-15.** The Two Versions of the `save(..)` Method That Throw `TitleTooLongException` Checked Exceptions

```
package com.apress.prospring6.nine.repos;

import com.apress.prospring6.nine.ex.TitleTooLongException;
// other import statements omitted

@Repository
public class AlbumRepoImpl implements AlbumRepo{

    @PersistenceContext
    private EntityManager em;

    // Declared in TransactionCfg.java, 'jpaProperties' bean:
    // 'jpaProps.put(Environment.STATEMENT_BATCH_SIZE, 30);'
    @Value("#{jpaProperties.get('hibernate.jdbc.batch_size')}")
    private int batchSize;

    @Override
    public Set<Album> save(Set<Album> albums) throws TitleTooLongException {
        final Set<Album> savedAlbums = new HashSet<>();
        int i = 0;
        for (Album a : albums) {
            savedAlbums.add(save(a));
            i++;
            if (i % batchSize == 0) {
                // Flush a batch of inserts and release memory.
                em.flush();
                em.clear();
            }
        }
    }
}
```



```

    }
    return savedAlbums;
}

@Override
public Album save(Album album) throws TitleTooLongException {
    if (50 < album.getTitle().length()) {
        throw new TitleTooLongException("Title " + album.getTitle() + "too long!");
    }
    if (album.getId() == null) {
        em.persist(album);
        return album;
    } else {
        return em.merge(album);
    }
}

// other methods omitted
}

```

The `save(Set<Album>)` method is wrapped in a transaction together with the `save(Singer)` method in the `AllServiceImpl` class, in the `saveSingerWithAlbums(..)` method, as shown in Listing 9-16.

**Listing 9-16.** `AllServiceImpl.saveSingerWithAlbums(..)` Transactional Method

```

package com.apress.prospring6.nine.services;

import com.apress.prospring6.nine.ex.TitleTooLongException;
import org.springframework.transaction.annotation.Transactional;
// other import statements omitted

@Service
@Transactional
public class AllServiceImpl implements AllService {
    // other methods and fields omitted

    @Transactional(rollbackFor = TitleTooLongException.class)
    @Override
    public void saveSingerWithAlbums(Singer s, Set<Album> albums) throws
TitleTooLongException {
        var singer = singerRepo.save(s);
        if (singer != null) {
            albums.forEach(a -> a.setSinger(singer));
            albumRepo.save(albums);
        }
    }
}

```

Since this is the method grouping multiple database operations together, its corresponding transaction is rolled back, and any partial operation is reverted by default if a `RuntimeException` or a `TitleTooLongException` is thrown as configured by `@Transactional(rollbackFor = TitleTooLongException.class)`.

To test this behavior we need two test methods. The test method in Listing 9-17 verifies the default rollback for any `RuntimeException` method. In this particular scenario, we are trying to insert the *Little Girl Blue* album, which already exists in the database, being inserted via the `add-nina.sql` test setup script.

**Listing 9-17.** Method Testing Transaction Rollback Caused by a `RuntimeException` Being Thrown

```

package com.apress.prospring6.nine;

import jakarta.persistence.PersistenceException;
// other import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {AllServiceTest.TestContainersConfig.class})
public class AllServiceTest extends TestContainersBase {

    @Test
    @SqlGroup({
        @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
    })
    @DisplayName("should perform a rollback because PersistenceException")
    void testRollbackRuntimeUpdate() {
        // (1)
        var singer = service.findByIdWithAlbums(5L).orElse(null);
        assertNotNull(singer);

        // (2)
        singer.setFirstName("Eunice Kathleen");
        singer.setLastName("Waymon");

        var album = new Album();
        album.setTitle("Little Girl Blue");
        album.setReleaseDate(LocalDate.of(1959,2, 20));
        album.setSinger(singer);
        // (3)
        var albums = Set.of(album);

        // (4)
        assertThrows(PersistenceException.class ,
            () -> service.saveSingerWithAlbums(singer, albums),
            "PersistenceException not thrown!");

        // (5)
        var nina = service.findByIdWithAlbums(5L).orElse(null);
        assertAll( "nina was not updated" ,
            () -> assertNotNull(nina),

```

```

        () -> assertEquals("Eunice Kathleen", nina.getFirstName()),
        () -> assertEquals("Waymon", nina.getLastName())
    );
}
// other methods and fields omitted
}

```

The test method is made of five parts (as indicated by the comments):

1. The singer is retrieved from the database by calling `service.findByIdWithAlbums(5L)`.
2. The singer's `firstName` and `lastName` are updated.
3. A set containing the *Little Girl Blue* album is created.
4. `service.saveSingerWithAlbums(singer, albums)` is invoked and the assumption that a `PersistenceException` is thrown is tested. Calling this method triggers the rollback of the transaction in which this method is executed, thus the changed `Singer` instance is reverted to its original state.
5. The singer is retrieved from the database by calling `service.findByIdWithAlbums(5L)` and the assumption about its first name and last name being unchanged is tested.

This test should pass because `PersistenceException` is a `RuntimeException` and, as mentioned previously, a transaction is by default rolled back for any `RuntimeException`. If you really want to be sure that the rollback happened, you can always check the log of the test method execution and look for messages mentioning the transaction rollback. Listing 9-18 shows log snippets printed in the console when the `testRollbackRuntimeUpdate()` method is executed mentioning the transaction being rolled back.

**Listing 9-18.** Console Log Method Testing Transaction Rollback Caused by a `RuntimeException` Being Thrown

```

DEBUG: AbstractPlatformTransactionManager - Creating new transaction with name
[com.apress.prospring6.nine.services.AllServiceImpl.saveSingerWithAlbums]:
PROPAGATION_REQUIRED,ISOLATION_DEFAULT,
-com.apress.prospring6.nine.ex.TitleTooLongException
DEBUG: TransactionImpl - begin
...
DEBUG: SqlStatementLogger - insert into ALBUM (VERSION, RELEASE_DATE, SINGER_ID, title)
values (?, ?, ?, ?)
WARN : Slf4JLogger - Error: 1062-23000: Duplicate entry '5-Little Girl Blue' for key
'SINGER_ID'
DEBUG: SqlExceptionHandler - could not execute statement [n/a]
java.sql.SQLIntegrityConstraintViolationException:
(conn=4) Duplicate entry '5-Little Girl Blue' for key 'SINGER_ID'
DEBUG: JdbcResourceLocalTransactionCoordinatorImpl$TransactionDriverControlImpl - JDBC
transaction marked for rollback-only (exception provided for stack trace)
TRACE: TransactionAspectSupport - Completing transaction for
[com.apress.prospring6.nine.services.AllServiceImpl.saveSingerWithAlbums]
after exception:
jakarta.persistence.PersistenceException:
org.hibernate.exception.ConstraintViolationException: could not execute statement

```

```
DEBUG: AbstractPlatformTransactionManager - Initiating transaction rollback
DEBUG: JpaTransactionManager - Rolling back JPA transaction on EntityManager [SessionImpl
(1299829127<open>)]
```

**DEBUG: TransactionImpl - rolling back**

Notice that the transaction is being rolled back and the cause is the `PersistenceException`, but also that the `TitleTooLongException` is mentioned in the description of the transaction being created to execute this method. This, of course, is the checked exception that we introduced and configured rollback for. To test that a rollback of the transaction is done, a different test must be written that causes this exception to be thrown. The test in Listing 9-19 sets a title for the album being inserted that is too long, causing the `TitleTooLongException` to be thrown.

**Listing 9-19.** Method Testing Transaction Rollback Caused by a `TitleTooLongException` (Checked) Being Thrown

```
package com.apress.prospring6.nine;

import jakarta.persistence.PersistenceException;
// other import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {AllServiceTest.TestContainersConfig.class})
public class AllServiceTest extends TestContainersBase {

    @Test
    @SqlGroup({
        @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
    })
    @DisplayName("should perform a rollback because TitleTooLongException")
    void testRollbackCheckedUpdate() {
        var singer = service.findByIdWithAlbums(5L).orElse(null);
        assertNotNull(singer);

        singer.setFirstName("Eunice Kathleen");
        singer.setLastName("Waymon");

        var album = new Album();
        album.setTitle("""
            Sit there and count your fingers
            What can you do?
            Old girl you're through
            Sit there, count your little fingers
            Unhappy little girl blue
            """);
        album.setReleaseDate(LocalDate.of(1959,2, 20));
        album.setSinger(singer);
        var albums = Set.of(album);
```

```

assertThrows(TitleTooLongException.class ,
    () -> service.saveSingerWithAlbums(singer, albums),
    "TitleTooLongException not thrown!");

var nina = service.findByIdWithAlbums(5L).orElse(null);
assertAll( "nina was not updated" ,
    () -> assertNotNull(nina),
    () -> assertNotEquals("Eunice Kathleen", nina.getFirstName()),
    () -> assertNotEquals("Waymon", nina.getLastName())
);
}

// other methods and fields omitted
}

```

When this test method is executed, the console log displays similar messages to the ones shown in Listing 9-18 mentioning the rollback.

The `rollbackFor` attribute can be configured with multiple values, and the exceptions that trigger a rollback must be of the configured type or their subclasses. If there is a need to restrict the rollback for an exact exception type, the `rollbackForClassName` attribute can be configured with an array of full checked exception class names.

The `noRollbackFor` attribute has a similar role to `rollbackFor`, but instead of configuring exception types for which rollback is triggered, it is used to configure checked exception types for which a rollback should not be triggered. The `noRollbackForClassName` attribute can be configured with an array of checked exception full class names for which rollback is not to be triggered.



It is recommended to use `rollbackFor` and `noRollbackFor` in your configuration, instead of `rollbackForClassName` and `noRollbackForClassName`. Doing so keeps the configuration more concise and the context more relaxed, as they provide matching the exception type and its subclasses in a type-safe manner.

---

## Using Programmatic Transactions

The second option is to control the transaction behavior programmatically. In this case, we have two options. The first one is to inject an instance of `PlatformTransactionManager` into the bean and interact with the transaction manager directly. Another option is to use the Spring-provided `TransactionTemplate` class, which simplifies your work a lot. In this section, we demonstrate using the `TransactionTemplate` class. To make it simple, in this section a new version of the `countSingers()` method is implemented for which the transactional behavior is provided using the `TransactionTemplate` bean. Listing 9-20 depicts the `ProgrammaticTransactionCfg` class, a configuration class introduced especially for demonstrating the use of programmatic transactions.

**Listing 9-20.** ProgrammaticTransactionCfg Configuration Class

```

package com.apress.prospring6.nine.config;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.transaction.TransactionDefinition;
import org.springframework.transaction.support.TransactionTemplate;

@Import({BasicDataSourceCfg.class})
@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.nine.repos", "com.apress.prospring6.nine.programmatic"})
public class ProgrammaticTransactionCfg {

    @Bean
    public TransactionTemplate transactionTemplate() {
        TransactionTemplate tt = new TransactionTemplate();
        tt.setPropagationBehavior(TransactionDefinition.PROPROPAGATION_REQUIRES_NEW);
        tt.setTimeout(30);
        tt.setTransactionManager(transactionManager());
        return tt;
    }

    @Bean
    public PlatformTransactionManager transactionManager() {
        JpaTransactionManager transactionManager = new JpaTransactionManager();
        transactionManager.setEntityManagerFactory(entityManagerFactory().getObject());
        return transactionManager;
    }

    // the rest of this class is identical to TransactionCfg.java
}

```

A `TransactionTemplate` bean is defined, using the `org.springframework.transaction.support.TransactionTemplate` class, with a few transaction attributes. The propagation mode is configured to `PROPAGATION_REQUIRES_NEW` so that log messages about the transaction are easy to spot.

The `TransactionTemplate` template adopts the same approach as other Spring templates, such as the `JdbcTemplate` introduced in **Chapter 6**. Also, the `@EnableTransactionManagement` annotation is not needed since transaction management is now done explicitly. With this configuration, the implementation of the `countSingers()` method changes to the one shown in **Listing 9-21**.

**Listing 9-21.** ProgrammaticServiceImpl Class Containing `countSingers()` Method with Explicit Transaction Management

```

package com.apress.prospring6.nine.programmatic;

import com.apress.prospring6.nine.repos.SingerRepo;
import org.springframework.stereotype.Service;
import org.springframework.transaction.support.TransactionTemplate;

@Service
public class ProgrammaticServiceImpl implements ProgrammaticService {

```

```

private final SingerRepo singerRepo;

private final TransactionTemplate transactionTemplate;

public ProgramaticServiceImpl(SingerRepo singerRepo, TransactionTemplate
transactionTemplate) {
    this.singerRepo = singerRepo;
    this.transactionTemplate = transactionTemplate;
}

@Override
public Long countSingers() {
    return transactionTemplate.execute(transactionStatus -> singerRepo.
countAllSingers());
}
}

```

A new class named `ProgramaticServiceImpl` is introduced to separate this transactional service from the ones configured with declarative transactions. The bean declared by this class requires a `SpringRepo` and a `TransactionTemplate` bean to be injected by Spring.

The `singerRepo.countAllSingers()` method is passed as an argument to the `TransactionTemplate.execute(..)` method and is wrapped in a declaration of an inner class that implements the `TransactionCallback<T>` interface. Then `doInTransaction()` is the method invoking the actual `singerRepo.countAllSingers()`. The logic runs within a transaction with the attributes as defined by the `transactionTemplate` bean. The reason you are not clearly seeing all of that in Listing 9-21 is because Java 8 lambda expressions are used. The code in Listing 9-22 is the expanded version (because it was written before lambda expressions were introduced) of the method shown in Listing 9-21.

**Listing 9-22.** Expanded Version of the `countSingers()` Method

```

package org.springframework.transaction.support.TransactionCallback;

@Override
public Long countSingers() {
    return transactionTemplate.execute(new TransactionCallback<Long>() {
        @Override
        public Long doInTransaction(TransactionStatus status) {
            return singerRepo.countAllSingers();
        }
    });
}

```

Testing this method is not different than what we've shown so far, but what needs to be pointed out is what to look for in the execution log. Listing 9-23 shows the testing method, without all the setup needed for it and the most interesting lines in the execution log.

**Listing 9-23.** `countSingers()` Test Method and Execution Log Snippet

```

@Test
@DisplayName("should count singers")
void testCount() {
    var count = service.countSingers();
}

```

```

    assertEquals(3, count );
}
//----- execution log ----
DEBUG: AbstractPlatformTransactionManager - Creating new transaction with name [null]:
PROPAGATION_REQUIRES_NEW,ISOLATION_DEFAULT,timeout_30
DEBUG: TransactionImpl - begin
DEBUG: SqlStatementLogger - select count(singer0_.ID) as col_0_0_ from SINGER singer0_
...
DEBUG: AbstractPlatformTransactionManager - Initiating transaction commit
DEBUG: JpaTransactionManager - Committing JPA transaction on EntityManager
[SessionImpl(981307724<open>)]
DEBUG: TransactionImpl - committing
DEBUG: JpaTransactionManager - Closing JPA EntityManager [SessionImpl(981307724<open>)]
after transaction

```

The only thing to observe here is that since the `transactionTemplate` bean does not know any details about the method being executed in a transaction, it cannot name the transaction, so the transaction name is set to `null`, but the transaction attributes shown in the log are the ones configured for the `transactionTemplate` in the `ProgrammaticTransactionCfg`.

During your development career, you might never get to write code using `TransactionTemplate` (or its reactive counterpart, `TransactionalOperator`), simply because declarative transaction is much more practical, but in the improbable case you'd ever need it, now you know it exists and how to use it.

## Considerations on Transaction Management

So, having discussed two ways for implementing transaction management, which one should you use? The declarative approach is recommended in all cases, and you should avoid implementing transaction management explicitly within your code as much as possible. Most of the time, when you find it necessary to code transaction control logic in the application, it is because of bad design, and in this case, you should consider refactoring your logic into manageable pieces and have the transaction requirements defined on those pieces declaratively.

There is another declarative way to configure transactional behavior in Spring, and that is by using AOP XML-style configuration. Since XML is not a focus of this book, you can check out the previous edition of this book if you are interested in this topic. For the declarative approach, using XML and using annotations both have their own pros and cons. Some developers prefer not to declare transaction requirements in code, while others prefer using annotations for easy maintenance, because you can see all the transaction requirement declarations within the code. Again, let the application requirements drive your decision, and once your team or company has standardized on the approach, stay consistent with the configuration style.



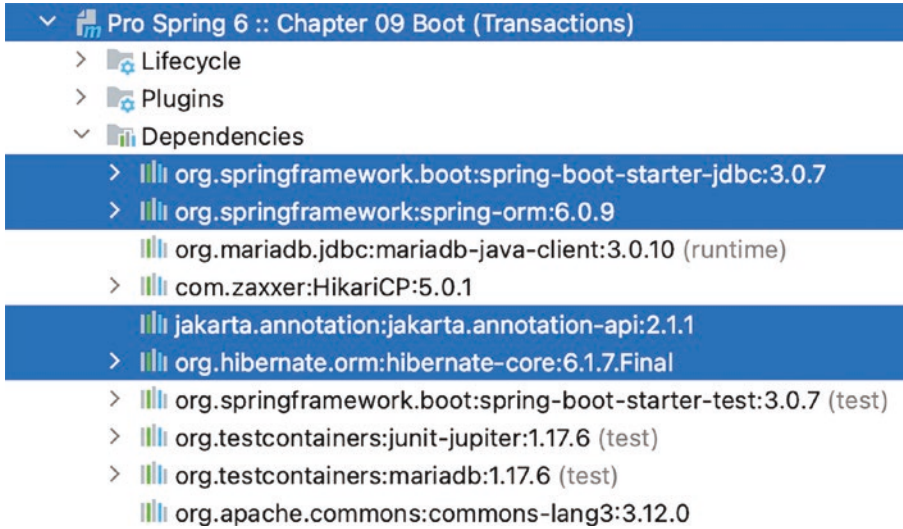
There is also a `@Transactional` annotation in the `jakarta.transaction` package. Spring supports this annotation as well, but it offers less configuration options than Spring's `@Transactional` does. So, when writing Spring applications, make sure you check the package the annotation is coming from.

---



## Transactional Configuration with Spring Boot

Without adding Spring Data in the mix, a Spring Boot transactional application is pretty easy to configure, since the main dependency is `spring-boot-starter-jdbc` and to add transactional-specific components requires only adding `spring-orm` and `hibernate-core` into the mix. The configuration for a Spring Boot transactional project that does not use Spring Data is shown in Figure 9-5.



**Figure 9-5.** Gradle View showing dependencies for the Spring Boot project

Using Spring Boot allows a somewhat simplified configuration, since the `application.properties`/`application.yaml` files can be used to provide configuration using various Spring properties, instead of declaring Java beans. As an example, take a look at the `application-dev.yaml` file contents in Listing 9-24.

**Listing 9-24.** `application-dev.yaml` Contents for the `chapter09-boot` Project

```
# datasource config
spring:
  datasource:
    driverClassName: org.mariadb.jdbc.Driver
    url: jdbc:mariadb://localhost:3306/musicdb?useSSL=false
    username: prospring6
    password: prospring6
    hikari:
```

```

        maximum-pool-size: 25
# JPA config
jpa:
  generate-ddl: false
  properties:
    hibernate:
      jdbc:
        batch_size: 10
        fetch_size: 30
        max_fetch_depth: 3
        show-sql: true
        format-sql: false
        use_sql_comments: false
        hbm2ddl:
          auto: none

# Logging config
logging:
  pattern:
    console: "%-5level: %class{0} - %msg%n"
  level:
    root: INFO
    org.springframework.boot: INFO
    com.apress.prospring6.nine: INFO

```

The configuration is split into three sections: data source, JPA, and logging. Properties with names starting with `spring.datasource` are set with values necessary for configuring a data source: connection URL, credentials, and connection pooling values. Properties with names starting with `spring.jpa` are set with values describing a persistence unit. You can easily recognize the Hibernate properties covered in **Chapter 7** and **8**. Properties starting with `logging` are set with the typical value for logging configuration that in classic applications could be found in `logback.xml` files.

All this means that in a Spring Boot application there is no need for a configuration class to declare a `DataSource` bean, Spring will autoconfigure it based on the properties in the configuration file. The `spring.jpa` properties are used by Spring Boot to autoconfigure the persistence layer—it configures a bean named `jpaVendorAdapter` of type `HibernateJpaVendorAdapter`, a `transactionManager` bean of type `JpaTransactionManager`, and many more beans, including `Properties` beans for Hibernate and JPA. The only thing Spring Boot does not configure is a `LocalSessionFactoryBean` bean, so that needs to be configured explicitly. Listing 9-25 shows the `TransactionalConfig` configuration that contains a single bean declaration of type `LocalSessionFactoryBean`.

**Listing 9-25.** `TransactionalConfig` Declaring a Bean of Type `LocalSessionFactoryBean` Using Beans Autoconfigured by Spring Boot

```

package com.apress.prospring6.nine.boot;

import org.springframework.boot.context.properties.ConfigurationProperties;
// other import statements omitted

@Configuration
@ComponentScan(basePackages = {
    "com.apress.prospring6.nine.boot.repos",
    "com.apress.prospring6.nine.boot.services"})

```

@EnableTransactionManagement

```
public class TransactionalConfig {

    @Autowired
    DataSource dataSource;

    @Bean
    @ConfigurationProperties("spring.jpa.properties")
    public Properties jpaProperties() {
        return new Properties();
    }

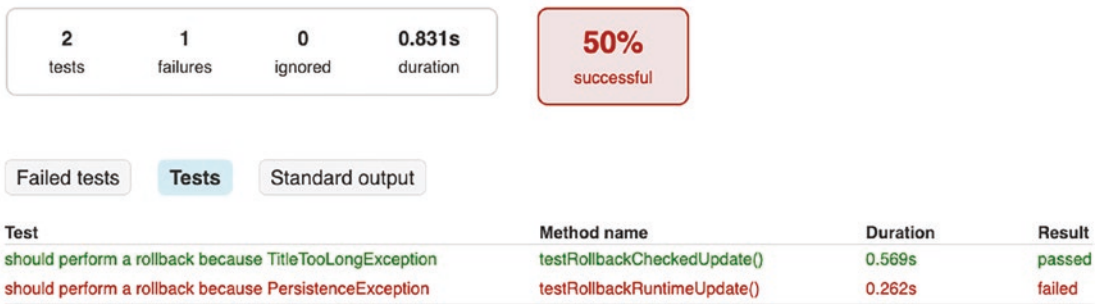
    @Bean
    public LocalSessionFactoryBean sessionFactory() {
        LocalSessionFactoryBean sessionFactory = new LocalSessionFactoryBean();
        sessionFactory.setDataSource(dataSource);
        sessionFactory.setPackagesToScan("com.apress.prospring6.nine.boot.entities");
        sessionFactory.setHibernateProperties(jpaProperties());
        return sessionFactory;
    }
}
```

Since the LocalSessionFactoryBean bean needs a data source, and needs the JPA properties to be configured, we need to access the JPA property values in the Spring Boot configuration file. This is done by configuring a bean of type java.util.Properties and annotating it with @ConfigurationProperties("spring.jpa.properties") to bind the properties declared in the Spring Boot configuration file to the Properties bean created by the method annotated with it.

And this is all that is needed to configure a Spring Boot transactional application. A Spring Boot test class can be created and the rollback tests can be added to it. When the test class is run, something peculiar happens, though—the test method in Listing 9-17, the one testing the rollback when a RuntimeException is thrown, fails. In the Gradle test page shown in Figure 9-6, it is quite obvious which test failed.

### Chapter9ApplicationTest

all > com.apress.prospring6.nine > Chapter9ApplicationTest



Wrap lines   
 Generated by Gradle 7.4.2 at 29 Jul 2022, 00:09:07

Figure 9-6. Gradle test page showing a test failure

If you look in the console log or click the test name, you will see this message:

```
org.opentest4j.AssertionFailedError:
PersistenceException not thrown!
==> Unexpected exception type thrown
    ==> expected: <jakarta.persistence.PersistenceException>
        but was: <org.springframework.dao.DataIntegrityViolationException>
```

So what is going on here? Why is there a different type of exception being thrown?

In **Chapter 6** you were introduced to the Spring hierarchy of runtime data access exceptions. Extensions of this `org.springframework.dao.DataAccessErrorException` class (`DataIntegrityViolationException` is one of these extensions) match specific data access exceptions and provide more information about the real cause of an exception when accessing a database. They wrap around the exceptions thrown by all layers below Spring, and thus this is how the SQL checked exception `java.sql.SQLIntegrityConstraintViolationException` gets wrapped in a `DataIntegrityViolationException` instead of a `PersistenceException`. This happens in a Spring Boot application because Spring Boot autoconfigures a lot more beans than a developer might think to do; in this case Spring Boot autoconfigures an exception translator for the persistence layer, via its `org.springframework.boot.autoconfigure.dao.PersistenceExceptionTranslationAutoConfiguration` configuration class.

This means the test needs to be updated for the Spring Boot application to take this into account. The new test is shown in [Listing 9-26](#).

**Listing 9-26.** The Spring Boot Version of the `testRollbackRuntimeUpdate()` Test Method

```
package com.apress.prospring6.nine;

import org.springframework.dao.DataIntegrityViolationException;
// other import statements omitted

@ActiveProfiles("test")
@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringBootTest(classes = Chapter9Application.class)
public class Chapter9ApplicationTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(Chapter9Application
Test.class);

    @Autowired
    AllService service;

    @Test
    @SqlGroup({
        @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD)
    })
    @DisplayName("should perform a rollback because DataIntegrityViolationException")
    void testRollbackRuntimeUpdate() {
        var singer = service.findByIdWithAlbums(5L).orElse(null);
        assertNotNull(singer);
    }
}
```

```

singer.setFirstName("Eunice Kathleen");
singer.setLastName("Waymon");

var album = new Album();
album.setTitle("Little Girl Blue");
album.setReleaseDate(LocalDate.of(1959,2, 20));
album.setSinger(singer);
var albums = Set.of(album);

assertThrows(DataIntegrityViolationException.class ,
    () -> service.saveSingerWithAlbums(singer, albums),
    "PersistenceException not thrown!");

var nina = service.findByIdWithAlbums(5L).orElse(null);
assertAll( "nina was not updated" ,
    () -> assertNotNull(nina),
    () -> assertNotEquals("Eunice Kathleen", nina.getFirstName()),
    () -> assertNotEquals("Waymon", nina.getLastName())
);
}
}

```

This test method checks for the `DataIntegrityViolationException` being thrown when the bad update is being executed and thus this test passes. If you look in the execution log in the console, you will notice the same messages mentioning the transaction rollback that were printed for the test checking for the `PersistenceException` earlier in the chapter.

## Transactional Tests

In **Chapter 4**, Table 4-5 listed and described the following test annotation that are relevant for transactional contexts:

- `@Rollback`
- `@Commit`
- `@BeforeTransaction`
- `@AfterTransaction`

The names of all four of them make pretty obvious their purposes. They are useful when writing transactional tests. Obviously, there is no need to annotate test methods with `@Transactional` when testing transactional services. You might want to do this to test your repositories in isolation. Although, with the introduction of Spring Data, testing repositories is not really necessary, as you will see in **Chapter 10**.

**Test-managed transactions** are not the same as **Spring-managed transactions**, the ones managed by Spring in the application context (created to run methods annotated with `@Transactional`), or the same as **application-managed transactions**, those managed programmatically within the application.

The text context is based on the application context and thus Spring-managed and application-managed transactions will typically participate in test-managed transactions. This can be easily seen when running the test classes `AllServiceTest` and `ProgramaticServiceTest` introduced in previous sections. If you look in the execution log for the text `Creating new transaction`, you will notice that transactions are

created for every test method. These transactions are the test-context transactions and are created by default in a test context for the test methods. This might cause issues if some Spring-managed transactions are declared with a propagation mode other than `REQUIRED` or `SUPPORTS`.

Annotating a test method with `@Transactional` causes the test to be run within a transaction that will, by default, be automatically rolled back after completion of the test. Annotating a test class with `@Transactional` causes each test method within that class hierarchy to be run within a transaction. Propagation mode, rollback reasons, isolation, and so forth can be configured for test methods as well, when annotated with `@Transactional`.

The `@Commit` annotation is an alias for `@Rollback(false)`; they can both be used at the class level and method level. When used at the class level, the behavior applies to all test methods in the class. You can override the behavior at the class level, but try not to mix them, because the behavior of your tests might become unpredictable.

The `@BeforeTransaction` and `@AfterTransaction` annotations are the equivalents of `@BeforeEach` and `@AfterEach` for transactional methods. `@BeforeTransaction` indicates that the annotated method should be executed before a transaction is started for a test method configured to run within a transaction via Spring's `@Transactional` annotation. `@AfterTransaction` annotates a method that is executed after a transaction is ended for a test method annotated with Spring's `@Transactional` annotation. Starting with Spring 4.3, these two annotations can be used on Java 8 interface default messages as well.

This is all that we can say about Spring transactional applications at the moment. The information provided in this chapter should be enough to help you configure and work confidently with transactions in Spring applications.

## Considerations on Transaction Management

So, having discussed the various ways for implementing transaction management, which one should you use? The declarative approach is recommended in all cases, and you should avoid implementing transaction management within your code as much as possible. Most of the time, when you find it necessary to code transaction control logic in the application, it is because of bad design, and in this case, you should consider refactoring your logic into manageable pieces and have the transaction requirements defined on those pieces declaratively.

For the declarative approach, using XML and using annotations both have their own pros and cons. Some developers prefer not to declare transaction requirements in code, while others prefer using annotations for easy maintenance, because you can see all the transaction requirement declarations within the code. Again, let the application requirements drive your decision, and once your team or company has standardized on the approach, stay consistent with the configuration style.

## Summary

Transaction management is a key part of ensuring data integrity in almost any type of application. In this chapter, we discussed how to use Spring to manage transactions with almost no impact on your source code.

You were introduced to using annotations to configure declarative transactional behavior. You were also shown how to implement programmatic transactional behavior and how to test transactional services.

Local transactions are supported inside/outside a JEE application server, and only simple configuration is required to enable local transaction support in Spring. However, setting up a global transaction environment involves more work and greatly depends on which JTA provider and corresponding back-end resources your application needs to interact with. Also, the future seems to be all microservices running on serverless environments, where global transactions no longer really have a purpose.

**Chapter 6** through **9** have focuses on working with SQL databases which are good for structured data. If the data you plan on working with is a little more chaotic, you might be interested in reading **Chapter 10** that aims to give you an overview of Spring support for NoSQL databases.



# Spring Data with SQL and NoSQL Databases

Now that you've been introduced to multiple aspects of data access, such as connecting to the database, executing native queries with JDBC, mapping tables to entity classes to allow database records to be treated as objects in the Java code, creating repository classes for data management using Hibernate sessions and `EntityManagerFactory`, and then executing multiple database operations in the same Spring-managed transaction, it is time to show you how to avoid writing all this code and let Spring do the job for you using the Spring Data.

The Spring Data project is a subproject under the Spring Data umbrella project<sup>1</sup>. The main objective of the Spring Data project is to provide additional features for simplifying application development with various data sources. The Spring Data project contains multiple subprojects for interacting with SQL and NoSQL databases, both classic and reactive ones. It provides powerful repository and custom object-mapping abstractions, generation of repository queries based on configuration, support for transparent auditing, the possibility to extend repository code, and easy integration with Spring MVC controllers.

Spring Data provides a plethora of features designed to make data access easy, and this chapter focuses on a few aspects without going too much into detail, because that would require doubling the size of this book.

In this chapter we discuss the following:

- *Introducing Spring Data Java Persistence API (JPA)*: We discuss the Spring Data JPA project and demonstrate how it can help simplify the development of data access logic. Since JPA applies to SQL databases, MariaDB is used in the code samples.
- *Tracking entity changes and auditing*: In database update operations, it's a common requirement to keep track of the date an entity was created or last updated and who made the change. Also, for critical information such as a customer, a history table that stores each version of the entity is usually required. We discuss how Spring Data JPA and Hibernate Envers (Hibernate Entity Versioning System) can help ease the development of such logic.
- *Spring Data for NoSQL databases*: We discuss what NoSQL databases are, why they are so interesting, what they are good for, and how accessing their data from a Spring application becomes easier with Spring Data. For the code samples, we have chosen MongoDB.

---

<sup>1</sup><https://spring.io/projects/spring-data>



- *Spring Data configuration with Spring Boot:* Spring Data makes things easier in Spring classic applications, but configuration becomes even easier in Spring Boot applications, since there is a special starter library with a lot of auto-configuration options.

In addition to being introduced to all these cool technologies, you will also be shown how to test your repositories and services, using Testcontainers as a database access provider.

## Introducing Spring Data JPA

Spring Data JPA eases development of applications that need to access JPA data sources; This obviously means applications that use Hibernate and Jakarta Persistence API components for data manipulation. The starting point in using Spring Data JPA is to add `spring-data-jpa` as a dependency to the project. Whether Maven or Gradle, adding this dependency to your project results in all required Spring dependencies being added to the application classpath. The only thing left is to add Hibernate Core Jakarta to the configuration and override the `jakarta.annotation-api` when a different (more recent version) is desired. In Figure 10-1 you can see the list of dependencies for the `chapter10` project, a Spring classic project using Spring Data JPA, as shown by the Gradle view in IntelliJ IDEA.

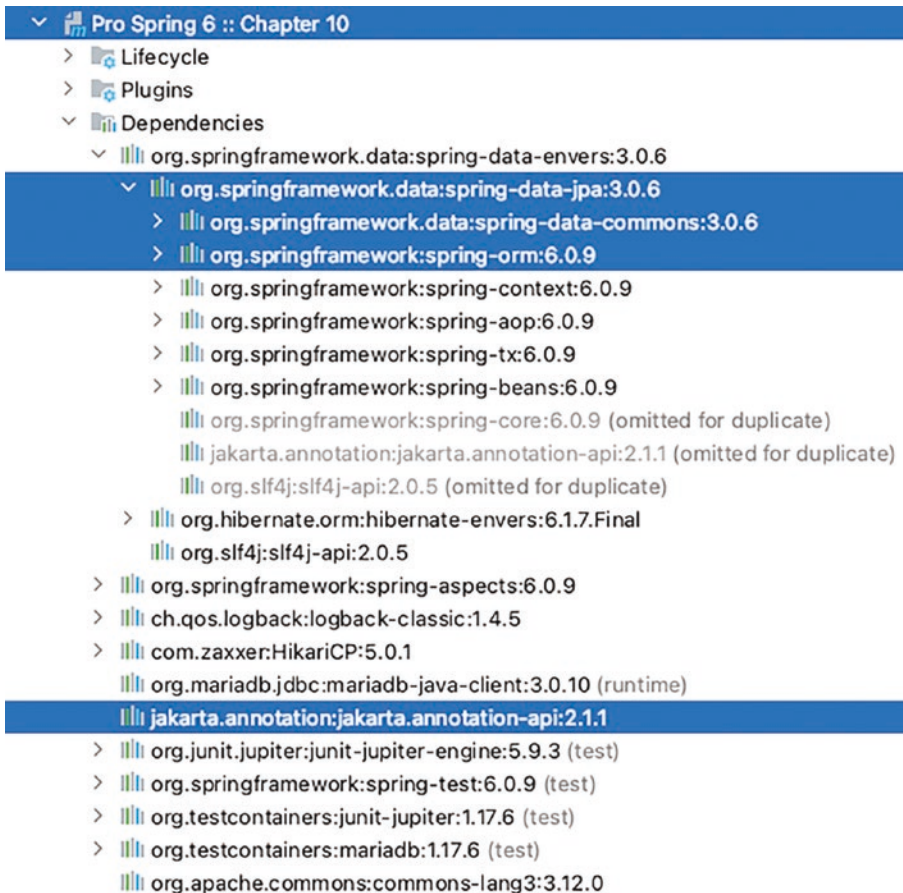


Figure 10-1. Gradle View showing dependencies for the `chapter10` project



## Using Spring Data JPA Repository Abstraction for Database Operations

In previous data access chapter, repository classes (classes used to interact with the database) were created explicitly by the developer, and build around Hibernate components (`Session`, `EntityManager`) or Spring (`JdbcTemplate`). They had to be explicitly configured as beans and injected wherever necessary. The same applies for adding transactional behavior; if a repository needed to be transactional, the developer had to explicitly add the `@Transactional` annotation on the methods communicating with the database.

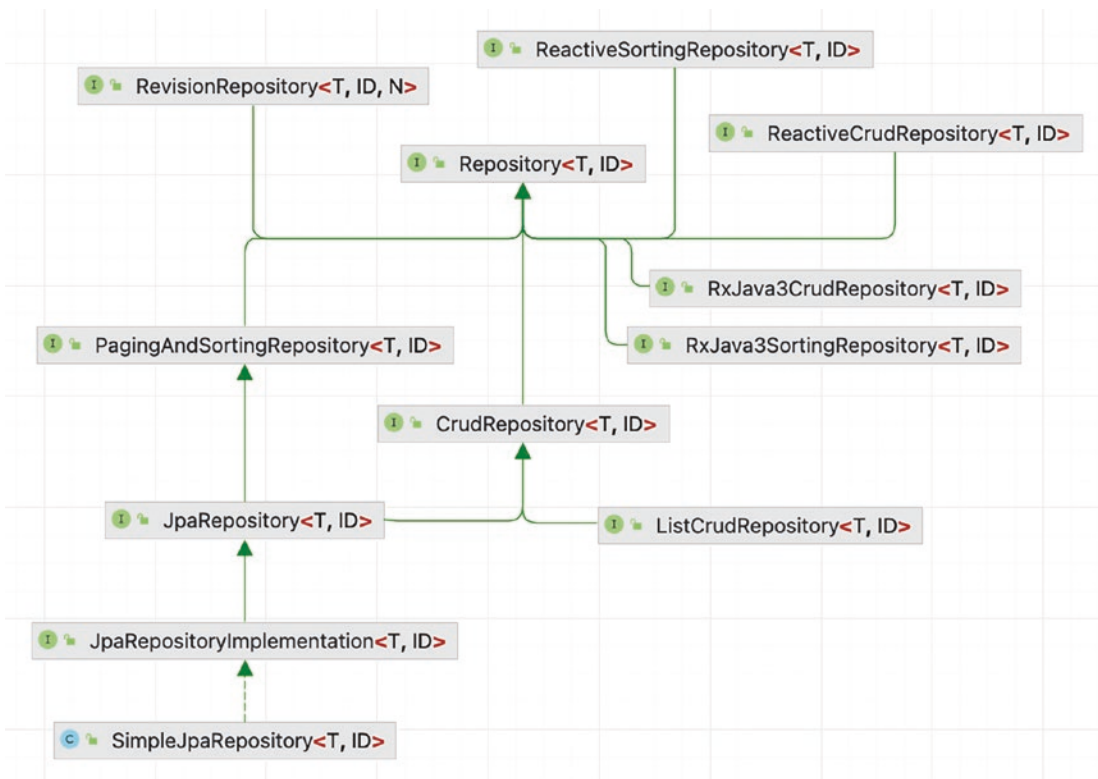
One of the main concepts of Spring Data and all its subprojects is the *Repository* abstraction, which belongs to the Spring Data Commons<sup>2</sup> project, one of the dependencies. In Spring Data JPA, the repository abstraction wraps the underlying JPA `EntityManager` and provides a simpler interface for JPA-based data access. What this means is that you do not have to write code using the `EntityManager` to access the data, unless you really have some custom query that Spring Data cannot generate for you based on your configurations.

The central interface within Spring Data is the `org.springframework.data.repository.Repository<T, ID>` interface, which is a marker interface (be sure not to mix it up with the `@Repository` stereotype annotation). Spring Data provides various extensions of the `Repository<T, ID>` interface; one of them is the `org.springframework.data.repository.CrudRepository<T, ID>` interface (which also belongs to the Spring Data Commons project), which we discuss in this section. Interfaces extending `Repository<T, ID>`, directly or by extending one of its subinterfaces, are called *domain repositories* because they replace the generic `T` with a concrete domain object type. These interfaces expose CRUD methods for managing domain objects.

Before explaining the `CrudRepository<T, ID>` interface and why it is important, take a look at Figure 10-2 that shows the Spring `Repository<T, ID>` interfaces hierarchy.

---

<sup>2</sup><https://github.com/spring-projects/spring-data-commons>



**Figure 10-2.** Spring Data Repository interfaces hierarchy

At this point you might be scratching your head and asking: *Hey, those are mostly interfaces, how are they supposed to do everything you mentioned previously?* Well, we are using Java 17 on this project, so technically, default methods might be an answer, but no. We are working with Spring, so the simplest answer is *proxying*. It will all become clear when you get to write some of your own repositories, but until then, let’s go back to the `CrudRepository<T, ID>` interface.

The `CrudRepository<T, ID>` interface<sup>3</sup> provides a number of commonly used methods when handling data. Listing 10-1 shows a code snippet representing the interface declaration, which is extracted from Spring Data Commons project source code.

**Listing 10-1.** The `CrudRepository<T, ID>` Source Code

```

package org.springframework.data.repository;

import java.util.Optional;

@NoRepositoryBean
public interface CrudRepository<T, ID> extends Repository<T, ID> {

```

<sup>3</sup><https://github.com/spring-projects/spring-data-commons/blob/main/src/main/java/org/springframework/data/repository/CrudRepository.java>

```

<S extends T> S save(S entity);
<S extends T> Iterable<S> saveAll(Iterable<S> entities);

Optional<T> findById(ID id);
boolean existsById(ID id);
Iterable<T> findAll();
Iterable<T> findAllById(Iterable<ID> ids);

long count();

void deleteById(ID id);
void delete(T entity);
void deleteAllById(Iterable<? extends ID> ids);
void deleteAll(Iterable<? extends T> entities);
void deleteAll();
}

```

Looking at this interface, you might recognize method signatures that we've previously added to our repository interfaces and then implemented in the repository classes. The `CrudRepository<T, ID>` interface declares a complete set of methods you might expect a repository class to offer for data access. The names are self-explanatory and—don't panic—you do not have to provide the implementation for them! To put your mind at ease, let's take a look at an example.



The entity classes used in this chapter are the same as those that have been used in **Chapters 6–9**. Please review any of the previous chapters or take a peek at the code for the previous chapters if you need a reminder. If you've read the other chapters, entity classes like `Singer` and `Album` should be familiar to you by now.

---

Listing 10-2 depicts a classic repository interface named `SingerRepository` that declares just a few finder methods.

**Listing 10-2.** Classic `SingerRepository` Interface

```

package com.apress.prospring6.ten;

import com.apress.prospring6.ten.entities.Singer;
import java.util.List;

public interface SingerRepository {
    List<Singer> findAll();
    List<Singer> findByFirstName(String firstName);
    List<Singer> findByFirstNameAndLastName(String firstName, String lastName);
}

```

This interface can now be revised to transform it into a Spring Data Domain Repository interface by modifying it to extend `CrudRepository<T, ID>` as shown in Listing 10-3.

**Listing 10-3.** Spring Data Domain Repository SingerRepository Interface

```

package com.apress.prospring5.ten;
// other import statements omitted
import org.springframework.data.repository.CrudRepository;

public interface SingerRepository extends CrudRepository<Singer, Long> {
    Iterable<Singer> findByFirstName(String firstName);
    Iterable<Singer> findByFirstNameAndLastName(String firstName, String lastName);
}

```

Notice that we just need to declare two methods in this interface, as the `findAll()` method is already provided by the `CrudRepository<T, ID>` interface. The `SingerRepository` interface extends the `CrudRepository<T, ID>` interface, passing in the entity class (`Singer`) and the ID type (`Long`). One fancy aspect of Spring Data's Repository abstraction is that when you use the common naming convention of `findBy{fieldName}`, such as `findByFirstName` and `findByFirstNameAndLastName` do, you don't need to provide Spring Data JPA with the named query. Instead, at runtime, Spring Data JPA will "infer" and construct the query for you based on the method name and entity class replacing the generic type. For example, for the `findByFirstName()` method, Spring Data JPA will automatically prepare the query `select s from Singer s where s.firstName = :firstName` for you and set the named parameter `firstName` from the argument.

Now that we have declared our interface, we must create the configuration that will tell Spring Data where to find this interface. This is done by annotating the configuration class with `@EnableJpaRepositories`, as shown in Listing 10-4.

**Listing 10-4.** Spring Data JPA Configuration

```

package com.apress.prospring6.ten.config;
// other import statements omitted
import org.springframework.transaction.annotation.EnableTransactionManagement;
import org.springframework.data.jpa.repository.config.EnableJpaRepositories;

@Import(BasicDataSourceCfg.class)
@Configuration
@EnableTransactionManagement
@ComponentScan(basePackages = {"com.apress.prospring6.ten"})
@EnableJpaRepositories("com.apress.prospring6.ten.repos")
public class DataJpaCfg {

    @Bean
    public PlatformTransactionManager transactionManager() {
        // code omitted
        return transactionManager;
    }

    @Bean
    public LocalContainerEntityManagerFactoryBean entityManagerFactory() {
        // code omitted
        factory.setPackagesToScan("com.apress.prospring6.ten.entities");
        return factory;
    }

    // rest of configuration omitted
}

```

The full configuration of this class and the `BasicDataSourceCfg` class have been covered repeatedly over the previous data access chapters (from **Chapter 6** until now), and really, the only requirement to tell Spring where the repository interfaces are is `@EnableJpaRepositories("com.apress.prospring6.ten.repos")`. The `@EnableJpaRepositories` annotation is quite powerful, allowing you to specify multiple locations, in various ways, by declaring configuration attributes pretty similar to those provided by `@ComponentScan`. The default attribute is `basePackages`, by the way. Aside from that, the `namedQueriesLocation` attribute is used to specify the location of a properties file containing named queries, the `entityManagerFactoryRef` attribute is used to specify the name of the `EntityManager` bean to use for creating queries, the `transactionManagerRef` attribute is used to specify the name of the `TransactionManager` bean to create the repository instances, and many other useful attributes (feel free to check the official documentation for).

So, how does this work? Recall from **Chapter 5** that there are two types of proxies: JDK proxies, which implement the same interface as the target object, and class-based proxies, which extend the target object class. Spring Data JPA requires the repositories to be declared as interfaces extending `Repository<T, ID>` or one of its subinterfaces. By adding the `@EnableJpaRepositories("com.apress.prospring6.ten.repos")` configuration, we tell Spring to look in this package for these type of interfaces. For each of them, the Spring Data infrastructure components register the persistence technology-specific `FactoryBean` to create the appropriate proxies that handle invocations of the query methods.

So now that we have a Spring Data domain repository interface and a configuration telling Spring where it is, the next step is to create a transactional service to use our repository. The `SingerServiceImpl` class shown in [Listing 10-5](#) just calls the `SingerRepository` instance methods.

**Listing 10-5.** `SingerServiceImpl` Class That Uses a Spring Data Repository Instance

```
package com.apress.prospring6.ten.service;

import java.util.stream.Stream;
import java.util.stream.StreamSupport;
// other import statements omitted

@Service
@Transactional
public class SingerServiceImpl implements SingerService {

    private final SingerRepository singerRepository;

    public SingerServiceImpl(SingerRepository singerRepository) {
        this.singerRepository = singerRepository;
    }

    @Override
    @Transactional(readOnly=true)
    public Stream<Singer> findAll() {
        return StreamSupport.stream(singerRepository.findAll().spliterator(), false);
    }

    @Override
    @Transactional(readOnly=true)
    public Stream<Singer> findByFirstName(String firstName) {
        return StreamSupport.stream(singerRepository.findByFirstName(firstName).
            spliterator(), false);
    }
}
```

```

@Override
@Transactional(readOnly=true)
public Stream<Singer> findByFirstNameAndLastName(String firstName, String lastName) {
    return StreamSupport.stream(singerRepository.findByFirstNameAndLastName(firstName,
        lastName).spliterator(), false);
}
}

```

You can see that instead of `EntityManager`, we need to inject the `singerRepository` instance into the service bean. This is generated by Spring based on the `SingerRepository` interface. All the low-level work is done for us because of Spring Data JPA. In Listing 10-6, you can see a testing class, and by now you should already be familiar with its content.

**Listing 10-6.** `SingerServiceTest` Test Class

```

package com.apress.prospring6.ten;
// import statements omitted

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {SingerServiceTest.TestContainersConfig.class})
public class SingerServiceTest extends TestContainersBase {
    private static final Logger LOGGER = LoggerFactory.getLogger(SingerServiceTest.class);

    @Autowired
    SingerService singerService;

    @Autowired
    ApplicationContext ctx;

    @Test
    public void testFindAll(){
        var singers = singerService.findAll().peek(s -> LOGGER.info(s.toString())).toList();
        assertEquals(3, singers.size());
    }

    @Test
    public void testFindByFirstName(){
        var singers = singerService.findByFirstName("John").peek(s -> LOGGER.info(s.
            toString())).toList();
        assertEquals(2, singers.size());
    }

    @Test
    public void testFindByFirstNameAndLastName(){
        var singers = singerService.findByFirstNameAndLastName("John", "Mayer").peek(s ->
            LOGGER.info(s.toString())).toList();
        assertEquals(1, singers.size());
    }
}

```

```

@Configuration
@Import(DataJpaCfg.class)
public static class TestContainersConfig {
    @Autowired
    Properties jpaProperties;

    @PostConstruct
    public void initialize() {
        jpaProperties.put(Environment.FORMAT_SQL, true);
        jpaProperties.put(Environment.USE_SQL_COMMENTS, true);
        jpaProperties.put(Environment.SHOW_SQL, true);
        jpaProperties.put(Environment.STATEMENT_BATCH_SIZE, 30);
    }
}
}

```

The test class is nothing special, and the Testcontainers MariaDB container configuration was isolated to the TestContainersBase class, to avoid repeating it here. When running this test class, all methods should pass, but as usual, let's crank up the log levels to TRACE for all Spring libraries and check out the execution log, which gives us a lot of information about what Spring is doing. Take a look at the log snippets in Listing 10-7.

**Listing 10-7.** SingerServiceTest Execution Log Snippets

```

DEBUG: RepositoryConfigurationDelegate - Scanning for JPA repositories in packages com.
apress.prospring6.ten.repos. <1>
TRACE: ClassPathScanningCandidateComponentProvider - Scanning file [../com/apress/
prospring6/ten/repos/SingerRepository.class]
DEBUG: ClassPathScanningCandidateComponentProvider - Identified candidate component class:
file [../com/apress/prospring6/ten/repos/SingerRepository.class]
TRACE: RepositoryConfigurationDelegate - Spring Data JPA - Registering repository:
singerRepository <1>
- Interface: com.apress.prospring6.ten.repos.SingerRepository <1>
- Factory: org.springframework.data.jpa.repository.support.JpaRepositoryFactoryBean <1>
INFO : RepositoryConfigurationDelegate - Finished Spring Data repository scanning in 37 ms.
Found 1 JPA repository interfaces.
...
DEBUG: RepositoryFactorySupport - Initializing repository instance for com.apress.
prospring6.ten.repos.SingerRepository...
...
DEBUG: RepositoryFactorySupport - Finished creation of repository instance for com.apress.
prospring6.ten.repos.SingerRepository.
...
TRACE: TransactionAspectSupport - Getting transaction for
[com.apress.prospring6.ten.service.SingerServiceImpl.findAll] <2>
TRACE: AbstractFallbackTransactionAttributeSource - Adding transactional method
'org.springframework.data.jpa.repository.support.SimpleJpaRepository.findAll'
with attribute: PROPAGATION_REQUIRED,ISOLATION_DEFAULT,readonly <3>
TRACE: TransactionAspectSupport - Getting transaction for
[org.springframework.data.jpa.repository.support.SimpleJpaRepository.findAll]

```

The configured package com.apress.prospring6.ten.repos and its subpackages are scanned, and the SingerRepository interface is identified as a candidate for creating a repository instance (lines marked with <1>).

The peculiar thing about this log is that it seems as if a transaction is created for the repository instance method being called (line marked with <2>). So, what is happening there? Well, the class backing up the proxy is `org.springframework.data.jpa.repository.support.SimpleJpaRepository<T, ID>` and if you check out the Spring code<sup>4</sup>, you will notice that this class is annotated with `@Transactional(readOnly = true)`. This is where your transactions for the repository methods come from. They are needed because any JPA operation should be done in a transactional context; that way, in case of errors, a rollback will ensure the database is left in a good state. This obviously means that for service methods that just call a single repository method, an extra transaction is not needed. Even if configured, since the default propagation mode is `PROPAGATION_REQUIRED`, (line marked with <3>) the service method will be executed within the same transaction as the repository method.

Before talking about more complex queries and how calling them is supported, let’s talk about the `JpaRepository<T, ID>` interface.

## Using JpaRepository

The `JpaRepository<T, ID>` interface is an even more advanced Spring interface than `CrudRepository<T, ID>` that can make creating custom repositories easier. The `JpaRepository<T, ID>` interface provides batch, paging, and sorting operations. Figure 10-3 shows the relationship between `JpaRepository<T, ID>` and the `CrudRepository<T, ID>` interface.

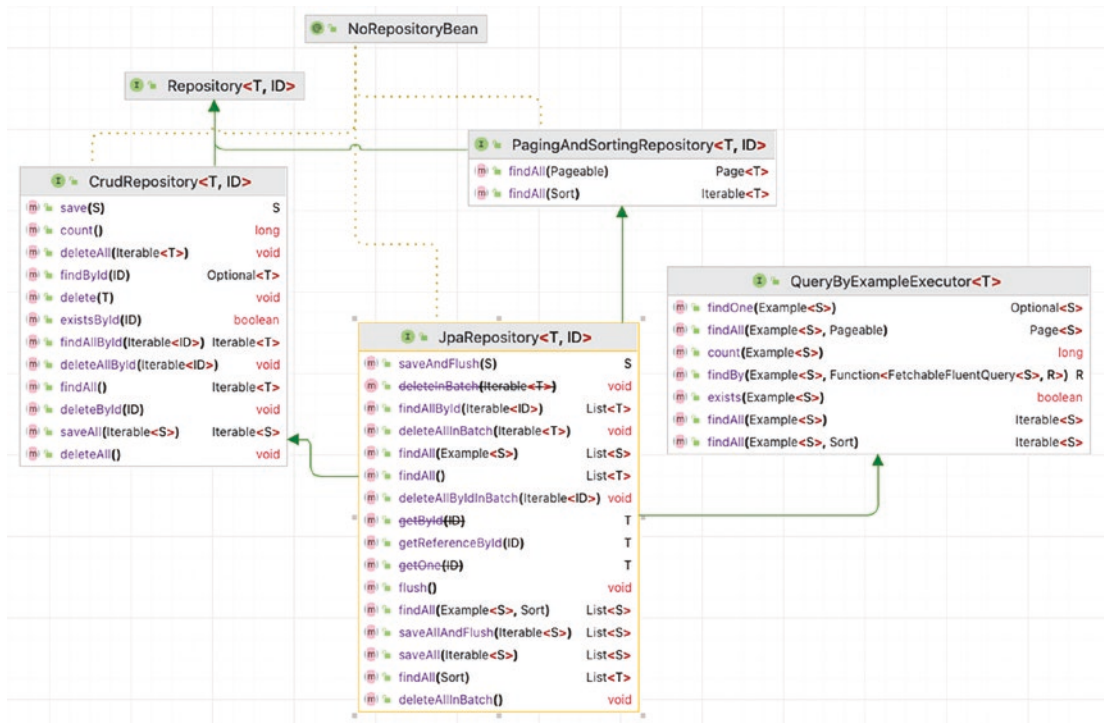


Figure 10-3. Spring Data `JpaRepository<T, ID>` hierarchy

<sup>4</sup><https://github.com/spring-projects/spring-data-jpa/blob/main/spring-data-jpa/src/main/java/org/springframework/data/jpa/repository/support/SimpleJpaRepository.java>



Depending on the complexity of the application, you can choose to use `CrudRepository<T, ID>` or `JpaRepository<T, ID>`. As you can see from Figure 10-3, `JpaRepository<T, ID>` extends `CrudRepository<T, ID>` and thus provides all the same functionalities.

## Spring Data JPA with Custom Queries

In complex applications, you might need custom queries that cannot be “inferred” by Spring.

In previous chapters, using named queries declared using the `@NamedQuery` annotation, we showed a way to provide support for query execution, whether with a `Hibernate Session` or `EntityManager`. Named queries are supported with Spring Data repositories, too. Spring Data tries to resolve a call to a method declared by the developer to a named query starting with the simple name of the configured domain class, followed by the method name separated by a dot. This way of naming queries was used when working with a `Hibernate Session` or `EntityManager` too, just to make the transition practical. Named queries with Spring Data do have some limitations, however; for example, named parameters are not supported. To show an example, consider a named query to select albums with a release date greater than 2010-01-01. Listing 10-8 presents the important code bits showing the named query.

**Listing 10-8.** Album Entity with a Named Query

```
package com.apress.prospring6.ten.entities;
import jakarta.persistence.NamedQuery;
// other import statements omitted

@Entity
@Table(name = "ALBUM")
@NamedQuery(name=Album.FIND_WITH_RELEASE_DATE_GREATER_THAN, query="select a from Album a
where a.releaseDate > ?1")
public class Album extends AbstractEntity {
    @Serial
    private static final long serialVersionUID = 3L;

    public static final String FIND_WITH_RELEASE_DATE_GREATER_THAN = "Album.
findWithReleaseDateGreaterThan";

    @Column
    private String title;
    @Column(name = "RELEASE_DATE")
    private LocalDate releaseDate;

    @ManyToOne
    @JoinColumn(name = "SINGER_ID")
    private Singer singer;

    // rest of the code omitted
}
```

For cases requiring named parameters, the query must be defined explicitly using the `@Query` annotation. We'll use this annotation to search for all music albums containing The in their title. Listing 10-9 depicts the `AlbumRepository` interface.

**Listing 10-9.** AlbumRepository with Named Queries and @Query Methods

```

package com.apress.prospring6.ten.repos;

import org.springframework.data.jpa.repository.Query;
import org.springframework.data.repository.query.Param;
// other import statements omitted

public interface AlbumRepository extends JpaRepository<Album, Long> {

    Iterable<Album> findBySinger(Singer singer);

    Iterable<Album> findWithReleaseDateGreaterThan(LocalDate rd);

    @Query("select a from Album a where a.title like %:title%")
    Iterable<Album> findByTitle(@Param("title") String t);
}

```

Spring Data matches the `findWithReleaseDateGreaterThan(..)` method to the query named `Album.findWithReleaseDateGreaterThan`. The query for the `findByTitle(..)` method has a named parameter called `title`. When the name of the named parameter is the same as the name of the argument in the method annotated with `@Query`, the `@Param` annotation is not needed. If the method argument has a different name, the `@Param` annotation is needed to tell Spring that the value of this argument is to be injected in the named parameter in the query.

The `AlbumServiceImpl` service class is quite simple and only uses the `albumRepository` bean to call its methods. It is depicted in Listing 10-10.

**Listing 10-10.** AlbumServiceImpl Service Calling AlbumRepository Methods

```

package com.apress.prospring6.ten.service;
// other import statements omitted
import java.util.stream.Stream;
import java.util.stream.StreamSupport;

@Service
@Transactional(readOnly = true)
public class AlbumServiceImpl implements AlbumService {

    private final AlbumRepository albumRepository;

    public AlbumServiceImpl(AlbumRepository albumRepository) {
        this.albumRepository = albumRepository;
    }

    @Override
    public Stream<Album> findBySinger(Singer singer) {
        return StreamSupport.stream(albumRepository.findBySinger(singer).
            spliterator(), false);
    }

    @Override
    public Stream<Album> findWithReleaseDateGreaterThan(LocalDate rd) {

```

```

        return StreamSupport.stream(albumRepository.findWithReleaseDateGreaterThan(rd).
            spliterator(), false);
    }

    @Override
    public Stream<Album> findByTitle(String title) {
        return StreamSupport.stream(albumRepository.findByTitle(title).
            spliterator(), false);
    }
}

```

The `findBySinger(..)` query is an easy one, and Spring Data is able to resolve this one on its own. For this reason, the test class won't cover this one. Feel free to write the test for this one yourself. Listing 10-11 shows the test class for the two slightly complex queries.

**Listing 10-11.** AlbumServiceTest Class

```

package com.apress.prospring6.ten;
// import statements omitted

@Testcontainers
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {AlbumServiceTest.TestContainersConfig.class})
public class AlbumServiceTest extends TestContainersBase {
    private static final Logger LOGGER = LoggerFactory.getLogger(AlbumServiceTest.class);

    @Autowired
    AlbumService albumService;

    @Test
    public void testFindWithReleaseDateGreaterThan(){
        var albums = albumService
            .findWithReleaseDateGreaterThan(LocalDate.of(2010, 1, 1))
            .peek(s -> LOGGER.info(s.toString())).toList();
        assertEquals(2, albums.size());
    }

    @Test
    public void testFindByTitle(){
        var albums = albumService
            .findByTitle("The")
            .peek(s -> LOGGER.info(s.toString())).toList();
        assertEquals(1, albums.size());
    }

    // test config class omitted
}

```

Spring Data repositories are quite powerful and versatile. Methods annotated with `@Query` also support sorting, by adding an `org.springframework.data.domain.Sort` parameter. Queries declared with the `@Query` annotations even support SpEL expressions.

The examples in this section only show queries that read data. Queries that modify data also need to be annotated with `@Modified`. Just as an example, the `SingerRepository` is modified to add a query that changes the first name of a singer record based on its id. The method declaration is depicted in Listing 10-12.

**Listing 10-12.** `@Modifying` Annotated Spring Data Query Method

```

Package com.apress.prospring6.ten.repos;
// other import statements omitted
import org.springframework.data.jpa.repository.Modifying;

public interface SingerRepository extends CrudRepository<Singer, Long> {
    // other method declarations omitted

    @Modifying(clearAutomatically = true)
    @Query("update Singer s set s.firstName = ?1 where s.id = ?2")
    int setFirstNameFor(String firstName, Long id);
}

```

The `@Modifying` annotation is designed to be used only together with the `@Query` annotation, and it makes no sense without it. If used on its own, it is just ignored by Spring Data.

The `@Modifying` annotation supports two attributes:

- `flushAutomatically`: When set to `true` (the default is `false`), it causes the underlying persistence context to be flushed *before* executing the modifying query.
- `clearAutomatically`: When set to `true` (the default is `false`), it causes the underlying persistence context to be flushed *after* executing the modifying query. This means the changed entities are persisted to the database, immediately after the execution of this method.

The reason why the `setFirstNameFor(..)` method was annotated with `@Modifying(clearAutomatically = true)` is that in the service method, this method is invoked to perform an update, then the entity to be returned is retrieved from the database using the `findById(id)` repository method. Since changes get flushed at the end of a transaction, and we have no control over when that might be, the returned entity might not be the updated one.

To make things interesting, the service method calling `setFirstNameFor(..)` returns the updated instance, which we can test. The service method is shown in Listing 10-13.

**Listing 10-13.** Service Method Calling `@Modified` Annotated Spring Data Query Method

```

package com.apress.prospring6.ten.service;
// import statements omitted

@Service
@Transactional
public class SingerServiceImpl implements SingerService {

    private final SingerRepository singerRepository;

    public SingerServiceImpl(SingerRepository singerRepository) {
        this.singerRepository = singerRepository;
    }
}

```

```

// other methods omitted

@Transactional(propagation = Propagation.REQUIRES_NEW, label = "modifying")
@Override
public Singer updateFirstName(String firstName, Long id) {
    singerRepository.findById(id).ifPresent(s ->
        singerRepository.setFirstNameFor(firstName, id));
    return singerRepository.findById(id).orElse(null);
}
}

```

The test method is depicted in Listing 10-14.

**Listing 10-14.** Test Method for the Service Method Calling @Modified Annotated Spring Data Query Method

```

package com.apress.prospring6.ten;
// other import statements omitted
import org.springframework.test.annotation.Rollback;

@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringJUnitConfig(classes = {SingerServiceTest.TestContainersConfig.class})
public class SingerServiceTest extends TestContainersBase {

    @Rollback
    @Test
    @SqlGroup({
        @Sql(scripts = {"classpath:testcontainers/add-nina.sql"},
            executionPhase = Sql.ExecutionPhase.BEFORE_TEST_METHOD),
    })
    @DisplayName("should update a singer's name")
    public void testUpdateFirstNameByQuery(){
        var nina = singerService.updateFirstName("Eunice Kathleen", 5L);
        assertAll( "nina was not updated" ,
            () -> assertNotNull(nina),
            () -> assertEquals("Eunice Kathleen", nina.getFirstName())
        );
    }
}

```



Notice that instead of cleaning up the context by using a @Sql annotation and a delete script, the @Rollback annotation introduced in **Chapter 9** is used.

---

The `@Modifying` annotation works in the same way for conditional delete queries as well. There are more database operations that can be made simple with Spring Data JPA repositories. However, covering all of them is beyond the scope of this book. Feel free to research on your own in the official documentation<sup>5</sup>.

## Projection Queries

**Chapters 7 and 8** already introduced the topic of projection queries, so this section shows only how to configure a projection query using Spring Data JPA.

To limit the result of a query to only a few fields, an interface is needed that exposes accessor methods for the properties to be read. Spring supports quite a few interesting ways to declare projection interfaces, but for simplicity, in this example we'll just show an interface that exposes the first name and last name of a singer. Since interfaces support default methods starting with Java 8, we'll add a default method to concatenate the first and last names and expose them as the full name. The repository method and the interface are both shown in Listing 10-15.

**Listing 10-15.** Projection Interface and Repository Method

```
package com.apress.prospring6.ten.service;
// import statements omitted

public interface SingerService {

    // other methods omitted

    Stream<FullName> findByLastName(String lastName);

    interface FullName {

        String getFirstName();
        String getLastName();

        default String getFullName() {
            return getFirstName().concat(" ").concat(getLastName());
        }
    }
}
```

The service method does nothing other than call the `findByLastName(..)` method, and the test method just prints the results and tests the assumption that a single result is returned. Both are provided in the book repository, but they won't be listed here.

The only thing interesting to see is the actual type of the objects being returned by the repository method. Since the database results are modeled using the `FullName` interface, there must be an implementation generated by Spring, right? Well, not in the actual sense. A proxy is created, yet again, and that proxy implements the `FullName` interface, so the method calls are forwarded to the Spring Data infrastructure components responsible for storing and returning the actual values. This can be easily seen by setting a breakpoint in the test method and inspecting the contents of the returned collection using IntelliJ IDEA's evaluate expression at runtime feature. Just right-click the source code while the execution is paused,

<sup>5</sup><https://docs.spring.io/spring-data/data-jpa/docs/current/reference/html>

choose **Evaluate Expression** in the context menu, and insert `singers.get(0)`. Notice the type of the object and, if you expand it, you will see the target objects and the interfaces implemented. It should look pretty similar to what is shown in Figure 10-4 (but note there's a small chance that some types might be renamed, moved, etc., by the time of the final Spring Data JPA).

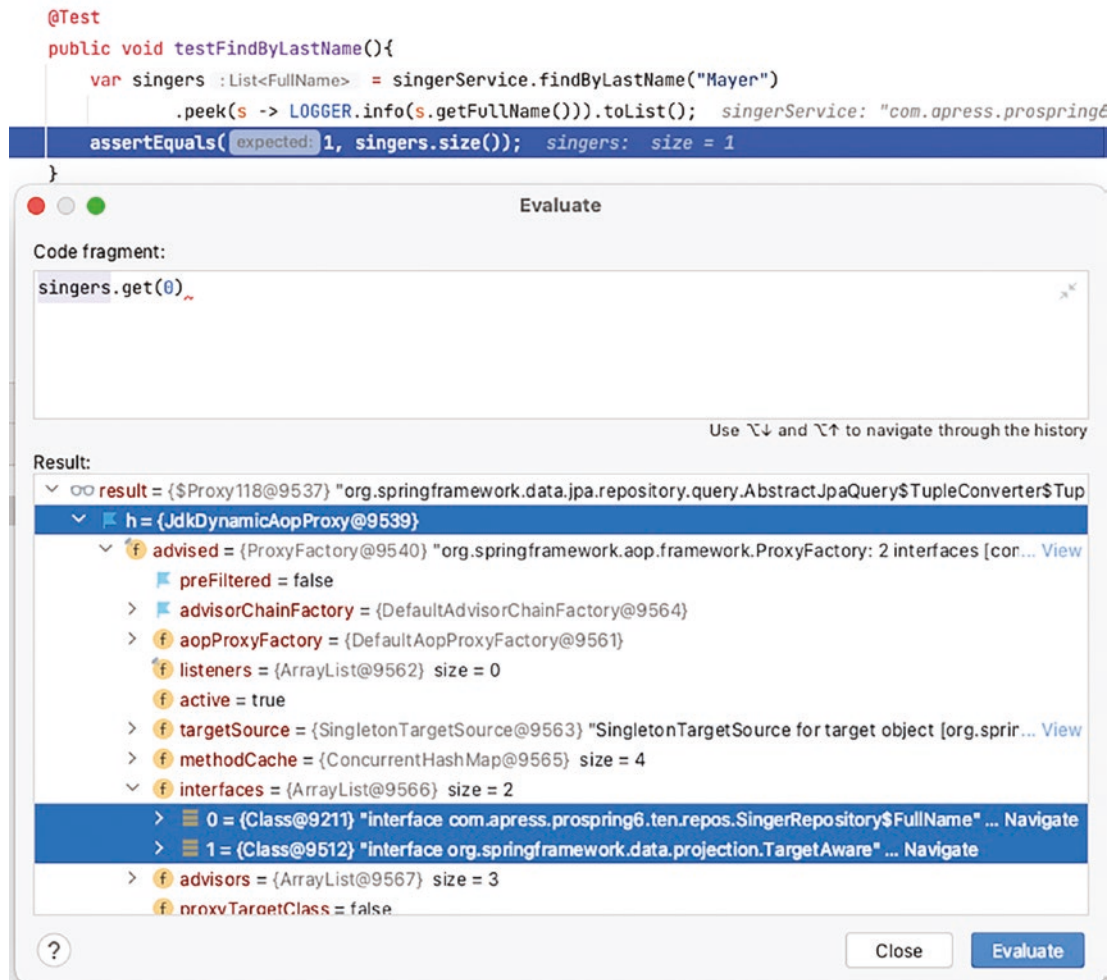


Figure 10-4. Inspecting Spring Data instances

## Keeping Track of Changes on the Entity Class

In most applications, we need to keep track of basic audit activities for the business data being maintained by users. The audit information typically includes the user who created the data, the date it was created, the date it was last modified, and the user who last modified it.

The Spring Data JPA project provides this function in the form of a JPA entity listener, which helps you to keep track of the audit information automatically. To use the feature, until Spring 4, the entity class needed to implement the `Auditable<U, ID, T extends TemporalAccessor> extends Persistable<ID>` interface

(belonging to Spring Data Commons)<sup>6</sup> or extend any class that implements this interface. Listing 10-16 shows the Auditable interface that was extracted from Spring Data’s reference documentation.

**Listing 10-16.** The Auditable<U, ID extends Serializable, T extends TemporalAccessor> Interface

```
package org.springframework.data.domain;

import java.time.temporal.TemporalAccessor;
import java.util.Optional;

public interface Auditable<U, ID, T extends TemporalAccessor>
    extends Persistable<ID> {

    Optional<U> getCreatedBy();
    void setCreatedBy(U createdBy);
    Optional<T> getCreatedDate();
    void setCreatedDate(T creationDate);
    Optional<U> getLastModifiedBy();
    void setLastModifiedBy(U lastModifiedBy);
    Optional<T> getLastModifiedDate();
    void setLastModifiedDate(T lastModifiedDate);
}
```

As you can see from the definition of the Auditable<U, ID, T extends TemporalAccessor> interface, the date types columns are restricted to types extending java.time.temporal.TemporalAccessor. Starting with Spring 5, implementing Auditable<U, ID, T extends TemporalAccessor> is no longer necessary because everything can be replaced by annotations.

To show how auditing works, let’s create a new table called SINGER\_AUDIT in the database schema, which is based on the SINGER table, with four audit-related columns added. The columns record when the entity was created and by who and the last user that edited the entity and when. Listing 10-17 shows the table creation script (AuditSchema.sql).

**Listing 10-17.** The SINGER\_AUDIT Table DDL

```
CREATE TABLE SINGER_AUDIT (
    ID INT NOT NULL AUTO_INCREMENT
    , FIRST_NAME VARCHAR(60) NOT NULL
    , LAST_NAME VARCHAR(40) NOT NULL
    , BIRTH_DATE DATE
    , VERSION INT NOT NULL DEFAULT 0
    , CREATED_BY VARCHAR(20) -- *
    , CREATED_DATE TIMESTAMP -- *
    , LAST_MODIFIED_BY VARCHAR(20) -- *
    , LAST_MODIFIED_DATE TIMESTAMP -- *
    , UNIQUE UQ_SINGER_AUDIT_1 (FIRST_NAME, LAST_NAME)
    , PRIMARY KEY (ID)
);
```

<sup>6</sup><https://github.com/spring-projects/spring-data-commons/blob/main/src/main/java/org/springframework/data/domain/Auditable.java>



The four marked columns indicate the audit-related columns. The `@CreatedBy`, `@CreatedDate`, `@LastModifiedBy`, and `@LastModifiedDate` annotations are part of the `org.springframework.data` annotation package. Using these annotations, the type restriction for the date columns no longer applies. To keep things neatly organized, an `@MappedSuperclass` named `AuditableEntity<U>` is added to the project to group the audit fields together. This class is shown in Listing 10-18.

**Listing 10-18.** The `AuditableEntity` Abstract Class

```
package com.apress.prospring6.ten.entities;
// other import statements omitted
import org.springframework.data.jpa.domain.support.AuditingEntityListener;
import jakarta.persistence.EntityListeners;
import org.springframework.data.annotation;

@MappedSuperclass
@EntityListeners(AuditingEntityListener.class)
public abstract class AuditableEntity<U> implements Serializable {
    @CreatedDate
    @Column(name = "CREATED_DATE")
    protected LocalDateTime createdDate;

    @CreatedBy
    @Column(name = "CREATED_BY")
    protected String createdBy;

    @LastModifiedBy
    @Column(name = "LAST_MODIFIED_BY")
    protected String lastModifiedBy;

    @LastModifiedDate
    @Column(name = "LAST_MODIFIED_DATE")
    protected LocalDateTime lastModifiedDate;

    // getters and setters omitted
}
```

The `@Column` annotations are applied on the auditing fields to map to the actual column in the table. The `@EntityListeners(AuditingEntityListener.class)` annotation registers `AuditingEntityListener` to be used for all entities extending this class in the persistent context.



The `@EntityListeners(AuditingEntityListener.class)` annotation replaces the need to declare an `orm.xml` configuration file, as indicated in the JPA specification:

```
<?xml version="1.0" encoding="UTF-8" ?>
<entity-mappings xmlns="http://java.sun.com/xml/ns/persistence/orm"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://java.sun.com/xml/ns/persistence/orm
    http://java.sun.com/xml/ns/persistence/orm_2_0.xsd"
```

```

version="2.0">
<description>JPA</description>
<persistence-unit-metadata>
  <persistence-unit-defaults>
    <entity-listeners>
      <entity-listener class="org.springframework.data.jpa.domain.support.Auditin
gEntityListener" />
    </entity-listeners>
  </persistence-unit-defaults>
</persistence-unit-metadata>
</entity-mappings>

```

---

Any class that needs auditing in our application should be declared to extend the `AuditableEntity<U>` class. So to map the `SINGER_AUDIT` table, the `SingerAudit` class depicted in Listing 10-19 needs to be written.

**Listing 10-19.** The `SingerAudit` Entity Class

```

package com.apress.prospring6.ten.entities;
// import statements omitted

@Entity
@Table(name = "SINGER_AUDIT")
public class SingerAudit extends AuditableEntity<SingerAudit> {
    @Serial
    private static final long serialVersionUID = 5L;

    @Id
    @GeneratedValue(strategy = IDENTITY)
    @Column(name = "ID")
    private Long id;

    @Version
    @Column(name = "VERSION")
    private int version;

    @Column(name = "FIRST_NAME")
    private String firstName;

    @Column(name = "LAST_NAME")
    private String lastName;

    @Column(name = "BIRTH_DATE")
    private LocalDate birthDate;

    // getters and setters omitted
}

```

To manage audited entities of type `SingerAudit`, a repository interface and a service class should be used. The `SingerAuditRepository` interface just extends `CrudRepository<SingerAudit, Long>`, which already declares all the methods that we are going to use for `SingerAuditService`. The `SingerAuditService` interface is shown in Listing 10-20.

**Listing 10-20.** The SingerAuditService Interface

```
package com.apress.prospring6.ten.service;
// import statements omitted

public interface SingerAuditService {
    Stream<SingerAudit> findAll();
    SingerAudit findById(Long id);
    SingerAudit save(SingerAudit singer);
}
```

The `SingerAuditServiceImpl` class that implements `SingerAuditService` does nothing more than call the `SingerAuditRepository` methods in a transactional context. Both are so simple they require no attention at this point. However, to tell Spring to take care of the automatic update of the audit fields, a little more configuration is needed: a configuration class must be annotated with `EnableJpaAuditing` and a bean that implements `AuditorAware<T>` must be configured, as shown in Listing 10-21.

**Listing 10-21.** The Spring Configuration Class for Enabling Automatic Auditing Support

```
package com.apress.prospring6.ten.config;

import org.apache.commons.lang3.RandomStringUtils;
import org.springframework.data.domain.AuditorAware;
import org.springframework.data.jpa.repository.config.EnableJpaAuditing;
// some import statements omitted

@EnableJpaAuditing
@Configuration
public class AuditCfg {

    @Bean
    public AuditorAware<String> auditorProvider() {
        return () -> Optional.of("prospring6-"
            + RandomStringUtils.random(6, true, true));
    }
}
```

This is a very simple configuration. Here's the thing: in production-level applications, to populate the `@CreatedBy` and `@LastModifiedBy` annotated fields, the value is provided by a bean that interacts with Spring Security. In real situations, this should be an instance containing user information, such as a `User` class that represents the logged-in user who is performing the data update action retrieved from the `SecurityContextHolder`. However, since that topic is quite advanced and is covered toward the end of the book (**Chapter 17**), a bean of type implementing `AuditorAware<String>` interface using a simplified lambda statement. The lambda statement in Listing 10-21 can be expanded to the following:

```
new AuditorAware<String>() {
    @Override
    public Optional<String> getCurrentAuditor() {
        {
            return Optional.of("prospring6");
        }
    }
};
```

In this anonymous implementation of `AuditorAware<String>`, the method `getCurrentAuditor()` is implemented. The value returned is `prospring6` concatenated with a randomly generated six-character text. This will help generate different user values, so we can test that the `@CreatedBy` and `@LastModifiedBy` annotated fields values were set.

Now that the configuration and the implementation is in place, the next step is to test our auditing support. Just to keep things limited to their own context, we added the `AuditServiceTest` class, which executes the three service methods in the `SingerAuditServiceImpl` class and checks the assumptions made about their effects. The test class and methods are shown in Listing 10-22.

**Listing 10-22.** The Class Used to Test the `SingerAuditServiceImpl` Class

```
package com.apress.prospring6.ten;
// import statements omitted

@Testcontainers
@Sql({ "classpath:testcontainers/audit/drop-schema.sql", "classpath:testcontainers/audit/
create-schema.sql" })
@SpringJUnitConfig(classes = {AuditServiceTest.TestContainersConfig.class})
public class AuditServiceTest extends TestContainersBase {

    private static final Logger LOGGER = LoggerFactory.getLogger(AuditServiceTest.class);

    @Autowired
    SingerAuditService auditService;

    @BeforeEach
    void setUp(){
        var singer = new SingerAudit();
        singer.setFirstName("BB");
        singer.setLastName("King");
        singer.setBirthDate(LocalDate.of(1940, 8, 16));
        auditService.save(singer);
    }

    @Test
    void testFindById() {
        var singer = auditService.findAll().findFirst().orElse(null);

        assertAll( "auditFindByIdTest" ,
            () -> assertNotNull(singer),
            () -> assertTrue(singer.getCreatedBy().isPresent()),
            () -> assertTrue(singer.getLastModifiedBy().isPresent()),
            () -> assertNotNull(singer.getCreatedDate()),
            () -> assertNotNull(singer.getLastModifiedDate())
        );
        LOGGER.info(">> created record: {} ", singer);
    }

    @Test
    void testUpdate() {
        var singer = auditService.findAll().findFirst().orElse(null);
        assertNotNull(singer);
    }
}
```

```

singer.setFirstName("Riley B.");
var updated = auditService.save(singer);

assertAll( "auditUpdateTest" ,
    () -> assertEquals("Riley B.", updated.getFirstName()),
    () -> assertTrue(updated.getLastModifiedBy().isPresent()),
    () -> assertNotEquals(updated.getCreatedBy().orElse(null), updated.
        getLastModifiedBy().orElse(null))
);
LOGGER.info(">> updated record: {} ", updated);
}

@Configuration
@Import({DataJpaCfg.class, AuditCfg.class})
public static class TestContainersConfig {
    @Autowired
    Properties jpaProperties;

    @PostConstruct
    public void initialize() {
        jpaProperties.put(Environment.FORMAT_SQL, true);
        jpaProperties.put(Environment.USE_SQL_COMMENTS, true);
        jpaProperties.put(Environment.SHOW_SQL, true);
        jpaProperties.put(Environment.STATEMENT_BATCH_SIZE, 30);
    }
}
}

```

The test methods should pass, and check that the values for the audit fields are populated.



These test methods reveal something important: `java.time.LocalDate` is not a good type for the fields annotated with `@CreateDate` and `@LastModifiedDate` for records designed to be edited more than once a day. For our examples, we used `java.time.LocalDateTime` to make it really obvious the records were changed.

---

JPA auditing support requires an additional library to be added to the classpath. Spring Data needs `spring-aspects` to create special proxies that intercept entity updates and add their own changes before the entities get persisted.

## Keeping Entity Versions by Using Hibernate Envers

In an enterprise application, for business-critical data, it is always a requirement to keep a few versions of each entity. For example, in a customer relationship management (CRM) system, each time a customer record is inserted, updated, or deleted, the previous version should be kept in a history or auditing table to fulfill the firm's auditing or other compliance requirements.

To accomplish this, there are two common options. The first one is to create database triggers that will clone the pre-update record into the history table before any update operations. The second is to develop the logic in the data access layer (for example, by using AOP). Both options have their drawbacks, however. The trigger approach is tied to the database platform, while implementing the logic manually is quite clumsy, might affect performance, and is very error-prone.

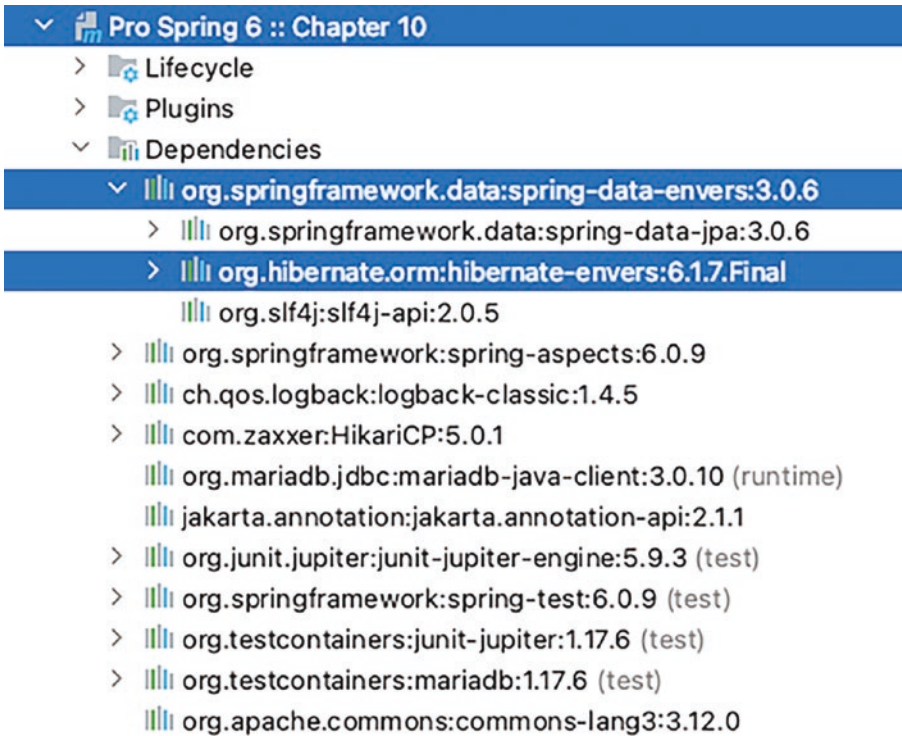
Hibernate Envers<sup>7</sup> (short for *entity versioning system*) is a Hibernate module specifically designed to automate the versioning of entities. In this section, we discuss how to use Envers to implement the versioning of the `SingerAudit` entity introduced in the previous section.

---

Hibernate Envers is not a feature of JPA. We mention it here because we believe it's more appropriate to cover this after we have discussed some basic auditing features that you can use with Spring Data JPA.

---

Spring Data provides a module for Hibernate Envers named `spring-data-envers`. `spring-data-jpa` is a transitive dependency of the Spring Data Envers library. Figure 10-5 shows the dependencies of a Spring Data project using Hibernate Envers for versioning entities.



**Figure 10-5.** Gradle View showing dependencies for the `chapter10 Envers` project

Envers supports two auditing strategies, which are shown in Table 10-1.

<sup>7</sup><https://hibernate.org/orm/envers/>

**Table 10-1.** Envers Auditing Strategies

Auditing Strategy	Description
Default	Envers maintains a column for the revision of the record. Every time a record is inserted or updated, a new record will be inserted into the history table with the revision number retrieved from a database sequence or table.
Validity audit	This strategy stores both the start and end revisions of each history record. Every time a record is inserted or updated, a new record will be inserted into the history table with the start revision number. At the same time, the previous record will be updated with the end revision number. It's also possible to configure Envers to record the timestamp at which the end revision was updated into the previous history record.

In this section, we demonstrate the validity audit strategy. Although it will trigger more database updates, retrieving the history records becomes much faster. Because the end revision timestamp is also written to the history records, it will be easier to identify the snapshot of a record at a specific point in time when querying the data.

## Adding Tables for Entity Versioning

To support entity versioning, we need to add a few tables. First, for each table that the entity (in this case, the `SingerAudit` entity class) will be versioning, we need to create the corresponding history table. For the versioning of records in the `SINGER_AUDIT` table, let's create a history table called `SINGER_AUDIT_H`. The code in Listing 10-23 shows the table creation script.

**Listing 10-23.** SQL Code Describing the Hibernate Audit Table for the `SingerAudit` Entity (`AuditSchema.sql`)

```
CREATE TABLE SINGER_AUDIT_H (
  ID INT NOT NULL AUTO_INCREMENT
  , FIRST_NAME VARCHAR(60) NOT NULL
  , LAST_NAME VARCHAR(40) NOT NULL
  , BIRTH_DATE DATE
  , VERSION INT NOT NULL DEFAULT 0
  , CREATED_BY VARCHAR(20)
  , CREATED_DATE TIMESTAMP
  , LAST_MODIFIED_BY VARCHAR(20)
  , LAST_MODIFIED_DATE TIMESTAMP
  , AUDIT_REVISION INT NOT NULL // *
  , ACTION_TYPE INT // *
  , AUDIT_REVISION_END INT // *
  , AUDIT_REVISION_END_TS TIMESTAMP // *
  , UNIQUE UQ_SINGER_AUDIT_H_1 (FIRST_NAME, LAST_NAME)
  , PRIMARY KEY (ID, AUDIT_REVISION)
);
```

To support the validity audit strategy, we need to add four columns for each history table, shown marked with `/**` in Listing 10-23 in the previous script snippet. Table 10-2 shows the columns and their purposes.

**Table 10-2.** *Envers Audit Columns Details*

Column	Data Type	Description
AUDIT_REVISION	INT	The start revision of the history record.
ACTION_TYPE	INT	The action type, with these possible values: 0 for add, 1 for modify, and 2 for delete.
AUDIT_REVISION_END	INT	The end revision of the history record.
AUDIT_REVISION_END_TS	TIMESTAMP	The timestamp at which the end revision was updated.

Hibernate Envers requires another table for keeping track of the revision number and the timestamp at which each revision was created for insert, add, update, or delete operations. The table should be named `REVINFO` and a foreign key should be added to the `SINGER_AUDIT_H` table to link each audited record to its versions. Its schema is very simple and is shown in Listing 10-24.

**Listing 10-24.** SQL Code Describing the Hibernate Audit `REVINFO` Table (`AuditSchema.sql`)

```
CREATE TABLE REVINFO (
    REVTSTMP BIGINT NOT NULL
    , REV INT NOT NULL AUTO_INCREMENT
    , PRIMARY KEY (REVTSTMP, REV)
);

ALTER TABLE SINGER_AUDIT_H
    ADD CONSTRAINT SINGER_AUDIT_H_TO_REVISION
        FOREIGN KEY ( AUDIT_REVISION ) REFERENCES REVINFO( REV);
```

The `REV` column is for storing each revision number, which will be auto-incremented when a new history record is created. The `REVTSTMP` column stores the timestamp (in a number format) when the revision was created.

## Configuring EntityManagerFactory for Entity Versioning

Hibernate Envers is implemented in the form of EJB listeners. We can configure those listeners in the `LocalContainerEntityManagerFactory` bean by setting a set of specific Envers properties. The Java configuration class is mostly identical to the one used so far for a transactional Spring application, the only difference being that the Envers properties are added to the `Properties` object set on the `LocalContainerEntityManagerFactoryBean` object by calling `setJpaProperties(..)`. In Listing 10-25 you can see these properties.

**Listing 10-25.** Envers Properties to Be Set on the `LocalContainerEntityManagerFactoryBean`

```
package com.apress.prospring6.ten.config;
// other import statements omitted
import org.hibernate.envers.configuration.EnversSettings;
import org.hibernate.cfg.Environment;

@Import(BasicDataSourceCfg.class)
@Configuration
@EnableTransactionManagement
```



```

@ComponentScan(basePackages = {"com.apress.prospring6.ten"})
@EnableJpaRepositories("com.apress.prospring6.ten.repos")
public class EnversConfig {

    // other bean declarations omitted

    @Bean
    public Properties jpaProperties() {
        Properties jpaProps = new Properties();
        jpaProps.put(Environment.HBM2DDL_AUTO, "none");
        jpaProps.put(Environment.FORMAT_SQL, false);
        jpaProps.put(Environment.STATEMENT_BATCH_SIZE, 30);
        jpaProps.put(Environment.USE_SQL_COMMENTS, false);
        jpaProps.put(Environment.SHOW_SQL, false);

        // Properties for Hibernate Envers
        jpaProps.put(EnversSettings.AUDIT_TABLE_SUFFIX, "_H");
        jpaProps.put(EnversSettings.REVISION_FIELD_NAME, "AUDIT_REVISION");
        jpaProps.put(EnversSettings.REVISION_TYPE_FIELD_NAME, "ACTION_TYPE");
        jpaProps.put(EnversSettings.AUDIT_STRATEGY, "org.hibernate.envers.strategy.
        ValidityAuditStrategy");
        jpaProps.put(EnversSettings.AUDIT_STRATEGY_VALIDITY_END_REV_FIELD_NAME, "AUDIT_
        REVISION_END");
        jpaProps.put(EnversSettings.AUDIT_STRATEGY_VALIDITY_STORE_REVEND_TIMESTAMP, "true");
        jpaProps.put(EnversSettings.AUDIT_STRATEGY_VALIDITY_REVEND_TIMESTAMP_FIELD_NAME,
        "AUDIT_REVISION_END_TS");
        return jpaProps;
    }

    @Bean
    public LocalContainerEntityManagerFactoryBean entityManagerFactory() {
        var factory = new LocalContainerEntityManagerFactoryBean();
        factory.setPersistenceProviderClass(HibernatePersistenceProvider.class);
        factory.setPackagesToScan("com.apress.prospring6.ten.entities");
        factory.setDataSource(dataSource);
        factory.setJpaProperties(jpaProperties());
        factory.setJpaVendorAdapter(jpaVendorAdapter());
        return factory;
    }
}

```

With this configuration, what happens under the hood is that audit event listeners (instances of types implementing `org.hibernate.envers.event.spi.EnversListener`) are attached to persistence events: add, insert, update, and delete. These listeners intercept the events post-insert, post-update, or post-delete and clone the pre-update snapshot of the entity class into the history table. The listeners are also attached to those association update events (pre-collection-update, pre-collection-remove, and pre-collection-recreate) for handling the update operations of the entity class's associations. Envers is capable of keeping the history of the entities within an association (for example, *one-to-many* or *many-to-many*).

The properties are set in the configuration in Listing 10-25 and explained briefly in Table 10-3.



All constants are declared in the `org.hibernate.envers.configuration.EnversSettings` interface. The interface name is not shown in Table 10-3 because that would make it very difficult to fit the table in the page<sup>8</sup>.



All property names in the second column start with `org.hibernate.envers`. This prefix is not shown in the table because that would make it very difficult to fit it in the page.

**Table 10-3.** *Envers configurations*

Constant	Property Name	Default Value	Description
AUDIT_TABLE_SUFFIX	audit_table_prefix	_AUD	The table name suffix for the versioned entity. For example, for the entity class <code>SingerAudit</code> , which is mapped to the <code>SINGER_AUDIT</code> table, Envers will keep the history in the table <code>SINGER_AUDIT_H</code> , since we defined the value <code>_H</code> for the property.
REVISION_FIELD_NAME	revision_field_name	REV	The history table's column for storing the revision number for each history record.
REVISION_TYPE_FIELD_NAME	revision_type_field_name	REVTTYPE	The history table's column for storing the update action type.
AUDIT_STRATEGY	audit_strategy	<code>org.hibernate.envers.strategy.DefaultAuditStrategy</code>	The audit strategy to use for entity versioning.
AUDIT_STRATEGY_VALIDITY_END_REV_FIELD_NAME	audit_strategy_validity_end_rev_field_name	REVEND	The history table's column for storing the end revision number for each history record. Required only when using the validity audit strategy.
AUDIT_STRATEGY_VALIDITY_STORE_REVEND_TIMESTAMP	audit_strategy_validity_store_revend_timestamp	false	Specifies whether to store the timestamp when the end revision number for each history record is updated. Required only when using the validity audit strategy.
AUDIT_STRATEGY_VALIDITY_REVEND_TIMESTAMP_FIELD_NAME	audit_strategy_validity_revend_timestamp_field_name	REVEND_TSTMP	The history table's column for storing the timestamp when the end revision number for each history record is updated. Required only when using the validity audit strategy and the previous property is set to true.

<sup>8</sup><https://docs.jboss.org/hibernate/orm/current/javadocs/org/hibernate/envers/configuration/EnversSettings.html>



The default values in Table 10-3 are the one used by Hibernate when configured to generate the database schema, and no values are explicitly configured for these properties.



You can find the full list of Hibernate properties in the Hibernate official documentation<sup>9</sup>.

## Enabling Entity Versioning and History Retrieval

To enable versioning of an entity, just annotate the entity class with the `@Audited` annotation provided by Hibernate. This annotation can be used at the class level and then the changes on all entity fields are audited. If you want to escape certain fields from auditing, you can use Hibernate's `@NotAudited` annotation on those fields. Listing 10-26 shows the `SingerAudit` class annotated with `@Audited` and the other Jakarta-specific annotations.

**Listing 10-26.** Entity Class Annotated with Hibernate's Envers `@Audited`

```
package com.apress.prospring6.ten.entities;
// other import statements omitted
import org.hibernate.envers.Audited;

@Entity
@Audited
@Table(name = "SINGER_AUDIT")
public class SingerAudit extends AuditableEntity<SingerAudit> {
    // body omitted
}
```

The entity class is annotated with `@Audited`, which Envers listeners will check for and perform versioning of the updated entities. By default, Envers will also try to keep a history of the associations; if you want to avoid this, you should use the `@NotAudited` annotation.

To retrieve the history records, Envers provides the `org.hibernate.envers.AuditReader` interface, which can be obtained from the `AuditReaderFactory` class. To do this, a new method called `findAuditByRevision()` is added to the `SingerAuditService` interface for retrieving the `SingerAudit` history records by audited record id and revision number. Listing 10-27 shows the `SingerAuditServiceImpl` implementation.

**Listing 10-27.** Service Method for Retrieving History Records by Revision

```
package com.apress.prospring6.ten.service;

import jakarta.persistence.PersistenceContext;
import org.hibernate.envers.AuditReaderFactory;
```

<sup>9</sup>[https://docs.jboss.org/hibernate/orm/current/userguide/html\\_single/Hibernate\\_User\\_Guide.html#envers-configuration](https://docs.jboss.org/hibernate/orm/current/userguide/html_single/Hibernate_User_Guide.html#envers-configuration)

```

@Service("singerAuditService")
@Transactional
public class SingerAuditServiceImpl implements SingerAuditService {
    private final SingerAuditRepository singerAuditRepository;

    @PersistenceContext
    private EntityManager entityManager;

    // other methods and fields omitted

    @Override
    public SingerAudit findAuditByRevision(Long id, int revision) {
        var auditReader = AuditReaderFactory.get(entityManager);
        return auditReader.find(SingerAudit.class, id, revision);
    }
}

```

The `SingerAuditServiceImpl` class must be modified, obviously, and the `EntityManager` must be injected into it so that the `AuditReaderFactory` can use it to create an `org.hibernate.envers.AuditReader` instance to read the audit records.

This can easily be avoided by using custom implementations for Spring Data custom repositories, and since the focus of this Spring, let's do that.

## Custom Implementations for Spring Data Repositories

Spring Data provides default options for handling database records and creating query methods with little coding. However, there are cases when that is not enough, and the Envers example introduced here is a good example.

To add a custom method to the default functionality of a Spring Data Repository, we need to define a fragment interface declaring the behavior we want to add. In our case, as depicted in Listing 10-28, the interface is named `CustomSingerAuditRepository` and declares a single method with the sole purpose of retrieving older versions of `SingerAudit` records using their `id` and revision number.

**Listing 10-28.** Fragment Interface Declaring a Method for Retrieving Versions of `SingerAudit` Records

```

package com.apress.prospring6.ten.repos.envers;

import com.apress.prospring6.ten.entities.SingerAudit;
import java.util.Optional;

public interface CustomSingerAuditRepository {

    Optional<SingerAudit> findAuditByIdAndRevision(Long id, int revision);

}

```

Now that we have an interface, we need to provide an implementation. This is where the class `CustomSingerAuditRepositoryImpl` depicted in Listing 10-29 comes in.

*Listing 10-29.* Implementation of the CustomSingerAuditRepository Interface

```

package com.apress.prospring6.ten.repos.envers;

import com.apress.prospring6.ten.entities.SingerAudit;
import jakarta.persistence.EntityManager;
import jakarta.persistence.PersistenceContext;
import org.hibernate.envers.AuditReaderFactory;

import java.util.Optional;

public class CustomSingerAuditRepositoryImpl implements CustomSingerAuditRepository {

    @PersistenceContext
    private EntityManager entityManager;

    @Override
    public Optional<SingerAudit> findAuditByIdAndRevision(Long id, int revision) {
        var auditReader = AuditReaderFactory.get(entityManager);
        var result = auditReader.find(SingerAudit.class, id, revision);
        if(result != null)
            return Optional.of(result);
        return Optional.empty();
    }
}

```



Notice that we just moved the Envers-specific code from `SingerAuditServiceImpl` to this class.

---

To tell Spring Data that we want this method to be added to its default set of functionalities, we need to make the Spring Data repository for the `SingerAudit` entity extend the `CustomSingerAuditRepository` too, like depicted in Listing 10-30.

*Listing 10-30.* Implementation of the CustomSingerAuditRepository Interface

```

package com.apress.prospring6.ten.repos;

import com.apress.prospring6.ten.entities.SingerAudit;
import com.apress.prospring6.ten.repos.envers.CustomSingerAuditRepository;
import org.springframework.data.jpa.repository.JpaRepository;

public interface SingerAuditRepository extends
    JpaRepository<SingerAudit, Long> ,
    CustomSingerAuditRepository { }

```



The most important part of the class name that corresponds to the fragment interface is the `Impl` postfix. This is what allows Spring Data to identify where the implementation for that method is coming from and add it to its JPA repository proxies. After all, convention over configuration is one of the core values of the Spring Framework.



However, being easy to customize is also a Spring value, and thus if you want to name your custom repository implementation differently, you have to tell Spring about it. The customization is somewhat limited; you can only specify a different postfix to replace the default `Impl`, using `@EnableJpaRepositories(repositoryImplementationPostfix = "${custom-prefix})`, but it is better than nothing.

This means that now the `SingerAuditServiceImpl` class can be cleaned up of the Envers-specific code and the `findAuditByRevision(..)` method just invokes the `findAuditByIdAndRevision(..)` method provided by the Spring JPA `SingerAuditRepository`, as shown in Listing 10-31.

**Listing 10-31.** Implementation of the `SingerAuditServiceImpl` Interface

```
package com.apress.prospring6.ten.service;
```

```
@Service("singerAuditService")
@Transactional
public class SingerAuditServiceImpl implements SingerAuditService {
    private final SingerAuditRepository singerAuditRepository;

    // other methods omitted

    @Transactional(readOnly=true)
    @Override
    public SingerAudit findAuditByRevision(Long id, int revision) {
        return singerAuditRepository.findAuditByIdAndRevision(id, revision).orElse(null);
    }
}
```

What is left is to test that this works. Writing a test method is not that difficult, but to make sure that our revisioning works, an update and a delete operation should be checked. The test class is shown in Listing 10-32.

**Listing 10-32.** Testing the Envers Auditing in a Spring Application

```
package com.apress.prospring6.ten;
```

```
// import statements omitted
```

```
@Testcontainers
@Sql({ "classpath:testcontainers/audit/drop-schema.sql", "classpath:testcontainers/audit/
create-schema.sql" })
@SpringJUnitConfig(classes = {EnversConfig.class, AuditCfg.class})
```

```

public class EnversServiceTest extends TestContainersBase {

    private static final Logger LOGGER = LoggerFactory.getLogger(EnversServiceTest.class);

    @Autowired
    SingerAuditService auditService;

    @BeforeEach
    void setUp(){
        var singer = new SingerAudit();
        singer.setFirstName("BB");
        singer.setLastName("King");
        singer.setBirthDate(LocalDate.of(1940, 8, 16));
        auditService.save(singer);
    }

    @Test
    void testFindAuditByRevision() {
        // update to create new version
        var singer = auditService.findAll().findFirst().orElse(null);
        assertNotNull(singer);
        singer.setFirstName("Riley B.");
        auditService.save(singer);

        var oldSinger = auditService.findAuditByRevision(singer.getId(), 1);
        assertEquals("BB", oldSinger.getFirstName());
        LOGGER.info(">> old singer: {} ", oldSinger);

        var newSinger = auditService.findAuditByRevision(singer.getId(), 2);
        assertEquals("Riley B.", newSinger.getFirstName());
        LOGGER.info(">> updated singer: {} ", newSinger);
    }

    @Test
    void testFindAuditAfterDeletion() {
        // delete record
        var singer = auditService.findAll().findFirst().orElse(null);
        auditService.delete(singer.getId());

        // extract from audit
        var deletedSinger = auditService.findAuditByRevision(singer.getId(), 1);
        assertEquals("BB", deletedSinger.getFirstName());
        LOGGER.info(">> deleted singer: {} ", deletedSinger);
    }
}

```

To get a glimpse of what is happening, you can try taking a look in the console log messages printed when the test methods are executed. Unfortunately, at this point in the book, if we enable the TRACE log for `org.hibernate`, the log becomes unreadable, but Listing 10-33 shows the most important bits.

**Listing 10-33.** Envers Auditing Test Execution Log

```

TRACE: TransactionAspectSupport - Getting transaction for
      [com.apress.prospring6.ten.service.SingerAuditServiceImpl.save]
TRACE: AbstractEntityPersister - Updating entity:
      [com.apress.prospring6.ten.entities.SingerAudit#1]
...
DEBUG: SqlStatementLogger - insert into REVINFO (REVTSTMP) values (?)
TRACE: AbstractEntityPersister - Inserting entity:
      [com.apress.prospring6.ten.entities.SingerAudit_H#component[
        id,AUDIT_REVISION]{id=1, AUDIT_REVISION=org.hibernate.envers.
DefaultRevisionEntity#1}]
DEBUG: SqlStatementLogger - insert into REVINFO (REVTSTMP) values (?)
TRACE: AbstractEntityPersister - Inserting entity:
      [com.apress.prospring6.ten.entities.SingerAudit_H#component[
        id,AUDIT_REVISION]{id=1, AUDIT_REVISION=org.hibernate.envers.
DefaultRevisionEntity#2}]
...
TRACE: TransactionAspectSupport - Getting transaction for
      [com.apress.prospring6.ten.service.SingerAuditServiceImpl.findAuditByRevision]
DEBUG: QueryTranslatorImpl - parse() - HQL:
      select e__ from com.apress.prospring6.ten.entities.SingerAudit_H e__
      where e__.originalId.AUDIT_REVISION.id <= :revision
        and e__.ACTION_TYPE <> :_p0
        and e__.originalId.id = :_p1
        and (e__.AUDIT_REVISION_END.id > :revision or e__.AUDIT_REVISION_END is null)
TRACE: QueryParameters - Named parameters: {_p1=1, _p0=DEL, revision=1}
DEBUG: Loader - Result row: EntityKey[com.apress.prospring6.ten.entities.SingerAudit_H#compo
nent[id,AUDIT_REVISION]{id=1, AUDIT_REVISION=org.hibernate.envers.DefaultRevisionEntity#1}]
INFO : EnversServiceTest - >> old singer: com.apress.prospring6.ten.entities.
SingerAudit@20524816[
  id=1,version=0,firstName=BB,lastName=King,birthDate=1940-08-16,
  createdBy=prospring6-0e94fe,
  createdDate=2022-08-07T13:40:31,
  lastModifiedBy=prospring6-0e94fe,
  lastModifiedDate=2022-08-07T14:40:30
]
...
TRACE: QueryParameters - Named parameters: {_p1=1, _p0=DEL, revision=2}
DEBUG: Loader - Result row: EntityKey[com.apress.prospring6.ten.entities.SingerAudit_H#compo
nent[id,AUDIT_REVISION]{id=1, AUDIT_REVISION=org.hibernate.envers.DefaultRevisionEntity#2}]
INFO : EnversServiceTest - >> updated singer: com.apress.prospring6.ten.entities.
SingerAudit@6347f9cc[
  id=1,version=0,firstName=Riley B.,lastName=King,birthDate=1940-08-16,
  createdBy=prospring6-0e94fe,
  createdDate=2022-08-07T14:40:30,
  lastModifiedBy=prospring6-TJFUWY,
  lastModifiedDate=2022-08-07T14:40:31
]
...

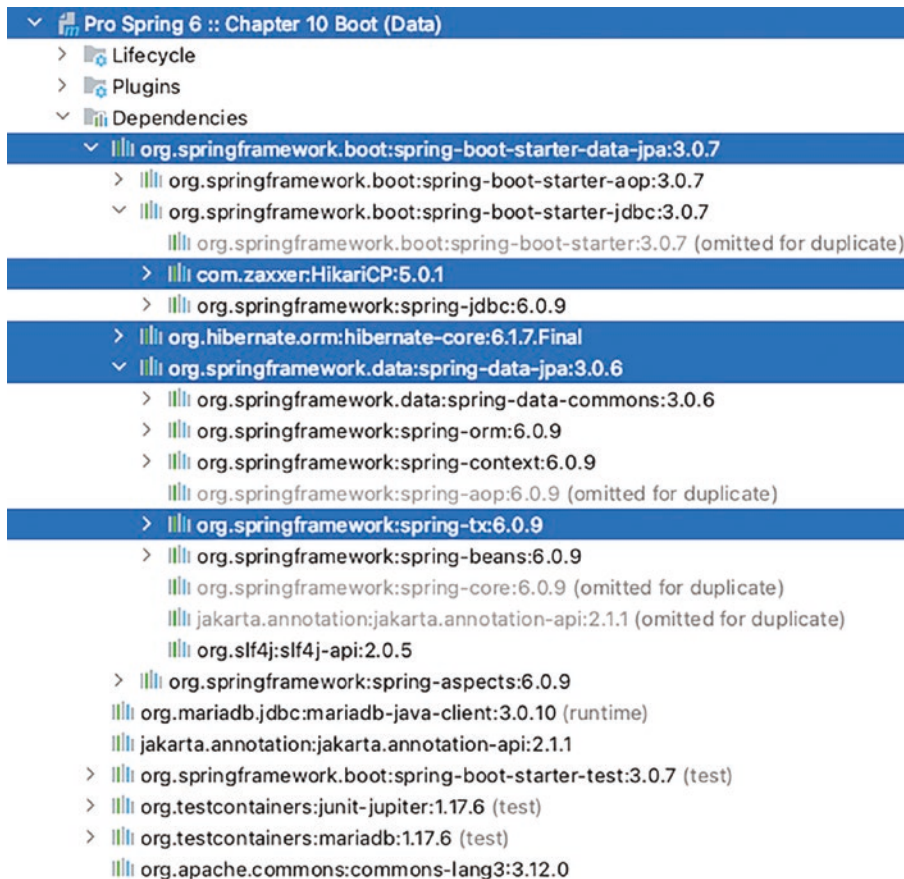
```



Notice how every action on the `SINGER_AUDIT` table causes an entry to be created in `REVINFO` and `SINGER_AUDIT_H`. Then, when `SingerAudit` entries are extracted with a certain revision, they are extracted from the `SINGER_AUDIT_H` table. After the update operation, the `SingerAudit`'s first name is changed to *Riley B*. As expected, when looking at the history, at revision 1, the first name is *BB*. At revision 2, the first name becomes *Riley B*. Also notice that the `lastModifiedDate` date and `lastModifiedBy` of revision 2 reflect the updated date and time and a different username, generated by the `AuditAware<String>` bean.

## Spring Boot Data JPA

Up to this point, we have configured everything explicitly, including entities, databases, repositories, and services. As you probably expect by now, there should be a Spring Boot starter artifact to make things easier. Spring Boot JDBC was introduced in [Chapter 9](#), but its capabilities truly shine in combination with Spring Data, and there is a starter library for that called `spring-boot-starter-data-jpa`. Adding this library to a project classpath adds transitively all the dependencies necessary to a Spring transactional application: `hibernate-core` for persistence, `HikariCP` for connection pooling, `spring-data-jpa` for data access using data repository interfaces, and `spring-tx` for transaction management. The project dependencies are shown in [Figure 10-6](#).



**Figure 10-6.** Gradle View showing dependencies for the `chapter10-boot` project

The Spring Boot Data JPA configuration has two parts: the main class annotated with `@SpringBootApplication` and the `application-dev.yaml` (or `application-dev.properties`) file. Of course, the `-dev` suffix is added because we are using an application profile named `dev`. This is a practical way to isolate bean declarations based on context.

For this project the `application-dev.yaml` file has the contents shown in Listing 10-34.

**Listing 10-34.** Spring Boot Data JPA Configuration `yaml` Configuration

```
# datasource config
spring:
  datasource:
    driverClassName: org.mariadb.jdbc.Driver
    url: jdbc:mariadb://localhost:3306/musicdb?useSSL=false
    username: prospring6
    password: prospring6
    # HikariCP
    hikari:
      maximum-pool-size: 25
# JPA config
jpa:
  generate-ddl: false
  properties:
    hibernate:
      naming:
        physical-strategy:
      jdbc:
        batch_size: 10
        fetch_size: 30
        max_fetch_depth: 3
        show-sql: true
        format-sql: false
        use_sql_comments: false
        hbm2ddl:
          auto: none

# Logging config
logging:
  pattern:
    console: "%-5level: %class{0} - %msg%n"
  level:
    root: INFO
    org.springframework.boot: DEBUG
    com.apress.prospring6.ten.boot: INFO
    org.springframework.orm.jpa: TRACE
```

The configuration is split in three sections: `datasource`, `jpa`, and `logging`. Properties with names starting with `spring.datasource` are set with values necessary for configuring a data source: connection URL, credentials, and connection pooling values. Properties with names starting with `spring.jpa` are set with values describing a persistence unit. You can easily recognize the Hibernate properties covered in **Chapters 7** and **8**. Properties starting with `logging` are set with the typical value for logging configuration that in classic applications could be found in `logback.xml` files.

In a Spring Boot Data JPA application, the autoconfiguration mechanism takes care of declaring the necessary beans like `DataSource`, `EntityManager`, `LocalSessionFactoryBean`, `TransactionManager`, and so on, based on the properties in the configuration file, but we still have to configure a few things:

- *Location of the entity classes:* Since the `LocalSessionFactoryBean` is autoconfigured for us, the way to specify the packages where the entity classes are is to use the `@EntityScan` annotation from the `org.springframework.boot.autoconfigure.domain` package.
- *Location of the Data repository interfaces:* This is easily done by adding the `@EnableJpaRepositories` annotation to a class annotated with `@Configuration`, if there is one, or the `@SpringBootApplication` annotated class if there is not.
- *Transactional behavior:* This is easily done by adding the `@EnableTransactionManagement` annotation to a class annotated with `@Configuration`, if there is one, or the `@SpringBootApplication` annotated class if there is not.

For the project analyzed in this section, the configuration is depicted in Listing 10-35.

**Listing 10-35.** Spring Boot Data JPA Annotation Configuration

```
package com.apress.prospring6.ten.boot;

import com.apress.prospring6.ten.boot.service.SingerService;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.boot.autoconfigure.domain.EntityScan;
import org.springframework.core.env.AbstractEnvironment;
import org.springframework.data.jpa.repository.config.EnableJpaRepositories;
import org.springframework.transaction.annotation.EnableTransactionManagement;

@EntityScan(basePackages = {"com.apress.prospring6.ten.boot.entities"})
@EnableTransactionManagement
@EnableJpaRepositories("com.apress.prospring6.ten.boot.repos")
@SpringBootApplication
public class Chapter10Application {

    private static final Logger LOGGER = LoggerFactory.getLogger(Chapter10Application.class);

    public static void main(String... args) {
        System.setProperty(AbstractEnvironment.ACTIVE_PROFILES_PROPERTY_NAME, "dev");
        var ctx = SpringApplication.run(Chapter10Application.class, args);
        var service = ctx.getBean(SingerService.class);

        LOGGER.info(" ---- Listing singers:");
        service.findAll().forEach(s -> LOGGER.info(s.toString()));
    }
}
```

As you can see, the Spring Boot main configuration class has a `main(..)` method. This makes this class executable, and running the code in this class's `main(..)` method ensures that the configuration is correct. However, running the class with the configuration shown so far ends with the following error:

```
Exception in thread "main" org.springframework.dao.InvalidDataAccessResourceUsageException:
JDBC exception executing SQL
```

```
[select s1_0.id,
      s1_0.birth_date,
      s1_0.first_name,
      s1_0.last_name,
      s1_0.version
 from singer s1_0
]; SQL [n/a]
```

```
...
Caused by: java.sql.SQLException: (conn=308) Table 'musicdb.singer' doesn't exist
at org.mariadb.jdbc.export.ExceptionFactory.createException(ExceptionFactory.java:280)
at org.mariadb.jdbc.export.ExceptionFactory.create(ExceptionFactory.java:368)
```

So, what is going on here? If the data source was configured correctly, why is the `singer` table not found? If you think the reason is that the table names are case-sensitive, you are somewhat right. Before explaining what is going on in this Spring Boot Data JPA application, let's talk about Hibernate naming strategies.

Hibernate uses two different naming strategies<sup>10</sup> to map names from the object model to the corresponding database names:

- **ImplicitNamingStrategy:** The proper logical name is determined from the domain model mapping, either from configuration annotations like `@Column` and `@Table` (as you've seen in previous chapters) or by Hibernate using an implementation of `org.hibernate.boot.model.naming.ImplicitNamingStrategy` configured via the `Environment.IMPLICIT_NAMING_STRATEGY` / `hibernate.implicit_naming_strategy` property.
- **PhysicalNamingStrategy:** The proper logical name is determined by Hibernate using an implementation of `org.hibernate.boot.model.naming.PhysicalNamingStrategy` configured via the `Environment.PHYSICAL_NAMING_STRATEGY` / `hibernate.physical_naming_strategy` property.

The purpose of these two strategies is to reduce the explicit configuration a developer must provide.

Many organizations define rules around the naming of database objects (tables, columns, foreign keys, etc.). The idea of a `PhysicalNamingStrategy` is to help implement such naming rules without having to hard-code them into the mapping via explicit names.

A few companies I (Iuliana) have worked for preferred to name database object in uppercase letters, because in the code, it was easier to discern between HQL and SQL native queries. This is the approach I kept for this book as well.

In a Spring Boot Data JPA application, the default strategy of determining database object names is an implementation of `PhysicalNamingStrategy` named `org.hibernate.boot.model.naming.CamelCaseToUnderscoresNamingStrategy` that is provided by Hibernate. As its name indicates, the logical names are assumed to be in camel case and separated by underscores. This is the reason why the `Singer` entity class gets mapped to the `singer` table, and since MariaDB is installed on a Linux container, database object names are case-sensitive, so `SINGER` is clearly not equal to `singer`.

<sup>10</sup>[https://docs.jboss.org/hibernate/orm/current/userguide/html\\_single/Hibernate\\_User\\_Guide.html#naming](https://docs.jboss.org/hibernate/orm/current/userguide/html_single/Hibernate_User_Guide.html#naming)

The solution here is to provide our own `PhysicalNamingStrategy` bean, instructing Spring Boot how to determine the database object names. The `PhysicalNamingStrategy` interface declares five methods for each named database object<sup>11</sup>. The body of this interface is declared in Listing 10-36.

**Listing 10-36.** Hibernate’s `PhysicalNamingStrategy` Interface

```
package org.hibernate.boot.model.naming;

import org.hibernate.Incubating;
import org.hibernate.engine.jdbc.env.spi.JdbcEnvironment;

@Incubating
public interface PhysicalNamingStrategy {

    Identifier toPhysicalCatalogName(Identifier logicalName, JdbcEnvironment jdbcEnvironment);

    Identifier toPhysicalSchemaName(Identifier logicalName, JdbcEnvironment jdbcEnvironment);

    Identifier toPhysicalTableName(Identifier logicalName, JdbcEnvironment jdbcEnvironment);

    Identifier toPhysicalSequenceName(Identifier logicalName, JdbcEnvironment jdbcEnvironment);

    Identifier toPhysicalColumnName(Identifier logicalName, JdbcEnvironment jdbcEnvironment);
}
```



The `@Incubating` annotation indicates something that is still being actively developed and therefore may change at a later time.

---

To make things simpler, we can extend the `PhysicalNamingStrategyImpl` class, provided by Hibernate, and override only the methods we are interested in. The `HibernateCfg` configuration class shown in Listing 10-37 declares a bean of an anonymous type extending `PhysicalNamingStrategyImpl`.

**Listing 10-37.** Custom `PhysicalNamingStrategy` Implementation

```
package com.apress.prospring6.ten.boot;

import org.hibernate.boot.model.naming.Identifier;
import org.hibernate.boot.model.naming.PhysicalNamingStrategyStandardImpl;
import org.hibernate.engine.jdbc.env.spi.JdbcEnvironment;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;

@Configuration(proxyBeanMethods = false)
public class HibernateCfg {
```

---

<sup>11</sup><https://github.com/hibernate/hibernate-orm/blob/main/hibernate-core/src/main/java/org/hibernate/boot/model/naming/PhysicalNamingStrategy.java>

```

@Bean
PhysicalNamingStrategyStandardImpl caseSensitivePhysicalNamingStrategy() {
    return new PhysicalNamingStrategyStandardImpl() {
        @Override
        public Identifier toPhysicalTableName(Identifier logicalName, JdbcEnvironment
        context) {
            return apply(logicalName, context);
        }

        @Override
        public Identifier toPhysicalColumnName(Identifier logicalName, JdbcEnvironment
        context) {
            return apply(logicalName, context);
        }

        private Identifier apply(final Identifier name, final JdbcEnvironment context) {
            if ( name == null ) {
                return null;
            }
            StringBuilder builder = new StringBuilder( name.getText().replace( '.',
            '_' ) );
            for ( int i = 1; i < builder.length() - 1; i++ ) {
                if ( isUnderscoreRequired( builder.charAt( i - 1 ), builder.charAt( i ),
                builder.charAt( i + 1 ) ) ) {
                    builder.insert( i++, '_' );
                }
            }
            return Identifier.toIdentifier(builder.toString().toUpperCase());
        }

        private boolean isUnderscoreRequired(final char before, final char current,
        final char after) {
            return Character.isLowerCase( before ) && Character.isUpperCase( current )
            && Character.isLowerCase( after );
        }
    };
}

```

The `proxyBeanMethods` attribute is set to `false` because methods annotated with `@Bean` in this class should not get proxied in order to enforce bean life-cycle behavior. The code used to determine the logical names for tables and columns is declared in the `apply()` method.

Executing the `Chapter10Application` class with this new configuration class we can see that the expected output, the singer instances as string, is printed in the console log.

The repository data classes and service classes are the same as shown in this chapter, in the classic Spring application. The test methods are the same as well, the only difference being in the configuration of the test context. An `application-test.yaml` or `application-test.properties` file is recommended, since the data source has to be replaced with a `Testcontainers` data source. The configuration file used in this section's example is shown in Listing 10-38.

**Listing 10-38.** Spring Boot Data JPA Test Configuration yaml Configuration

```

spring:
  datasource:
    url: "jdbc:tc:mariadb:10.9-rc:///testdb?TC_INITSCRIPT=testcontainers/create-schema.sql"
  jpa:
    properties:
      hibernate:
        jdbc:
          batch_size: 10
          fetch_size: 30
          max_fetch_depth: 3
          show-sql: true
          format-sql: true
          use_sql_comments: true
          hbm2ddl:
            auto: none

# Logging config
logging:
  pattern:
    console: "%-5level: %class{0} - %msg%n"
  level:
    root: INFO
    org.springframework.boot: DEBUG
    com.apress.prospring6.ten.boot: DEBUG
    org.springframework.orm.jpa: TRACE

```

Notice that Hibernate-specific properties useful for debugging are set to true and the logging configuration is more detailed.

The Spring Boot test configuration class is annotated with `@SpringBootTest` and additional annotations required to set up a test context, as shown in Listing 10-39.

**Listing 10-39.** Spring Boot Data Test Class

```

package com.apress.prospring6.ten.boot;

import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.test.context.ActiveProfiles;
import org.springframework.test.context.jdbc.Sql;
import org.springframework.test.context.jdbc.SqlMergeMode;
import org.testcontainers.junit.jupiter.Testcontainers;
// other import statements omitted

@ActiveProfiles("test")
@Testcontainers
@SqlMergeMode(SqlMergeMode.MergeMode.MERGE)
@Sql({ "classpath:testcontainers/drop-schema.sql", "classpath:testcontainers/create-
schema.sql" })
@SpringBootTest(classes = {Chapter10Application.class})
public class Chapter10ApplicationTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(Chapter10Application.class);

```

```

@Autowired
SingerService singerService;

@Test
public void testFindAll(){
    var singers = singerService.findAll().peek(s -> LOGGER.info(s.toString())).toList();
    assertEquals(3, singers.size());
}
// other test methods omitted
}

```

What tells Spring Boot to initialize the test context based on the configuration in `application-test.yml` is the `@ActiveProfiles("test")` annotation enabling the test context. The `@SpringBootTest(classes = {Chapter10Application.class})` annotation is explicitly configured to use the `Chapter10Application` configuration. This is not necessary when there is a single Spring Boot test class named exactly as the Spring Boot configuration class suffixed with `Test`, but throughout the book's examples, this form is used for a bit of extra clarity, to make it obvious where the configuration for the beans tested is coming from.

## Considerations Using Spring Data JPA

Using Spring Data JPA's Repository abstraction can help simplify JPA application development. Spring Boot can simplify development even more, but customizing configurations might require a bit of learning. Referring again to the *I Love Lucy* episode "Paris at Last" introduced in **Chapter 6**, Spring Data JPA is the last translator in the chain. Its job is based on the ones before it, the JDBC driver, JPA, and Hibernate (and similar, like Oracle TopLink), and it is what makes writing Java code to access data easiest, because it focuses on the business logic and hides the technical complexity and boilerplate code. All these technical layers together make it pretty easy and fast to implement the persistence layer. Spring Data JPA also makes customizing transactional behavior easy. Spring Data (and the frameworks it relies on) is very popular, for big enterprise projects; for smaller projects, might be overkill. Plus, the more technologies you add in your project, the steeper the learning curve is for developers and the more failure points you add at the points where those are glued together.

Thus far this chapter has introduced the core concepts and interfaces of Spring Data JPA repositories. JPA is suitable when working with normalized SQL databases. How about when working with nonstructured, non-strongly relational data that is not a good fit for a SQL database? Does Spring Data offer something for that? Of course! You can learn about that in the next section.

## Spring Data with MongoDB<sup>12</sup>

Almost all data is relational in some way, and for years SQL databases that represented those relationship through concrete objects, like foreign keys, dominated the industry. Organizing data to reduce duplication and storage costs, however, introduced delays when handling that data since relationships had to be taken into account. As the quantity of data grows, the quantity of metadata describing relationships grows too, and operations become slower. Relational databases are well suited to accomplish tasks that involve a lot of tables, that involve complex and huge queries, and in which transactional operations are crucial (ACID) and speed is not always a requirement. Performing big cascade deletes while keeping relationships and data integrity are other good use cases for relational databases.

<sup>12</sup><https://spring.io/projects/spring-data-mongodb>



In this new age of the Internet, speed is the most common requirement. SQL databases, although efficient in storing data and very precise and consistent in providing it when requested, are not suitable for Internet services, where speed is more important than data integrity. NoSQL databases are useful when your data isn't strongly structured, when their relationships aren't deep, when you need to save data for a small amount of time (caching), or your queries aren't too complex. For example, eBay is using a NoSQL database called MongoDB, and Amazon is using DynamoDB, a proprietary NoSQL database created to satisfy its own commercial needs. DynamoDB is known to be the most suitable NoSQL database for shopping sites, as it is highly customizable, fast, and infinitely scalable in the Amazon cloud.

Thus, NoSQL databases appear to satisfy this need for getting things quickly, even if not always consistent. For example, when you access the Amazon shopping site, you don't expect to get the most recent products immediately, but you will eventually get them. Also, being nonrelational, NoSQL databases have some data duplication, thus data integrity comes second to speed of retrieval.

Another thing you need to keep in mind is that relational databases are not a very good model of real systems. They force you to declare your full data structure before you even start writing the code to interact with them, and making changes later is tricky, which is a problem because in real life changes happen constantly. The main advantage of NoSQL is that, aside from a main identifier for every record, everything is easily modifiable later. Amazon's DynamoDB is a step even further in that direction because, aside from the primary key, all columns—named *attributes*—in a record can be different from record to record. This level of flexibility, unfortunately, means that writing a Spring Data library for working with DynamoDB is almost impossible.

Since NoSQL databases have become widely used, it is only suitable to add a section about how Spring can help interact with them. Spring provides quite a few data libraries for working with NoSQL databases, but the Spring team's favorite is MongoDB<sup>13</sup>, for which classic and reactive API is provided. Aside from that, there is support for Apache Cassandra<sup>14</sup> (an open source NoSQL Database Manage able to handle massive amounts of data, and is fast too), Couchbase<sup>15</sup> (a modern cloud database that offers the robust capabilities required for business-critical applications on a highly scalable and available platform), and Redis<sup>16</sup> (an open source, BSD licensed, in-memory data structure store, used as a database, cache, and message broker).

Recently, since it has become clear that fully nonrelational data does not exist, the NoSQL term is slowly changing meaning from “non-SQL” to “not only SQL.” So, feel free to explore the NoSQL data realm, because you'll likely end up working with one of these databases.

## MongoDB Concepts

For this section, you can install MongoDB on your computer, but the recommended way is to use Docker and set up the container as recommended in the CHAPTER10-MONGO.adoc file present in the chapter10-mongo project. Of course, you can skip this step altogether and just run the tests that use a Testcontainers MongoDB container.

MongoDB is a document-oriented NoSQL database used for high-volume data storage. Instead of using tables and rows as in the traditional relational databases, MongoDB makes use of collections and documents. Documents in a collection do not have a fixed structure, like all rows in a table do.

Although we already mentioned what NoSQL databases are good for, to keep things consistent, the `Singer` class is mapped to a MongoDB collection named `singers`. This is done in Spring by annotating the `Singer` class with `@Document`, from the package `org.springframework.data.mongodb.core.mapping`. This annotation is useful to configure the collection name to be different from the class name, since the MongoDB standard is to name collections with the plural of the type of documents in it.

---

<sup>13</sup><https://www.mongodb.com>

<sup>14</sup><https://cassandra.apache.org>

<sup>15</sup><https://www.couchbase.com>

<sup>16</sup><https://redis.io/>

The Singer class is shown in Listing 10-40.

**Listing 10-40.** Singer Class Configured As a MongoDB Document

```
package com.apress.prospring6.ten.document;

import org.springframework.data.mongodb.core.index.Indexed;
import org.springframework.data.mongodb.core.mapping.Document;
import org.springframework.data.mongodb.core.mapping.MongoId;

import java.time.LocalDate;

@Document(collection = "singers")
public class Singer {

    @MongoId
    public String id;

    @Indexed
    public String firstName;

    @Indexed
    public String lastName;

    private LocalDate birthDate;

    public Singer() {
    }

    public Singer(String firstName, String lastName, LocalDate birthDate) {
        this.firstName = firstName;
        this.lastName = lastName;
        this.birthDate = birthDate;
    }

    // getters & setters omitted
}
```

MongoDB requires that all documents have an `_id` field. Using Spring Data, the field mapped to it is annotated with `@Id` or `@MongoId` from the `org.springframework.data.mongodb.core.mapping`. The `@MongoId` annotation is meta-annotated with `@Id` and, although used here to make it obvious that this class maps to a MongoDB document, it provides the possibility to configure the field type using `@MongoId(FieldType.*)`. When annotated like this, Spring Data will attempt to convert the value to the declared type.

The `@Indexed` annotation tells the mapping framework to call `createIndex(...)` on that property of your document, making searches faster.

If the name of the field is required to be different in the document than the in the Java class, you can annotate it with the `@Field` annotation to configure the desired value.

In Spring, types are mapped to and from a MongoDB representation using a set of built-in converters. This is the reason why we can declare the `LocalDate birthDate` field without any conversion annotation.

Now that we have a document, the next step is to create a repository for handling `Singer` instances. The approach is similar to the one shown for Spring Data JPA. In Spring Data MongoDB, there is a `MongoRepository<T, ID>` interface that is an extension of `CrudRepository<T, ID>` from the `org.springframework.data.repository` package (there is also a reactive version, but more about that in [Chapter 20](#)), and that is the interface our `SingerRepository` interface must extend. The `SingerRepository` interface is shown in [Listing 10-41](#).

**Listing 10-41.** `SingerRepository` MongoDB Data Repository Interface

```
package com.apress.prospring6.ten.repos;

import com.apress.prospring6.ten.document.Singer;
import org.springframework.data.mongodb.repository.MongoRepository;
import org.springframework.data.mongodb.repository.Query;
import org.springframework.data.repository.query.Param;

import java.time.LocalDate;

public interface SingerRepository extends MongoRepository<Singer, String> {

    Iterable<Singer> findByFirstName(String firstName);

    @Query("{ 'firstName' : ?0, 'lastName' : ?1}")
    Iterable<Singer> findByPositionedParams(String fn, String ln);

    @Query("{ 'firstName' : :#{#fn}, 'lastName' : :#{#ln}}")
    Iterable<Singer> findByNamedParams(@Param("fn") String fn, @Param("ln") String ln);
}
```

The `SingerRepository` interface introduced here contains two MongoDB custom queries. When writing MongoDB query expressions, parameters can be specified by position or they can be named, just like for SQL queries. The only thing that is different is the query expression syntax; MongoDB queries are essentially JSON objects. The `findByPositionedParams(...)` method uses indexes that match the order of the parameters, the `?0` corresponds to the first argument in the method, and the value of the argument will be used instead of `?0`. This means that developers must keep track of positions and not mix them up, because, although MongoDB won't fail, it won't return the expected result. However, query expressions are pretty simple, and thus this is the recommended approach.

It is possible to use named parameters as well, which are referenced via their names mixed with the `@Param` annotation and SpEL expressions. The expressions are more complex and verbose, but this approach is more flexible and there is no risk of mistakenly positioning the arguments. Use whichever option you are more comfortable with.

As we are already accustomed to, a `SingerService` bean is used to invoke repository methods, and its implementation, being basic, is not worth repeating here. What is important is the Spring configuration for connecting to a MongoDB instance and enabling Spring Data MongoDB repository support.

To connect to a MongoDB instance, a bean of type `com.mongodb.client.MongoClient` is needed. This bean can be declared by the developer directly in a `@Configuration` class as shown in [Listing 10-42](#).

*Listing 10-42.* MongoClient Bean Declaration

```
package com.apress.prospring6.ten.config;

import com.mongodb.client.MongoClients;
import com.mongodb.client.MongoClient;

@Configuration
public class MongoCfg {

    @Bean
    public MongoClient mongoClient() {
        return MongoClients.create("mongodb://prospring6:prospring6@localhost:27017/
            musicdb?authSource=admin");
    }
}
```

The `MongoClients.create(..)` static method is used to create a `MongoClient` instance based on the connection string provided as an argument. The connection string in the listing is built upon this template:

```
mongodb://[username:password@]host1[:port1][,...hostN[:portN]][/[defaultauthdb][?options]]
```

The concrete connection string used in this section has the following components:

- It starts with `mongodb://`, which represents the type of driver we are using (in the same way MySQL connection strings start with `jdbc:`).
- `prospring6:prospring6` represents `user:password` used to connect to the MongoDB database.
- `localhost` represents the location where the database is installed, in this case on the same machine where the code is executed (or in a container managed by the local Docker runtime).
- `27017` represents the connection port.
- `musicdb` is the name of the database, and the `prospring6` user must have the `dbOwner` role on it.
- `authSource=admin` is a parameter pointing to the collection where the user data is located, so the provided username and password can be checked against it.

This way of creating a `MongoClient` is the most direct one. When using Spring Data MongoDB, the recommended approach is to declare a Spring `MongoClientFactoryBean` as shown in Listing 10-43.

*Listing 10-43.* MongoClientFactoryBean Bean Declaration

```
package com.apress.prospring6.ten.config;

import org.springframework.data.mongodb.core.MongoClientFactoryBean;

@Configuration
public class MongoCfg {
```

```

@Bean
public MongoClientFactoryBean mongoClientFactory() {
    MongoClientFactoryBean mongo = new MongoClientFactoryBean();
    mongo.setConnectionString("mongodb://prospring6:prospring6@localhost:27017/
musicdb?authSource=admin");
    return mongo;
}
}

```

Enabling support for MongoDB Data repositories is done by annotating the configuration class with `@EnableMongoRepositories`. If no base package is configured, the infrastructure scans the package of the annotated configuration class.

Spring MongoDB Data repositories use a bean of `org.springframework.data.mongodb.core.MongoTemplate` to exchange data with the MongoDB instance, and thus this bean must be created too. Listing 10-44 shows the full configuration class, with the connection string being read from a `mongo.properties` file.

**Listing 10-44.** Spring Data MongoDB Application Full Configuration

```

/** === Contents of 'mongo.properties' file ===
mongo.url=mongodb://prospring6:prospring6@localhost:27017/musicdb?authSource=admin
mongo.db=musicdb
*/

```

```

package com.apress.prospring6.ten.config;

```

```

import org.springframework.data.mongodb.core.MongoTemplate;
import org.springframework.data.mongodb.core.MongoClientFactoryBean;

```

```

@ComponentScan(basePackages = {"com.apress.prospring6.ten.service"})
@EnableMongoRepositories(basePackageClasses = SingerRepository.class)
@Configuration
@PropertySource("classpath:mongo.properties")
public class MongoCfg {

```

```

    @Value("${mongo.url}")
    private String url;

```

```

    @Bean
    public MongoClientFactoryBean mongoClientFactory() {
        MongoClientFactoryBean mongo = new MongoClientFactoryBean();
        mongo.setConnectionString(url);
        return mongo;
    }

```

```

    @Bean
    public MongoTemplate mongoTemplate() {
        return new MongoTemplate(mongoClientFactory());
    }
}

```

So far, so good, but Spring can do a lot more with MongoDB, and thus it provides the `AbstractMongoClientConfiguration` class that declares a lot of MongoDB-specific infrastructure beans. It is recommended to configure your MongoDB application by extending this class and overriding its `mongoClientSettings()` method to provide the connection string. Based on this instance, Spring Data configures the `MongoClientFactoryBean`, the `MongoTemplate`, and all the other infrastructure beans. And if customization is needed, a lot of its methods can be overridden. Listing 10-45 shows the version of `MongoCfg` that extends class `AbstractMongoClientConfiguration` and overrides a few of its methods, especially `autoIndexCreation()` to turn on automatic index creation, since we have fields annotated with `@Indexed` in our configuration.

**Listing 10-45.** `MongoCfg` Class That Extends Class `AbstractMongoClientConfiguration`

```
package com.apress.prospring6.ten.config;

import com.mongodb.ConnectionString;
import com.mongodb.MongoClientSettings;
import org.springframework.data.mongodb.config.AbstractMongoClientConfiguration;
import org.springframework.data.mongodb.repository.config.EnableMongoRepositories;
// other import statements omitted

@ComponentScan(basePackages = {"com.apress.prospring6.ten.service"})
@EnableMongoRepositories
@Configuration
@PropertySource("classpath:mongo.properties")
public class MongoCfg extends AbstractMongoClientConfiguration {

    @Value("${mongo.url}")
    private String url;

    @Value("${mongo.db}")
    private String database;

    @Override
    protected String getDatabaseName() {
        return database;
    }

    @Override
    protected Collection<String> getMappingBasePackages() {
        return Collections.singleton("com.apress.prospring6.ten.repos");
    }

    @Override
    public boolean autoIndexCreation() {
        return true;
    }

    @Override
    protected MongoClientSettings mongoClientSettings() {
        MongoClientSettings.Builder builder = MongoClientSettings.builder();
        builder.applyConnectionString(new ConnectionString(url));
    }
}
```

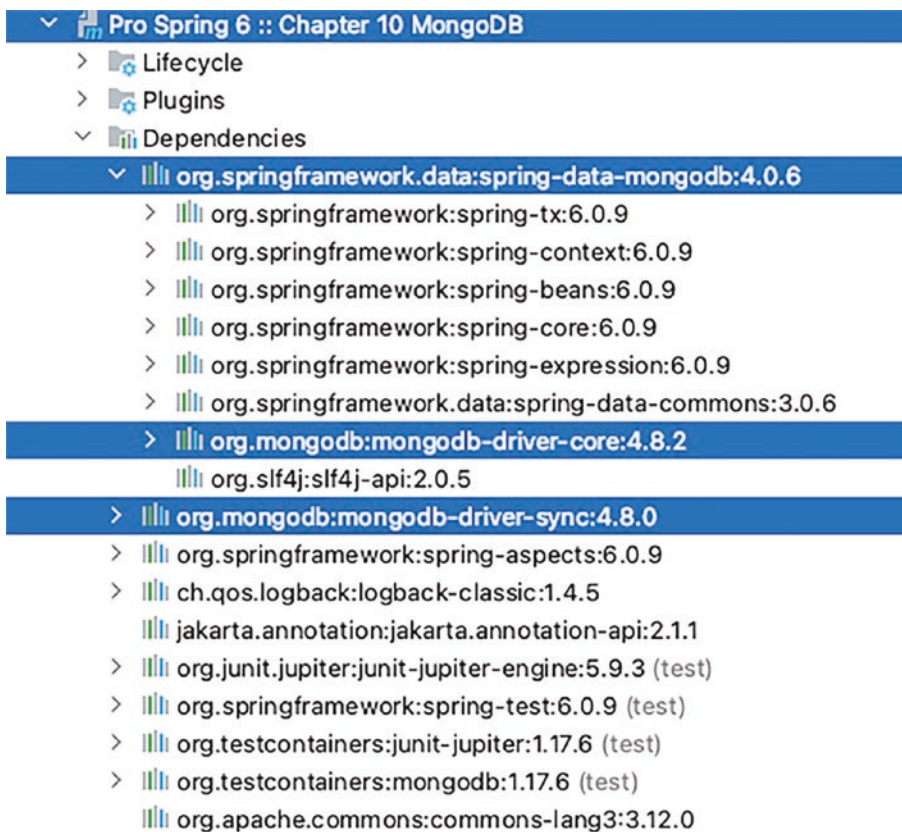
```

    this.configureClientSettings(builder);
    return builder.build();
}
}

```

The `getMappingBasePackages()` method is used to configure where the classes annotated with `@Document` are; if the method is not overridden, the infrastructure scans the package of the annotated configuration class and its sub-packages.

As for the project dependencies, because all these classes have to come from somewhere, the main dependencies of the project are the `spring-data-mongodb` and `mongodb-driver-sync` libraries. The `mongodb-driver-sync` library is a wrapper around `mongodb-driver-core` to provide classic behavior when interacting with a MongoDB instance. There is also a wrapper providing reactive behavior in the `mongodb-driver-reactivestreams` library. Figure 10-7 shows the dependencies for the `chapter10-mongo` project.



**Figure 10-7.** Gradle View showing dependencies for the `chapter10-mongo` project

One thing that needs to be mentioned here is that starting with MongoDB 4.0, transactions are supported as well. Transactions are built on top of Sessions and, consequently, require an active `com.mongodb.session.ClientSession`. If a `TransactionManager` bean is not configured, transactions are disabled.

Spring provides the `MongoTransactionManager` class for MongoDB transaction management. The `MongoTransactionManager` class binds a `ClientSession` session to the thread. `MongoTemplate` detects the session and operates on these resources, which are associated with the transaction accordingly. Since Spring Data MongoDB repositories are backed up by a `MongoTemplate` bean, their methods are executed in a transactional context.

Listing 10-46 shows the `MongoCfg` class modified for a transactional behavior.

**Listing 10-46.** `MongoCfg` Class with Transaction Management Configured

```
package com.apress.prospring6.ten.config;
// other import statements omitted
import org.springframework.data.mongodb.MongoDatabaseFactory;
import org.springframework.data.mongodb.MongoTransactionManager;
import org.springframework.transaction.annotation.EnableTransactionManagement;

@ComponentScan(basePackages = {"com.apress.prospring6.ten.service"})
@EnableMongoRepositories(basePackages = {"com.apress.prospring6.ten.repos"})
@Configuration
@PropertySource("classpath:mongo.properties")
@EnableTransactionManagement
public class MongoCfg extends AbstractMongoClientConfiguration {

    @Bean
    MongoTransactionManager transactionManager(MongoDatabaseFactory dbFactory) {
        return new MongoTransactionManager(dbFactory);
    }

    // other methods omitted
}
```

With this configuration, `@Transactional` can be used for configuring `SingerServiceImpl` as a transactional service. Programmatic transactions are supported as well, and the syntax is identical to the syntax already shown in **Chapter 9**.

Because of Spring Data consistency in its APIs, writing tests for a Spring Data Mongo application is no different from writing tests for a Spring Data JPA application.

If you are interested in working with Spring and MongoDB, the official documentation from Spring<sup>17</sup> and MongoDB<sup>18</sup> are rich and easy to follow. Also, feel free to give the Spring Boot MongoDB starter a try. A simple project is provided in the book repository.

## Considerations Using Spring Data

Whether you are using Spring Data JPA or MongoDB or any other module for a specific database, Spring Data reduces the work you have to do by a lot. Add in Spring Boot, and even configuration work is reduced considerably. However, to manage data efficiently, you must understand all the building blocks of the data managing infrastructure. This is what this book is good for, because it slowly builds all the layers, showing you the effort that you will be spared by using all that Spring has to offer correctly.

<sup>17</sup><https://docs.spring.io/spring-data/data-mongo/docs/current/reference/html/#reference>

<sup>18</sup><https://www.mongodb.com/docs/manual/reference/>



Still, depending on the size and scope of the project, using Spring Data might be overkill, so take that into consideration before starting to write your application.

It's like choosing a smartphone for your 83-year-old grandma who only needs to make and receive phone calls, and because she has arthritis, she might drop it a lot. So, it makes no sense to buy her an expensive, complex, fragile phone that provides a lot of functionalities that she will never use, when all her needs can be satisfied by a flip phone. So, consider the needs your project is trying to satisfy and choose the tools based on that.

## Summary

Since this is the last chapter in the series of chapters covering data access, an overall summary is in order:

- JPA is a specification that defines an API for object-relational mappings and for managing persistent objects. It existed as part of JEE until Oracle decided to make it open source and donate it to Jakarta. This triggered a package rename from `javax` to `jakarta`, and you might see the JPA acronym expanded to Jakarta Persistence API also, instead of the classic Java Persistence API. Both of them mean the same thing: the set of Java components used to map database objects and actions to Java objects and actions.
- All JPA implementations, such as Hibernate and EclipseLink latest's version, have aligned to the new specification.
- Spring Data JPA adds a layer on top of JPA and uses all its features, like entity and, association mapping, entity life-cycle management, and adds its own features, like the Spring Data no-code repositories.
- There are multiple Spring Data libraries, each designed to reduce boilerplate code when working with a particular database. Spring Data JPA is suitable for working with any relational database. For NoSQL databases, there are several libraries for MongoDB, CouchBase, Redis, etc.
- Transactional behavior is easy to configure by declaring a `TransactionManager` bean and annotating service classes and methods with Spring's `@Transactional` annotation. It is configured in the same way for relational databases and nonrelational databases, with only the type of the `TransactionManager` being different.
- Spring Data Boot starter libraries reduce the effort a developer must make to interact with a database by reducing the code necessary to be written to configure the application.
- Testcontainers is an amazing tool for testing Spring applications that require a database because it is easy to set up, allowing you to reuse most of the production-scoped configuration. This enables you to run integration tests in a test context as close to the production context as possible. Of course, it requires you to have Docker installed and access to the Internet so that container images can be pulled when needed.

This concludes the data access chapter series. The data access topic is touched again, but just a little bit, in **Chapter 20**, in the “Reactive Data Access” section.



# Validation, Formatting, and Type Conversion

In an enterprise application, data validation is critical. The purpose of data validation is to verify that the data being processed fulfills all predefined business requirements as well as ensures the data integrity and usefulness in all layers of the application.

In application development, data validation is always mentioned alongside conversion and formatting. The reason is that the format of the source of data most likely is different from the format being used in the application. For example, in a web application, a user enters information in the web browser front end. When the user saves that data, it is sent to the server (after the local validation has completed). On the server side, a data-binding process is performed, in which the data from the HTTP request is extracted, converted, and bound to corresponding domain objects (for example, a user enters singer information in an HTML form that is then bound to a `Singer` object in the server), based on the formatting rules defined for each attribute (for example, the date format pattern is `yyyy-MM-dd`). When the data binding is complete, validation rules are applied to the domain object to check for any constraint violation. If everything runs fine, the data is persisted, and a success message is displayed to the user. Otherwise, validation error messages are populated and displayed to the user.

In this chapter, you will learn how Spring provides sophisticated support for type conversion, field formatting, and validation. Specifically, this chapter covers the following topics:

- *The Spring type conversion system and the Formatter service provider interface (SPI):* We present the generic type conversion system and `Formatter<T>` SPI. We cover how the new services can be used to replace the previous `PropertyEditor` support and how they convert between any Java types.
- *Validation in Spring:* We discuss how Spring supports domain object validation. First, we provide a short introduction to Spring's own `Validator` interface. Then, we focus on the JSR-349 (Bean Validation) support.

## Converting String Values Using PropertyEditors

In Spring 3, a new type conversion system was introduced, providing a powerful way to convert between any Java types within Spring-powered applications. All classes are in the `org.springframework.core.convert` package. This section shows how this new service can perform the same functionality provided by the previous `PropertyEditor` support, as well as how it supports the conversion between any Java types. We also demonstrate how to implement a custom type converter by using the `Converter` SPI.

**Chapter 4** covered how Spring handles the conversion from a `String` in the properties files into the properties of POJOs by supporting `PropertyEditors`. Let's do a quick review here and then cover how Spring's `Converter` SPI (available since 3.0) provides a more powerful alternative.

**Listing 11-1** shows a record named `Blogger`. We are using records because we know we do not intend to modify these beans in any way, nor do we need to proxy them (it also reduces the code we need to write).

*Listing 11-1.* The Blogger Record with Various Field Types

```
package com.apress.prospring6.eleven.domain;

import java.net.URL;
import java.time.LocalDate;

public record Blogger (String firstName,
                     String lastName,
                     LocalDate birthDate,
                     URL personalSite) {}
```

For the `birthDate` attribute, the `java.time.LocalDate` type is used. In addition, there is a `URL` type field that indicates the blogger's personal web site, if applicable. Suppose we want to construct `Blogger` instances in Spring's `ApplicationContext`, with values stored either in Spring's configuration or in a properties file. To make things practical, the `AppConfig` class declares two `Blogger` beans: `awsBlogger`, which is created with property values injected using `@Value` annotations with hard-coded values, and `springBlogger`, which is created with property values injected using `@Value` annotations with values read from the `blogger.properties` configuration file. The properties file is configured using the `@PropertySource` annotation introduced in **Chapter 4**. The `AppConfig` class is shown in **Listing 11-2** and in the comment on top of it you can see the contents of the `blogger.properties` file.

*Listing 11-2.* A Spring Configuration Class Declaring Two Blogger Beans

```
package com.apress.prospring6.eleven;

import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.PropertySource;

import java.net.URL;
import java.time.LocalDate;
```

```

/*
springBlogger.firstName=Iuliana
springBlogger.lastName=Cosmina
springBlogger.birthDate=1983-08-16
springBlogger.personalSite=https://iuliana-cosmina.com
*/
@PropertySource("classpath:blogger.properties")
@Configuration
public class AppConfig {

    @Bean
    public Blogger awsBlogger(@Value("Alex") String firstName,
                              @Value("DeBrie") String lastName,
                              @Value("https://www.alexdebrie.com") URL personalSite,
                              @Value("1980-01-02") LocalDate birthDate) throws Exception {
        return new Blogger(firstName, lastName, birthDate, personalSite);
    }

    @Bean
    public Blogger springBlogger(@Value("${springBlogger.firstName}") String firstName,
                                  @Value("${springBlogger.lastName}") String lastName,
                                  @Value("${springBlogger.personalSite}") URL personalSite,
                                  @Value("${springBlogger.birthDate}") LocalDate birthDate)
        throws Exception {
        return new Blogger(firstName, lastName, birthDate, personalSite);
    }
}

```

An attempt to create an application context based on the `AppConfig` class would fail with a stacktrace making it quite obvious that Spring cannot convert the text representations of calendar dates to `java.time.LocalDate`:

```

org.springframework.beans.factory.UnsatisfiedDependencyException:
Error creating bean with name 'awsBlogger' defined in com.apress.prospring6.eleven.
AppConfig:
    Unsatisfied dependency expressed through method 'awsBlogger' parameter 3:
    Failed to convert value of type 'java.lang.String' to required type 'java.time.
    LocalDate';
    Cannot convert value of type 'java.lang.String' to required type 'java.time.
    LocalDate':
        no matching editors or conversion strategy found
    at app//org.springframework.beans.factory.support.ConstructorResolver.createArgument
    Array(ConstructorResolver.java:774)
Caused by: java.lang.IllegalStateException:
    Cannot convert value of type 'java.lang.String' to required type 'java.time.LocalDate':
    no matching editors or conversion strategy found at
    org.springframework.beans.TypeConverterDelegate.convertIfNecessary(TypeConverter
    Delegate.java:262)

```

To fix this, we need to tell Spring how to do the conversion of text representations of calendar dates to `java.time.LocalDate`. We can do so by using an extension of `PropertyEditorSupport` like the `LocalDatePropertyEditor` shown in Listing 11-3.

*Listing 11-3.* `LocalDatePropertyEditor` Class

```
package com.apress.prospring6.eleven.property.editor;

import java.beans.PropertyEditorSupport;
import java.time.LocalDate;
import java.time.format.DateTimeFormatter;

public class LocalDatePropertyEditor extends PropertyEditorSupport {
    private DateTimeFormatter dateFormat = DateTimeFormatter.ofPattern("yyyy-MM-dd");

    @Override
    public void setAsText(String text) throws IllegalArgumentException {
        setValue(LocalDate.parse(text, dateFormat));
    }
}
```

A `CustomEditorConfigurer` bean needs to be part of the configuration to register our custom property editor: the `LocalDatePropertyEditor`. The old-style approach, introduced in Spring 2, is to declare a `PropertyEditorRegistrar` bean that maps the `LocalDatePropertyEditor` instance to the type the text representation is converted to, in this case `LocalDate`. By the magic of lambda expressions, a bean of a custom type implementing `PropertyEditorRegistrar` can be created in a single line. Listing 11-4 shows the configuration class declaring all the necessary beans to enable the proper conversion of text representations to `LocalDate`.

This bean can be created on the spot using lambda expressions like the one in Listing 11-4.

*Listing 11-4.* `PropertyEditorRegistrar` Class

```
package com.apress.prospring6.eleven.property.editor;

import org.springframework.beans.PropertyEditorRegistrar;
import org.springframework.beans.factory.config.CustomEditorConfigurer;
// other import statements omitted

import java.time.LocalDate;

@Configuration
public class CustomRegistrarCfg {

    @Bean
    public PropertyEditorRegistrar registrar(){
        return registry ->
            registry.registerCustomEditor(LocalDate.class, new LocalDatePropertyEditor());
    }
}
```

```

@Bean
public CustomEditorConfigurer customEditorConfigurer() {
    var cus = new CustomEditorConfigurer();
    var registrars = new PropertyEditorRegistrar[1];
    registrars[0] = registrar();
    cus.setPropertyEditorRegistrars(registrars);
    return cus;
}
}

```

To test this class, we need to build an application context based on the `AppConfig` bean classes and the `CustomRegistrarCfg` and retrieve the two blogger beans and print their properties to the console. This can be done using a test method, as shown in Listing 11-5.

**Listing 11-5.** ConvertersTest Class and Method Used to Test the `LocalDatePropertyEditor`

```
package com.apress.prospring6.eleven;
```

```

public class ConvertersTest {
    private static final Logger LOGGER = LoggerFactory.getLogger(ConvertersTest.class);

    @Test
    public void testCustomPropertyEditorRegistrar() {
        try (var ctx = new AnnotationConfigApplicationContext(AppConfig.class,
            CustomRegistrarCfg.class)) {
            var springBlogger = ctx.getBean("springBlogger", Blogger.class);
            LOGGER.info("SpringBlogger info: {}", springBlogger);

            var awsBlogger = ctx.getBean("awsBlogger", Blogger.class);
            LOGGER.info("AwsBlogger info: {}", awsBlogger);
        }
    }
}

```

*// expected output*

```

INFO ConvertersTest -
    SpringBlogger info: Blogger{ firstName='Iuliana',
                        lastName='Cosmina',
                        birthDate=1983-08-16,
                        personalSite=https://iuliana-cosmina.com}
INFO ConvertersTest -
    AwsBlogger info: Blogger{firstName='Alex',
                            lastName='DeBrie',
                            birthDate=1980-01-02,
                            personalSite=https://www.alexdebrie.com/}

```

When running this method, the context should be successfully created and the two beans retrieved from it and printed.

There is another version of this configuration, that requires a single bean of type `CustomEditorConfigurer` that registers the custom property editor by mapping it to a certain type, and a custom `PropertyEditorRegistrar` is not necessary, as shown in the configuration class in Listing 11-6.

*Listing 11-6.* CustomEditorCfg Class

```
package com.apress.prospring6.eleven.property.editor;

import org.springframework.beans.factory.config.CustomEditorConfigurer;
// other imports statement omitted

@Configuration
public class CustomEditorCfg {

    @Bean
    public CustomEditorConfigurer customEditorConfigurer() {
        var cus = new CustomEditorConfigurer();
        cus.setCustomEditors(Map.of(LocalDate.class, LocalDatePropertyEditor.class));
        return cus;
    }
}
```

This is the old way of doing it. The new way involves classes from the `org.springframework.core.convert` package and is discussed in the next section.

## Introducing Spring Type Conversion

Spring 3.0 introduced a general type conversion system that resides under the package `org.springframework.core.convert`. In addition to providing an alternative to `PropertyEditor` support, the type conversion system can be configured to convert between any Java types and POJOs (while `PropertyEditor` is focused on converting `String` representations in the properties file into Java types).

### Implementing a Custom Converter

To see the type conversion system in action, let's revisit the previous example and use the same `Blogger` class. Suppose this time we want to use the type conversion system to convert the date in `String` format into the blogger's `birthDate` property, which is of `LocalDate` type. To support the conversion, instead of creating a custom `PropertyEditor`, we create a custom converter by implementing the `org.springframework.core.convert.converter.Converter<S, T>` interface. Listing 11-7 shows the custom converter.

*Listing 11-7.* LocalDateConverter Implementation

```
package com.apress.prospring6.eleven.converter.bean;

import org.springframework.core.convert.converter.Converter;

import java.time.LocalDate;
import java.time.format.DateTimeFormatter;

public class LocalDateConverter implements Converter<String, LocalDate> {
    private DateTimeFormatter dateFormat = DateTimeFormatter.ofPattern("yyyy-MM-dd");
```

```

@Override
public LocalDate convert(String source) {
    return LocalDate.parse(source, dateFormat);
}
}

```

We implement the interface `Converter<String, DateTime>`, which means the converter is responsible for converting a `String` (the source type `S`) to a `LocalDate` type (the target type `T`).

To use this converter instead of the `PropertyEditor`, we need to configure an instance of the `org.springframework.core.convert.ConversionService` interface in Spring's `ApplicationContext`. Listing 11-8 shows the Java configuration class.

**Listing 11-8.** Java Configuration Class for Using a Converter Implementation

```

package com.apress.prospring6.eleven.converter.bean;

import org.springframework.context.support.ConversionServiceFactoryBean;
// other import statements omitted

@Configuration
@ComponentScan
public class ConverterCfg {

    @Bean
    public ConversionServiceFactoryBean conversionService() {
        var conversionServiceFactoryBean = new ConversionServiceFactoryBean();
        var convs = new HashSet<>();
        convs.add(new LocalDateConverter());
        conversionServiceFactoryBean.setConverters(convs);
        conversionServiceFactoryBean.afterPropertiesSet();
        return conversionServiceFactoryBean;
    }
}

```

Here we instruct Spring to use the type conversion system by declaring a `conversionService` bean with the class `ConversionServiceFactoryBean`. This type of bean groups multiple conversion services. If no conversion service bean is defined, Spring will use the `PropertyEditor`-based system.

By default, the type conversion service supports conversion between common types including strings, numbers, enums, collections, maps, and so on. In addition, the conversion from `String` instances to Java types within the `PropertyEditor`-based system is supported.

The testing method is almost identical to the one shown in Listing 11-5, the only difference being that the `CustomRegistrarCfg` class is replaced with `ConverterCfg`.

## Converting Between Arbitrary Types

The real strength of the type conversion system is the ability to convert between arbitrary types.

Listing 11-9 introduces the record `SimpleBlogger` that only has two fields and the converter implementation that converts a `Blogger` instance to a `SimpleBlogger` instance.



*Listing 11-9.* SimpleBlogger Record and Converter

```

package com.apress.prospring6.eleven.domain;

import com.apress.prospring6.eleven.Blogger;
import org.springframework.core.convert.converter.Converter;

import java.net.URL;

public record SimpleBlogger (String fullName, URL personalSite) {

    public static class BloggerToSimpleBloggerConverter implements Converter<Blogger,
SimpleBlogger> {

        @Override
        public SimpleBlogger convert(Blogger source) {
            return new SimpleBlogger(source.firstName() + " " + source.lastName(), source.
personalSite());
        }
    }
}

```

To add this converter to the application context configuration, an instance of `BloggerToSimpleBloggerConverter` needs to be added to the converters set of the `ConversionServiceFactoryBean` as shown in Listing 11-10.

*Listing 11-10.* SimpleBlogger Class and Converter

```

package com.apress.prospring6.eleven.converter.bean;

// import statements omitted

@Configuration
@ComponentScan
public class ConverterCfg {

    @Bean
    public ConversionServiceFactoryBean conversionService() {
        var conversionServiceFactoryBean = new ConversionServiceFactoryBean();
        var convs = new HashSet<>();
        convs.add(new LocalDateConverter());
        convs.add(new SimpleBlogger.BloggerToSimpleBloggerConverter());
        conversionServiceFactoryBean.setConverters(convs);
        conversionServiceFactoryBean.afterPropertiesSet();
        return conversionServiceFactoryBean;
    }
}

```

To test this converter, we need to retrieve the converter bean from the context and convert one of our `Blogger` instances to a `SimpleBlogger` instance, as shown in Listing 11-11.

*Listing 11-11.* Conversion to SimpleBlogger

```

package com.apress.prospring6.eleven;

import org.springframework.core.convert.ConversionService;

public class ConvertersTest {
    @Test
    public void testConvertingToSimpleBlogger() {
        try (var ctx = new AnnotationConfigApplicationContext(AppConfig.class, ConverterCfg.class)) {
            var springBlogger = ctx.getBean("springBlogger", Blogger.class);
            LOGGER.info("SpringBlogger info: {}", springBlogger);

            var conversionService = ctx.getBean(ConversionService.class);
            var simpleBlogger = conversionService.convert(springBlogger, SimpleBlogger.class);
            LOGGER.info("simpleBlogger info: {}", simpleBlogger);
        }
    }
}
// expected output
INFO ConvertersTest - SpringBlogger info:
    Blogger[firstName=Iuliana,
            lastName=Cosmina,
            birthDate=1983-08-16,
            personalSite=https://iuliana-cosmina.com]
INFO ConvertersTest - simpleBlogger info: SimpleBlogger[fullName=Iuliana Cosmina,
            personalSite=https://iuliana-cosmina.com]

```

As you have probably noticed, the conversion from string to `java.net.URL` was done automatically for the `personalSite` field. This is because Spring registers out of the box a set of converters that handle the most common development use cases (e.g., from a string representing a list of items separated by commas to an `Array`, from a `List` to a `Set`, etc.).

With Spring's type conversion service, you can create custom converters easily and perform conversion at any layer within your application. One possible use case is that you have two systems with the same blogger information that you need to update. However, the database structure is different (for example, system A has two field names, but system B has a single field, and so on). You can use the type conversion system to convert the objects before persisting to each individual system.

Starting with Spring 3.0, Spring MVC makes heavy use of the conversion service (as well as the `Formatter` SPI discussed in the next section). In the web application context configuration, the Java configuration class annotated with `@EnableWebMvc` introduced in Spring 3.1 will automatically register all default converters (for example, `StringToArrayConverter`, `StringToBooleanConverter`, and `StringToLocaleConverter`, all residing under the `org.springframework.core.convert.support` package) and formatters (for example, `CurrencyStyleFormatter`, `DateFormatter`, and `AbstractNumberFormatter`, all residing under various subpackages within the `org.springframework.format` package). More details are covered in **Chapter 14**, when we discuss web application development in Spring.

## Field Formatting in Spring

Besides the type conversion system, another great feature that Spring brings to developers is the Formatter SPI. As you might expect, this SPI can help configure the field-formatting aspects. In the Formatter SPI, the main interface for implementing a formatter is the `org.springframework.format.Formatter<T>` interface. Spring provides a few implementations of commonly used types, including `CurrencyStyleFormatter`, `DateFormatter`, `AbstractNumberFormatter`, and `PercentStyleFormatter`.

Implementing a custom formatter is as easy as implementing a customer converter. We will use the same Blogger record, but instead of using a converter, we'll implement a custom formatter for converting the `LocalDate` type of the `birthDate` attribute to and from a `String`. This involves extending Spring's `org.springframework.format.support.FormattingConversionServiceFactoryBean` class and providing our custom formatter. The `FormattingConversionServiceFactoryBean` class is a factory class that provides convenient access to the underlying `FormattingConversionService` class, which supports the type conversion system, as well as field formatting according to the formatting rules defined for each field type.

In Listing 11-12 you can see a custom class that extends the `FormattingConversionServiceFactoryBean` class, with a custom formatter defined for formatting Java's `LocalDate` type. Notice that the formatter is configurable with a date pattern.

*Listing 11-12.* `ApplicationConversionServiceFactoryBean` Implementation

```
package com.apress.prospring6.eleven.formatter.factory;

import org.springframework.format.Formatter;
import org.springframework.format.support.FormattingConversionServiceFactoryBean;
// other import statements omitted

@Service("conversionService")
public class ApplicationConversionServiceFactoryBean extends
FormattingConversionServiceFactoryBean {
    private static final Logger LOGGER = LoggerFactory.getLogger(ApplicationConversion
ServiceFactoryBean.class);

    private static final String DEFAULT_DATE_PATTERN = "yyyy-MM-dd";
    private DateTimeFormatter dateTimeFormatter;
    private String datePattern = DEFAULT_DATE_PATTERN;
    private final Set<Formatter<?>> formatters = new HashSet<>();

    public String getDatePattern() {
        return datePattern;
    }

    @Autowired(required = false)
    public void setDatePattern(String datePattern) {
        this.datePattern = datePattern;
    }
}
```

```

@PostConstruct
public void init() {
    dateTimeFormatter = DateTimeFormatter.ofPattern(datePattern);
    formatters.add(getDateTimeFormatter());
    setFormatters(formatters);
}
public Formatter<LocalDate> getDateTimeFormatter() {
    return new Formatter<>() {
        @Override
        public LocalDate parse(String source, Locale locale)
            throws ParseException {
            LOGGER.info("Parsing date string: " + source);
            return LocalDate.parse(source, dateTimeFormatter);
        }

        @Override
        public String print(LocalDate source, Locale locale) {
            LOGGER.info("Formatting datetime: " + source);
            return source.format(dateTimeFormatter);
        }
    };
}
}

```

In Listing 11-12, the custom formatter implementation is shown in bold font. It implements the `Formatter<LocalDate>` interface and implements the two methods defined by the interface. The `parse(..)` method parses the `String` format into the `LocalDate` type (the locale was also passed for localization support), while the `LOGGER.info(..)` method is to format a `LocalDate` instance into a `String`. The date pattern can be injected into the bean (or the default will be `yyyy-MM-dd`). Also, in the `init()` method, the custom formatter is registered by calling the `setFormatters()` method. You can add as many formatters as required.

Since `ApplicationConversionServiceFactoryBean` is configured as a bean, the simplest way to use it is just to create an annotation context using the `AppConfig` class and this bean. Listing 11-13 shows a test method creating this context and printing the two `Blogger` beans.

**Listing 11-13.** `ApplicationConversionServiceFactoryBean` Implementation test

```

package com.apress.prospring6.eleven;
// import statements omitted

public class FormattersTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(FormattersTest.class);

    @Test
    public void testFormattingFactoryService() {
        try (var ctx = new AnnotationConfigApplicationContext(AppConfig.class,
            ApplicationConversionServiceFactoryBean.class)) {
            var springBlogger = ctx.getBean("springBlogger", Blogger.class);
            LOGGER.info("SpringBlogger info: {}", springBlogger);
        }
    }
}

```

```

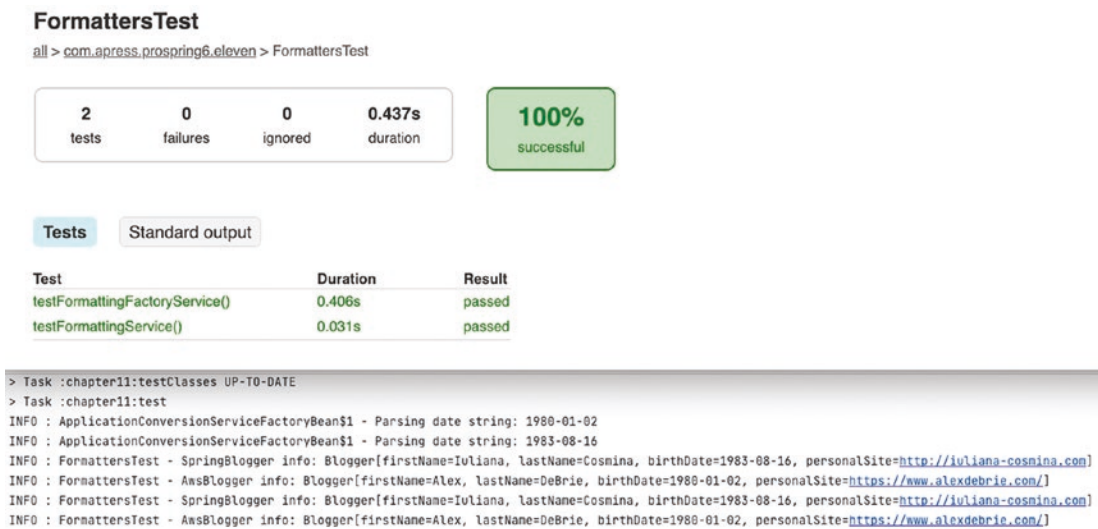
        var awsBlogger = ctx.getBean("awsBlogger", Blogger.class);
        LOGGER.info("AwsBlogger info: {}", awsBlogger);
    }
}
}

```

The purpose of this test is to show that the application context is created correctly, and the two Blogger beans are too.



This method might not look like a test because there are no assertion statements, but this method essentially tests the assumption that all beans in the configuration are configured correctly. If you run the Gradle build, a very nice web page with test results is generated for you. Figure 11-1 shows this page and the console execution log showing these tests passing.



**Figure 11-1.** Gradle test result page and log showing the test methods under *FormattersTest* passing

The output of executing the `testFormattingFactoryService()` test method is similar to the output shown in the conversion section (Listing 11-11), proving that the responsibility of converting a text representation to a `LocalDate` was taken over by the `Formatter<LocalDate>` instance.

The `Formatter<T>` SPI is a composed interface, extending interfaces `Printer<T>` and `Parser<T>`. All three interfaces are part of the `org.springframework.format` package. Each of the methods implemented in the `Formatter<LocalDate>` shown in Listing 11-12 is provided by one of these interfaces. The three interfaces are shown in Listing 11-14.<sup>1</sup>

<sup>1</sup><https://github.com/spring-projects/spring-framework/tree/main/spring-context/src/main/java/org/springframework/format>

**Listing 11-14.** Spring Formatting SPI Interfaces

```
// ---- Formatter.java ----
package org.springframework.format;

public interface Formatter<T> extends Printer<T>, Parser<T> {
}

// ---- Printer.java ----
@FunctionalInterface
public interface Printer<T> {
    String print(T fieldValue, Locale locale);
}

// ---- Parser.java ----
import java.text.ParseException;
import java.util.Locale;

@FunctionalInterface
public interface Parser<T> {
    T parse(String clientValue, Locale locale) throws ParseException;
}
```

Every time you need a formatter, all you have to do is implement the `Formatter<T>` interface and parametrize it with the desired type and then add it to the Spring configuration using either custom `FormattingConversionServiceFactoryBean` or by declaring a bean of type `FormattingConversionService` and adding the formatter instance to it. The easiest is to use the `DefaultFormattingConversionService`, an out-of-the-box specialization of `FormattingConversionService` configured by default with converters and formatters appropriate for most applications.

Listing 11-15 shows the `FormattingServiceCfg` class that declares a bean named `conversionService` that is a `DefaultFormattingConversionService` to which the `Formatter<LocalDate>` implementation is added.

**Listing 11-15.** Configuration Class Using `DefaultFormattingConversionService` to Register a Custom Formatter

```
package com.apress.prospring6.eleven.formatter;

import org.springframework.format.Formatter;
import org.springframework.format.support.DefaultFormattingConversionService;
import org.springframework.format.support.FormattingConversionService;
// other import statements omitted

@Configuration
public class FormattingServiceCfg {

    @Bean
    public FormattingConversionService conversionService() {
        var formattingConversionServiceBean = new DefaultFormattingConversionService(true);
        formattingConversionServiceBean.addFormatter(localDateFormatter());
        return formattingConversionServiceBean;
    }
}
```

```

protected Formatter<LocalDate> localDateFormatter() {
    return new Formatter<LocalDate>() {
        @Override
        public LocalDate parse(String source, Locale locale) throws ParseException {
            return LocalDate.parse(source, getDateFormatter());
        }

        @Override
        public String print(LocalDate source, Locale locale) {
            return source.format(getDateFormatter());
        }

        protected DateTimeFormatter getDateFormatter(){
            return DateTimeFormatter.ofPattern("yyyy-MM-dd");
        }
    };
}

```



When declaring a bean of type `FormattingConversionService` to customize the list of converters and formatters in your Spring application, make sure this bean is named `conversionService`, because Spring does not like it any other way. The same applies for a bean of type `ConversionServiceFactoryBean`, the convenient implementation to configure access to a `ConversionService` configured with converters appropriate for most environments.



Notice that the `DefaultFormattingConversionService` constructor with a value of `true`. This value is assigned to the `registerDefaultFormatters` field and is necessary to enable the set of default formatters in the context. If set to `false` this bean will just enable the default set of converters.

---

## Validation in Spring

Validation is a critical part of any application. Validation rules applied on domain objects ensure that all business data is well structured and fulfills all the business definitions. The ideal case is that all validation rules are maintained in a centralized location, and the same set of rules are applied to the same type of data, no matter which source the data comes from (for example, from user input via a web application, from a remote application via web services, from a JMS message, or from a file).

When talking about validation, conversion and formatting are important too, because before a piece of data can be validated, it should be converted to the desired POJO according to the formatting rules defined for each type. For example, a user enters some blogger information via a web application within a browser and then submits that data to a server. On the server side, if the web application was developed in Spring MVC, Spring will extract the data from the HTTP request and perform the conversion from a `String` to the desired type based on the formatting rule (for example, a `String` representing a date will be converted into a `LocalDate` field, with the formatting rule `yyyy-MM-dd`). The process is called *data binding*. When the data

binding is complete and the domain object constructed, validation will then be applied to the object, and any errors will be returned and displayed to the user. If validation succeeds, the object will be persisted to the database.

Spring supports two main types of validation. The first one is provided by Spring. Validators are created by implementing the `org.springframework.validation.Validator` interface, depicted in Listing 11-16.<sup>2</sup>

**Listing 11-16.** Spring's Validator Interface

```
package org.springframework.validation;

public interface Validator {

    boolean supports(Class<?> clazz);
    void validate(Object target, Errors errors);

}
```

The other type of validation is via Spring's support of JSR-349 (Bean Validation)<sup>3</sup>, now renamed Jakarta Bean Validation. We present both type of validation in the coming sections.

## Using the Spring Validator Interface

Using Spring's `Validator` interface, we can develop some validation logic by creating a class to implement the interface. Let's see how it works. For the `Blogger` class that we've worked with so far, suppose the first name cannot be empty. To validate `Blogger` objects against this rule, a custom validator is needed. The code snippet in Listing 11-17 shows the `BloggerValidator` validator class.

**Listing 11-17.** Custom Validator for Blogger Class

```
package com.apress.prospring6.eleven.validator;

import org.springframework.validation.Errors;
import org.springframework.validation.ValidationUtils;
import org.springframework.validation.Validator;
// other import statements omitted

@Component("simpleBloggerValidator")
public class SimpleBloggerValidator implements Validator {
    @Override
    public boolean supports(Class<?> clazz) {
        return Blogger.class.equals(clazz);
    }
}
```

<sup>2</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-context/src/main/java/org/springframework/validation/Validator.java>

<sup>3</sup><https://jcp.org/en/jsr/detail?id=349>



```

@Override
public void validate(Object target, Errors errors) {
    ValidationUtils.rejectIfEmpty(errors, "firstName", "field.required");
}
}

```

The validator class implements the `Validator` interface and implements two methods. The `supports(..)` method indicates whether validation of the passed-in class type is supported by the validator. The `validate(..)` method performs validation on the passed-in object. The result will be stored in an instance of the `org.springframework.validation.Errors` interface. In the `validate(..)` method, we perform a check only on the `firstName` attribute and use the convenient `ValidationUtils.rejectIfEmpty(..)` method to ensure that the first name of the blogger is not empty. The last argument is the error code, which can be used for looking up validation messages from resource bundles to display localized error messages.



To add this bean to a Spring application context, a `@ComponentScan(basePackages = {"com.apress.prospring6.eleven.validator"})` is required on an existing configuration class, and when the application starts it will be automatically picked up. However, in our test methods, we avoid that annotation to avoid test context pollution, and instead we build it explicitly from the application configuration class `AppConfig` and any other validator bean class targeted by the test.



Any external data entering a system needs to be validated, converted, and formatted to types that are known. Converters, formatters, and validators are necessary components for applications that handle user-provided data, like web applications with forms, or applications that import data from any third-party source.

---

Using Spring MVC for writing Spring applications is covered in **Chapter 14**. In this type of applications is where the power of converters, formatters, and validators truly shines. Since we are not there yet, application contexts in this chapter are created by direct instantiation, and the validator is invoked explicitly. The `SimpleBloggerValidator` is tested in Listing 11-18.

*Listing 11-18.* Testing the Custom Validator for the Blogger Class

```

package com.apress.prospring6.eleven;

import com.apress.prospring6.eleven.formatter.FormattingServiceCfg;
import com.apress.prospring6.eleven.validator.BloggerValidator;
import org.springframework.validation.BeanPropertyBindingResult;
import org.springframework.validation.ValidationUtils;
// other import statements omitted

public class SpringValidatorTest {

```

```

private static final Logger LOGGER = LoggerFactory.getLogger(SpringValidatorTest.class);

@Test
void testSimpleBloggerValidator() throws MalformedURLException {
    try (var ctx = new AnnotationConfigApplicationContext(AppConfig.
        class, FormattingServiceCfg.class, SimpleBloggerValidator.class)) {
        var blogger = new Blogger("", "Pedala", LocalDate.of(2000, 1, 1), new
            URL("https://none.co.uk"));

        var bloggerValidator = ctx.getBean(SimpleBloggerValidator.class);
        var result = new BeanPropertyBindingResult(blogger, "blogger");

        ValidationUtils.invokeValidator(bloggerValidator, blogger, result);

        var errors = result.getAllErrors();
        assertEquals(1, errors.size());
        errors.forEach(e -> LOGGER.info("Object '{}' failed validation. Error code: {}",
            e.getObjectName(), e.getCode()));
    }
}

```

In the test method in Listing 11-18, a `Blogger` object is constructed with the first name set to an empty `String` value. Then, the validator bean is retrieved from `ApplicationContext`. To store the validation result, an instance of the `BeanPropertyBindingResult` class is constructed using the object to be validated and a name for it, which is what the second argument is for. This might be useful for reporting the error to the next service in the chain, or for logging. To perform the validation, the `ValidationUtils.invokeValidator()` method is called, and then a normal assertion statement checks the number of error objects returned. Since the `Blogger` instance is created with no `firstName`, the validation fails and an error object with the `field.required` error code is created.

This example shows a very simple validation, just checking that a property of the object is empty, but the `validate(..)` method can be even more complex, testing more of the object properties against different rules.



A null value is not the same as an empty `String` value, so a `Blogger` object with a null first name will not fail the validation rule described by the `SimpleBloggerValidator` class.

---

For example, the version of `BloggerValidator` in Listing 11-19 checks if at least one of `firstName` or `lastName` is present and not null (the `StringUtils.isEmpty(..)` method makes sure of that), and the `birthDate` is bigger than the 1st of January 1983.

**Listing 11-19.** Complex Validator Implementation for Blogger

```

package com.apress.prospring6.eleven.validator;

import org.apache.commons.lang3.StringUtils;
// import statements omitted

@Component("complexBloggerValidator")

```

```

public class ComplexBloggerValidator implements Validator {
    @Override
    public boolean supports(Class<?> clazz) {
        return Blogger.class.equals(clazz);
    }

    @Override
    public void validate(Object target, Errors errors) {
        var b = (Blogger) target;
        if(StringUtils.isEmpty(b.firstName()) && StringUtils.isEmpty(b.lastName())) {
            errors.rejectValue("firstName", "firstNameOrLastName.required");
            errors.rejectValue("lastName", "firstNameOrLastName.required");
        }
        if(b.birthDate().isBefore(LocalDate.of(1983,1,1))) {
            errors.rejectValue("birthDate", "birthDate.greaterThan1983");
        }
    }
}

```

Aside from this, the `Validator` interface can be implemented to validate complex objects by reusing validation logic for nested objects. To show this, a new class is needed named `BloggerWithAddress` that models exactly what its name says: a blogger with an address. The address is modeled using a record, the blogger with a class because this allows for a validation to be applicable to all the classes extending it. Listing 11-20 shows the `Address` record and the `BloggerWithAddress` class.

**Listing 11-20.** Complex `BloggerWithAddress` with a Nested Field of Type `Address`

```

// ---- Address.java ----
package com.apress.prospring6.eleven.domain;

public record Address(String city, String country) {
}

// ---- BloggerWithAddress.java ----
package com.apress.prospring6.eleven.domain;

public class BloggerWithAddress {
    private String firstName;
    private String lastName;
    private LocalDate birthDate;
    private URL personalSite;
    private Address address;

    // getters and setters omitted
}

```

Listing 11-21 shows the `AddressValidator` that verifies that both city and country fields are populated and that they contain only letters.

**Listing 11-21.** AddressValidator Class

```

package com.apress.prospring6.eleven.validator;

import org.apache.commons.lang3.StringUtils;
// other import statements omitted

@Component("addressValidator")
public class AddressValidator implements Validator {
    @Override
    public boolean supports(Class<?> clazz) {
        return Address.class.equals(clazz);
    }

    @Override
    public void validate(Object target, Errors errors) {
        ValidationUtils.rejectIfEmpty(errors, "city", "city.empty");
        ValidationUtils.rejectIfEmpty(errors, "country", "country.empty");

        var address = (Address)target;
        if(!StringUtils.isAlpha(address.city())) {
            errors.rejectValue("city", "city.onlyLettersAllowed");
        }
        if(!StringUtils.isAlpha(address.country())) {
            ValidationUtils.rejectIfEmpty(errors, "country", "country.onlyLettersAllowed");
        }
    }
}

```

Listing 11-22 shows the BloggerWithAddressValidator validator that checks that fields address and personalSite are populated, that at least one of firstName and lastName is populated, and that the address is valid by using the AddressValidator.

**Listing 11-22.** BloggerWithAddressValidator Class

```

package com.apress.prospring6.eleven.validator;
// import statements omitted

@Component("bloggerWithAddressValidator")
public class BloggerWithAddressValidator implements Validator {

    private final Validator addressValidator;

    public BloggerWithAddressValidator(Validator addressValidator) {
        if (!addressValidator.supports(Address.class)) {
            throw new IllegalArgumentException("The supplied [Validator] must " +
                "support the validation of [Address] instances.");
        }
        this.addressValidator = addressValidator;
    }
}

```

```

@Override
public boolean supports(Class<?> clazz) {
    return BloggerWithAddress.class.isAssignableFrom(clazz);
}

@Override
public void validate(Object target, Errors errors) {
    ValidationUtils.rejectIfEmptyOrWhitespace(errors, "address", "address.required");
    ValidationUtils.rejectIfEmptyOrWhitespace(errors, "personalSite", "personalSite.
    required");
    var b = (BloggerWithAddress) target;
    if(StringUtils.isEmpty(b.getFirstName()) && StringUtils.isEmpty(b.getLastName())) {
        errors.rejectValue("firstName", "firstNameOrLastName.required");
        errors.rejectValue("lastName", "firstNameOrLastName.required");
    }
    try {
        errors.pushNestedPath("address");
        ValidationUtils.invokeValidator(this.addressValidator, b.getAddress(), errors);
    } finally {
        errors.popNestedPath();
    }
}
}

```

Notice that the `BloggerWithAddressValidator` is a composed object that has a nested `AddressValidator` field. This field is used to validate the nested address field in a `BloggerWithAddress` instance. Notice the body of the `supports(..)` method. The `BloggerWithAddress.class.isAssignableFrom(clazz)` statement validates that the target object is either an instance of `BloggerWithAddress`, either an instance of its superclass.

The two methods `pushNestedPath(..)` and `popNestedPath(..)` are used to generate nested error properties for the error messages. For example, when the current path is `blogger.`, a call to `pushNestedPath("address")` results in the path being changed to `blogger.address.`, which means the error properties are relative to this path. Then, a call to `popNestedPath()` results in the path reverting to `blogger.` again.

To test this implementation, we'll do the same as before: construct a Spring configuration using the `AddressValidator`, `BloggerWithAddressValidator`, and the existing `AppConfig` class. Then we'll create a `BloggerWithAddress` instance that fails the validation and check that our validator reports the existing error. The code is shown in Listing 11-23.

**Listing 11-23.** Testing the `BloggerWithAddressValidator` Class

```

package com.apress.prospring6.eleven;
// import statements omitted

public class SpringValidatorTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(SpringValidatorTest.class);

    @Test
    void testBloggerWithAddressValidator() throws MalformedURLException {

```

```

try (var ctx = new AnnotationConfigApplicationContext(AppConf
ig.class, FormattingServiceCfg.class, AddressValidator.class,
BloggerWithAddressValidator.class)) {
    var address = new Address("221B", "UK");
    var blogger = new BloggerWithAddress( null, "Mazzie", LocalDate.of(1973, 1, 1),
null, address);

    var bloggerValidator = ctx.getBean(BloggerWithAddressValidator.class);
    var result = new BeanPropertyBindingResult(blogger, "blogger");

    ValidationUtils.invokeValidator(bloggerValidator, blogger, result);

    var errors = result.getAllErrors();
    assertEquals(2, errors.size());
    errors.forEach(e -> LOGGER.info("Error Code: {}", e.getCode()));
}
}
}
}
\\ expected output
DEBUG ValidationUtils - Validator found 2 errors
INFO SpringValidatorTest - Error Code: personalSite.required
INFO SpringValidatorTest - Error Code: city.onlyLettersAllowed

```

The objects in bold font both fail the validation: the address has a city named 221B and the blogger has a null `personalSite`.

The examples in this section all print the error codes. Outputting messages that correspond to validation errors is a topic for **Chapter 14**. That's pretty much it for Spring validation. The next sections cover Spring integration with Jakarta's Bean Validation API and Hibernate Validator.

## Using JSR-349/Jakarta Bean Validation

As of Spring 4, full support for JSR-349 (Bean Validation 3.0)<sup>4</sup> has been implemented. The Bean Validation API defines a set of constraints in the form of Java annotations (for example, `@NotNull`) under the package `jakarta.validation.constraints` that can be applied to the domain objects. In addition, custom validators (for example, class-level validators) can be developed and applied by using annotation.

Using the Bean Validation API frees you from coupling to a specific validation service provider. By using the Bean Validation API, you can use standard annotations and the API for implementing validation logic to your domain objects, without knowing the underlying validation service provider. For example, `Hibernate Validator`<sup>5</sup> is a JSR-349 reference implementation.

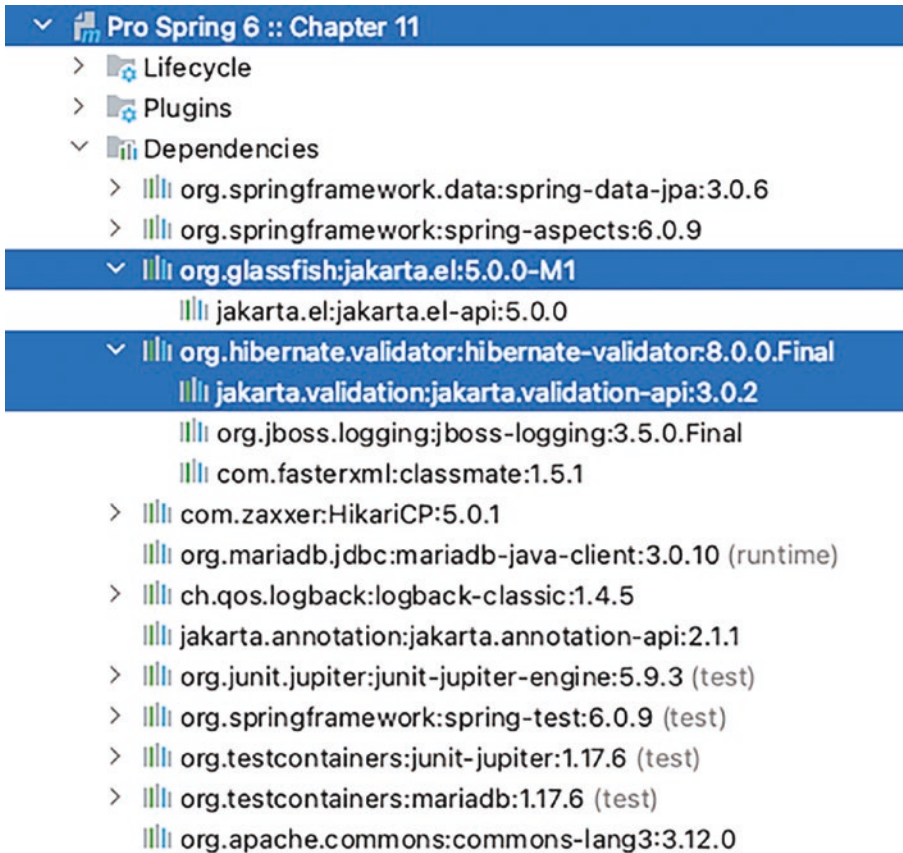
Spring provides seamless support for the Bean Validation API. The main features include support for JSR-349 standard annotations for defining validation constraints, custom validators, and configuration of JSR-349 validation within Spring's `ApplicationContext`. We'll go through these features one by one in the following sections.

<sup>4</sup><https://beanvalidation.org/3.0>

<sup>5</sup><https://hibernate.org/validator>

## Dependencies

For the next sections we need to add the `hibernate-validator` library to the `chapter11` project's classpath. The current version specific to Jakarta 10 is `8.0.0.Final`. Its transitive dependency is `jakarta.validation-api` version `3.0.2`. Also, an implementation of `jakarta.el.ExpressionFactory` is needed, because it provides an implementation for creating and evaluating Jakarta Expression Language expressions, thus the Glassfish `jakarta.el` version `5.0.0-M1` library is added too. They are configured using Maven/Gradle and are shown in the IntelliJ IDEA Gradle View in Figure 11-2.



**Figure 11-2.** Gradle View showing dependencies for the `chapter11` project

## Defining Validation Constraints on Domain Object Properties

For the next sections, the type targeted by validation is a more interesting variation of `Singer`, that has two enum type fields used to set its genre and gender. The `Singer` class is shown in Listing 11-24 together with the two enum declarations.

**Listing 11-24.** The Enriched `Singer` Class

```
package com.apress.prospring6.eleven.domain;

import jakarta.validation.constraints.NotNull;
import jakarta.validation.constraints.Size;
```

```

public class Singer {

    @NotNull
    @Size(min=2, max=60)
    private String firstName;

    private String lastName;

    @NotNull
    private Genre genre;

    private Gender gender;

    // setters and getters omitted

    public enum Genre {
        POP("P"), JAZZ("J"), BLUES("B"), COUNTRY("C");
        private String code;
        private Genre(String code) {
            this.code = code;
        }
        public String toString() {
            return this.code;
        }
    }

    public enum Gender {
        MALE("M"), FEMALE("F"), UNSPECIFIED("U");
        private String code;
        Gender(String code) {
            this.code = code;
        }
        @Override
        public String toString() {
            return this.code;
        }
    }
}

```

In this domain object the validation annotations are shown in bold font. Two constraints are applied to the `firstName` property: the `@NotNull` annotation, which indicates that the value should not be null, and the `@Size` annotation, which governs the length of the `firstName` property. The `@NotNull` constraint is applied to the `genre` property too. The `genre` property indicates the music genre a singer belongs to, while the `gender` property is not relevant for a musical career (or for any career), so it could be null.

## Configuring Bean Validation Support in Spring

To configure support of the Bean Validation API in Spring's `ApplicationContext`, we define a bean of type `org.springframework.validation.beanvalidation.LocalValidatorFactoryBean` in Spring's configuration. Listing 11-25 depicts the configuration class.



**Listing 11-25.** Configuring Support for Jakarta Validation in a Spring Application

```
package com.apress.prospring6.eleven.validator;

import org.springframework.validation.beanvalidation.LocalValidatorFactoryBean;
// other import statements omitted

@Configuration
@ComponentScan
public class JakartaValidationCfg {
    @Bean
    LocalValidatorFactoryBean validator() {
        return new LocalValidatorFactoryBean();
    }
}
```

The declaration of a `LocalValidatorFactoryBean` bean and enabling component scanning in the current package so the `SingerValidationService` bean is registered are all that is needed. Listing 11-26 shows `SingerValidationService`, a service class that provides a validation service for the `Singer` class.

**Listing 11-26.** `SingerValidationService`, a Validation Service for the `Singer` Class

```
package com.apress.prospring6.eleven.validator;

// other import statements omitted
import jakarta.validation.ConstraintViolation;
import jakarta.validation.Validator;
import org.springframework.stereotype.Service;

@Service("singerValidationService")
public class SingerValidationService {

    private final Validator validator;

    public SingerValidationService(Validator validator) {
        this.validator = validator;
    }

    public Set<ConstraintViolation<Singer>> validateSinger(Singer singer) {
        return validator.validate(singer);
    }
}
```

An instance of the `jakarta.validation.Validator` was injected.



Note the difference from the Spring-provided `Validator` interface, which is `org.springframework.validation.Validator`. Using Jakarta Validator allows you to decouple the business logic from Spring if necessary.

---

Once the `LocalValidatorFactoryBean` is defined, you can inject any `Validator` bean anywhere in your application and use it. To perform validation on a POJO, the `Validator.validate(..)` method is called. The validation results will be returned as a `Set` of the `ConstraintViolation<T>` interface.

To test this configuration, we'll use the same approach as before, as shown in Listing 11-27.

**Listing 11-27.** Testing `SingerValidationService`

```
package com.apress.prospring6.eleven;

import com.apress.prospring6.eleven.validator.JakartaValidationCfg;
import com.apress.prospring6.eleven.validator.SingerValidationService;
import jakarta.validation.ConstraintViolation;
// other import statements omitted

public class JakartaValidationTest {

    private static final Logger LOGGER = LoggerFactory.
        getLogger(JakartaValidationTest.class);

    @Test
    void testSingerValidation() {
        try (var ctx = new AnnotationConfigApplicationContext(JakartaValidationCfg.class)) {
            var singerBeanValidationService = ctx.getBean(SingerValidationService.class);
            Singer singer = new Singer();
            singer.setFirstName("J");
            singer.setLastName("Mayer");
            singer.setGenre(null);
            singer.setGender(null);
            var violations = singerBeanValidationService.validateSinger(singer);
            assertEquals(2, violations.size());
            listViolations(violations);
        }

        private static void listViolations(Set<ConstraintViolation<Singer>> violations) {
            violations.forEach(violation ->
                LOGGER.info("Validation error for property: {} with value: {} with error
                    message: {}",
                        violation.getPropertyPath(), violation.getInvalidValue(), violation.
                            getMessage()));
        }
    }

    // expected output
    INFO : Version - HV000001: Hibernate Validator 8.0.0.Alpha1
    ...
    INFO JakartaValidationTest -
        Validation error for property: genre
            with value: null
            with error message: must not be null
    INFO JakartaValidationTest -
        Validation error for property: firstName
            with value: J
            with error message: size must be between 2 and 60
```

As shown in this listing, a `Singer` object is constructed with `firstName` and `genre` violating the constraints declared using annotations. The `SingerValidationService.validateSinger(..)` method is called, which in turn will invoke JSR-349 (Jakarta Bean Validation 3.0). Running the program also prints in the console the rules that were violated and the values that were rejected. As you can see, there are two violations, and the messages are shown. In the output, you can see that Hibernate Validator had already constructed default validation error messages based on the annotation. You can also provide your own validation error message, which we demonstrate in the next section.

## Creating a Custom Validator

Besides property-level validation, we can apply class-level validation. This applies when in the same class a field value depends on the value of another field; for example, `age` and `dateOfBirth` are related to each other, and an object is not valid if `age` is 15 and `dateOfBirth` is 1980-01-01. For the `Singer` class, for country singers, we want to make sure that the `lastName` and `gender` properties are not null (again, not that the gender really matters, but just for educational purposes). In this case, we can develop a custom validator to perform the check. In the Bean Validation API, developing a custom validator is a two-step process. First, create an `Annotation` type for the validator, as shown in Listing 11-28. The second step is to develop the class that implements the validation logic.

*Listing 11-28.* Annotation for Custom Validator for Singer Instances

```
package com.apress.prospring6.eleven.validator;

import jakarta.validation.Constraint;
import jakarta.validation.Payload;

import java.lang.annotation.*;

@Retention(RetentionPolicy.RUNTIME)
@Target(ElementType.TYPE)
@Constraint(validatedBy=CountrySingerValidator.class)
@Documented
public @interface CheckCountrySinger {
    String message() default "Country Singer should have gender and last name defined";
    Class<?>[] groups() default {};
    Class<? extends Payload>[] payload() default {};
}
```

The `@Target(ElementType.TYPE)` annotation means that the annotation should be applied only at the class level. The `@Constraint` annotation indicates that it's a validator, and the `validatedBy` attribute specifies the class providing the validation logic. Within the body, three attributes are defined (in the form of a method), as follows:

- The `message` attribute defines the message (or error code) to return when the constraint is violated. A default message can also be provided in the annotation.
- The `groups` attribute specifies the validation group, if applicable. It's possible to assign validators to different groups and perform validation on a specific group.
- The `payload` attribute specifies additional payload objects (of the class implementing the `jakarta.validation.Payload` interface). It allows you to attach additional information to the constraint (for example, a payload object can indicate the severity of a constraint violation).

The code in Listing 11-29 shows the `CountrySingerValidator` class that provides the validation logic.

**Listing 11-29.** `CountrySingerValidator` Class

```
package com.apress.prospring6.eleven.validator;

import com.apress.prospring6.eleven.domain.Singer;
import jakarta.validation.ConstraintValidator;
import jakarta.validation.ConstraintValidatorContext;

public class CountrySingerValidator implements ConstraintValidator<CheckCountrySinger,
Singer> {

    @Override
    public void initialize(CheckCountrySinger constraintAnnotation) {}

    @Override
    public boolean isValid(Singer singer, ConstraintValidatorContext context) {
        return singer.getGenre() == null || (!singer.isCountrySinger() ||
            (singer.getLastName() != null && singer.getGender() != null));
    }
}
```

`CountrySingerValidator` implements the `ConstraintValidator<CheckCountrySinger, Singer>` interface, which means that the validator checks the `@CheckCountrySinger` annotation on the `Singer` classes. The `isValid()` method is implemented, and the underlying validation service provider (for example, Hibernate Validator) will pass the instance under validation to the method. In the method, we verify that if the singer is a country music singer, the `lastName` and `gender` properties should not be null. The result is a Boolean value that indicates the validation result.

To enable the validation, apply the `@CheckCountrySinger` annotation to the `Singer` class, as shown in Listing 11-30.

**Listing 11-30.** Annotated `Singer` Class

```
package com.apress.prospring6.eleven.domain;

import com.apress.prospring6.eleven.validator.CheckCountrySinger;

// other import statements omitted

@CheckCountrySinger
public class Singer {

    @NotNull
    @Size(min=2, max=60)
    private String firstName;

    private String lastName;

    @NotNull
    private Genre genre;
```

```

private Gender gender;

public boolean isCountrySinger() {
    return genre == Genre.COUNTRY;
}

```

*// getters and setter omitted*

Notice that the class in Listing 11-29, `CountrySingerValidator`, is not declared as a bean. It is an implementation of `jakarta.validation.ConstraintValidator` and therefore is automatically detected by the `SingerValidationService` bean. To test the custom validation, another test method is needed, shown in Listing 11-31.

**Listing 11-31.** Testing Custom Validation

**Package com.apress.prospring6.eleven;**

*//import statements omitted*

```

public class JakartaValidationTest {

    private static final Logger LOGGER = LoggerFactory.
        getLogger(JakartaValidationTest.class);

    @Test
    void testCountrySingerValidation() {
        try (var ctx = new AnnotationConfigApplicationContext(JakartaValidationCfg.class)) {
            var singerBeanValidationService = ctx.getBean(SingerValidationService.class);
            Singer singer = new Singer();
            singer.setFirstName("John");
            singer.setLastName("Mayer");
            singer.setGenre(Singer.Genre.COUNTRY);
            singer.setGender(null);
            var violations = singerBeanValidationService.validateSinger(singer);
            assertEquals(1, violations.size());
            listViolations(violations);
        }
    }

    private static void listViolations(Set<ConstraintViolation<Singer>> violations) {
        violations.forEach(violation ->
            LOGGER.info("Validation error for property: {} with value: {} with error
                message: {}",
                violation.getPropertyPath(), violation.getInvalidValue(), violation.
                    getMessage()));
    }
}

```

*// expected output*

```

INFO : JakartaValidationTest - Validation error for property:
    with value: Singer{firstName='John', lastName='Mayer', genre=C, gender=null}
    with error message: Country Singer should have gender and last name defined

```

In the output, you can see that the value being checked (which is the `Singer` instance) violates the validation rule for country singers, because the `gender` property is `null`. Note also that in the output, the property path is empty because this is a class-level validation error.

## Using `AssertTrue` for Custom Validation

Besides implementing a custom validator, another way to apply custom validation using the Bean Validation API is to use the `@AssertTrue` annotation. To use this annotation for the `Singer` class, the `@CheckCountrySinger` annotation should be removed, and the `isCountrySinger()` method should be annotated with `@AssertTrue`. Additionally, the validation logic from the `CountrySingerValidator.isValid(..)` method should be moved in the body of the `isCountrySinger()` method as well. We want to keep the `Singer` class as it is, to avoid undesired interactions between validation beans. So a duplicate class named `SingerTwo` is created with these changes and a validator for these types of instances named `SingerTwoValidationService` is added to the configuration.

In Listing 11-32 you can see the `SingerTwo` class containing the `isCountrySinger()` method. The `SingerTwoValidationService` is almost identical to `SingerValidationService`, the only difference being the domain object type it works on.

**Listing 11-32.** Using the `@AssertTrue` Annotation

```
package com.apress.prospring6.eleven.domain;

import jakarta.validation.constraints.AssertTrue;
// other import statements omitted

public class SingerTwo {

    @NotNull
    @Size(min=2, max=60)
    private String firstName;

    private String lastName;

    @NotNull
    private Singer.Genre genre;

    private Singer.Gender gender;

    @AssertTrue(message="ERROR! Individual singer should have gender and last name defined")
    public boolean isCountrySinger() {
        return genre == null || (!genre.equals(Singer.Genre.COUNTRY) ||
            (gender != null && lastName != null));
    }
    // setters and getters omitted
}
```

When invoking validation, the provider invokes the checking and makes sure that the result is true. JSR-349/Jakarta Bean Validation also provides the `@AssertFalse` annotation to check for some condition that should be false. The test method in Listing 11-33 tests whether the validation rule introduced by the `@AssertTrue` annotation is violated.

**Listing 11-33.** Testing the `@AssertTrue` Annotation

```
package com.apress.prospring6.eleven;
```

```
// import statements omitted
```

```
public class JakartaValidationTest {
```

```
    private static final Logger LOGGER = LoggerFactory.getLogger
        (JakartaValidationTest.class);
```

```
    @Test
```

```
    void testCountrySingerTwoValidation() {
```

```
        try (var ctx = new AnnotationConfigApplicationContext(JakartaValidationCfg.class)) {
```

```
            var singerBeanValidationService = ctx.getBean(SingerTwoValidationService.class);
```

```
            var singer = new SingerTwo();
```

```
            singer.setFirstName("John");
```

```
            singer.setLastName("Mayer");
```

```
            singer.setGenre(Singer.Genre.COUNTRY);
```

```
            singer.setGender(null);
```

```
            var violations = singerBeanValidationService.validateSinger(singer);
```

```
            assertEquals(1, violations.size());
```

```
            violations.forEach(violation ->
```

```
                LOGGER.info("Validation error for property: {} with value: {} with error
                    message: {}",
```

```
                    violation.getPropertyPath(), violation.getInvalidValue(),
```

```
                    violation.getMessage());
```

```
        }
```

```
    }
```

```
}
```

```
// expected output
```

```
INFO : JakartaValidationTest - Validation error for property: countrySinger
```

```
with value: false
```

```
with error message: ERROR! Individual singer should have gender and last name defined
```

Implementing validation this way makes it clear which rule was violated and allows a custom message to be configured. It also provides the advantage of keeping the code in the same scope. Some developers might say that the domain object is polluted with validation logic and recommend against this approach, but we like this approach for simple validation rules. When the code required to validate the domain objects becomes bigger than the domain object, that is when a separate validator class is needed.

## Deciding Which Validation API to Use

Having discussed Spring's own `Validator` interface and the Bean Validation API, which one should you use in your application? JSR-349/Jakarta Bean Validation is definitely the way to go. The following are the major reasons:

- JSR-349/Jakarta Bean Validation is a JEE standard and is broadly supported by many front-end/back-end frameworks (for example, Spring, JPA 3, Spring MVC, etc.).
- JSR-349/Jakarta Bean Validation provides a standard validation API that hides the underlying provider, so you are not tied to a specific provider.

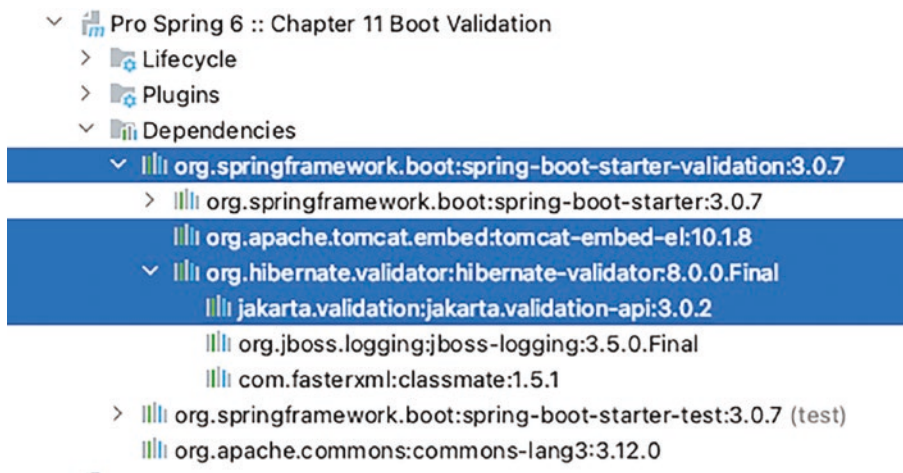
- Spring tightly integrates with JSR-349 starting with version 4. For example, in the Spring MVC web controller, you can annotate the argument in a method with the `@Valid` annotation (under the package `jakarta.validation`), and Spring will invoke JSR-349 validation automatically during the data-binding process. Moreover, in a Spring MVC web application context configuration, a simple annotation (`@EnableWebMvc`) configures Spring to automatically enable the Spring type conversion system and field formatting, as well as support of JSR-349 (Bean Validation).
- If you are using JPA 3, the provider will automatically perform JSR-349/Jakarta Bean Validation validation to the entity before persisting, providing another layer of protection.

For detailed information about using Jakarta Bean Validation with Hibernate Validator as the implementation provider, please refer to Hibernate Validator's documentation page.

## Configuring Validation in a Spring Boot Application

As you can probably imagine by now, there is a Spring Boot starter library that adds all the necessary libraries to the project classpath, so you can start writing your validators right away. The library is named `spring-boot-starter-validation` and having it in the classpath also removes the necessity of explicitly declaring a `LocalValidatorFactoryBean`.

Figure 11-3 shows the collection of libraries added to the project classpath by Spring Boot.



**Figure 11-3.** Gradle View showing dependencies for the `chapter11-boot` project

To test that the validation works, without any other explicit configuration, we copied the `Singer` object and the `SingerValidationService` into this project, next to the main class, the one annotated with `@SpringBootApplication`, and modified the main method to create a `Singer` instance and validate it using the `SingerValidationService` bean as we've done so far in the chapter.



Figure 11-4 shows the project content.

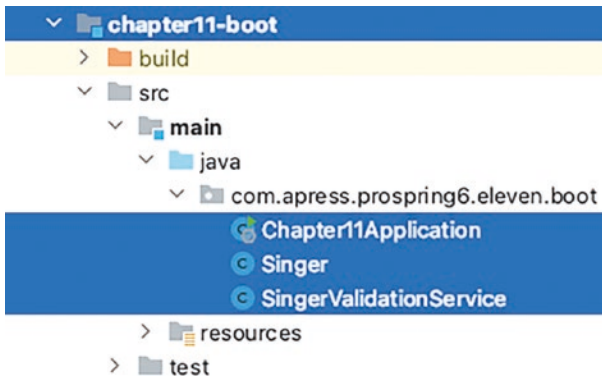


Figure 11-4. Project view showing the contents of the chapter11-boot project

The code to test our validation is in the body of the `@SpringBootApplication` class for simplicity reasons. What would be the point to have an empty main method anyway? You can see the code validating the `Singer` object in Listing 11-34.

*Listing 11-34.* Spring Boot main Method Validating a Singer Instance

```
package com.apress.prospring6.eleven.boot;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.core.env.AbstractEnvironment;

@SpringBootApplication
public class Chapter11Application {

    private static final Logger LOGGER = LoggerFactory.getLogger(
        Chapter11Application.class);

    public static void main(String... args) {
        System.setProperty(AbstractEnvironment.ACTIVE_PROFILES_PROPERTY_NAME, "dev");
        var ctx = SpringApplication.run(Chapter11Application.class, args);

        var singerBeanValidationService = ctx.getBean(SingerValidationService.class);
        var singer = new Singer();
        singer.setFirstName("J");
        singer.setLastName("Mayer");
        singer.setGenre(null);
        singer.setGender(null);
        var violations = singerBeanValidationService.validateSinger(singer);
        if(violations.size() != 2) {
            LOGGER.error("Unexpected number of violations: {}", violations.size());
        }
    }
}
```

```
violations.forEach(violation ->
    LOGGER.info("Validation error for property: {} with value: {} with error
message: {}",
        violation.getPropertyPath(), violation.getInvalidValue(), violation.
getMessage()));
}
```

## Summary

In this chapter, we covered the Spring type conversion system as well as the field Formatter SPI. You saw how the new type conversion system can be used for arbitrary type conversion, in addition to the `PropertyEditors` support.

We also covered validation support in Spring, Spring's `Validator` interface, and the recommended JSR-349/Jakarta Bean Validation support in Spring. Since the Spring Boot Validation starter library exists, it was mentioned in the Spring Boot section.

The gist of this chapter is simple: you can implement and configure conversion, formatting, and validation in multiple ways in a Spring application.

## CHAPTER 12



# Task Execution and Scheduling

Task scheduling is a common feature in enterprise applications. Task scheduling is composed mainly of three parts:

- *The task*: The piece of business logic needed to run at a specific time or on a regular basis
- *The trigger*: Specifies the condition under which the task should be executed
- *The scheduler*: Executes the task based on the information from the trigger

Specifically, this chapter covers the following topics:

- *Task execution in Java*: We briefly discuss Spring's `TaskExecutor` interface and how tasks are executed.
- *Task scheduling in Spring*: We discuss how Spring supports task scheduling, focusing on the `TaskScheduler` abstraction introduced in Spring 3. We also cover scheduling scenarios such as fixed-interval scheduling and cron expressions.
- *Asynchronous task execution*: We show how to use the `@Async` annotation in Spring to execute tasks asynchronously.

If you are a somewhat experienced developer, you are probably aware of the concept of execution threads. A Java application is described by code that the JVM can run on one or multiple threads, and one of the threads is the non-daemon thread that calls the `main(..)` method of a main class. In Java, the class to model an execution thread is `java.lang.Thread`. An execution thread can be created by extending this class and overriding its `run()` method. The resulting instance models an execution thread that must be started explicitly by invoking its `start()` method.

There's another way to create threads, however, and this is by creating a class implementing `java.lang.Runnable`. This interface provides a common protocol for objects that wish to execute code, including the `Thread` class. This means that `Runnable` instances can be created and passed to some components, called *executors*, that execute the code in the way they were configured: sequentially, in parallel, using threads provided by a thread pool. In case it's not obvious what a task is, in a Java application a *task* is any instance of type `Runnable`.

In Java, the `java.util.concurrent.Executor` interface represents the abstraction for asynchronous task execution. In Spring, there is an interface that extends this one and is basically identical, with the exception that it is annotated with `@FunctionalInterface` to mark it as a functional interface: `org.springframework.core.task.TaskExecutor`.



This interface is necessary for backward compatibility with JDK 1.4 in Spring 2.x.

---

Spring's `TaskExecutor` interface is depicted in Listing 12-1.

*Listing 12-1.* Spring's `org.springframework.core.task.TaskExecutor` Interface

```
package org.springframework.core.task;

import java.util.concurrent.Executor;

@FunctionalInterface
public interface TaskExecutor extends Executor {

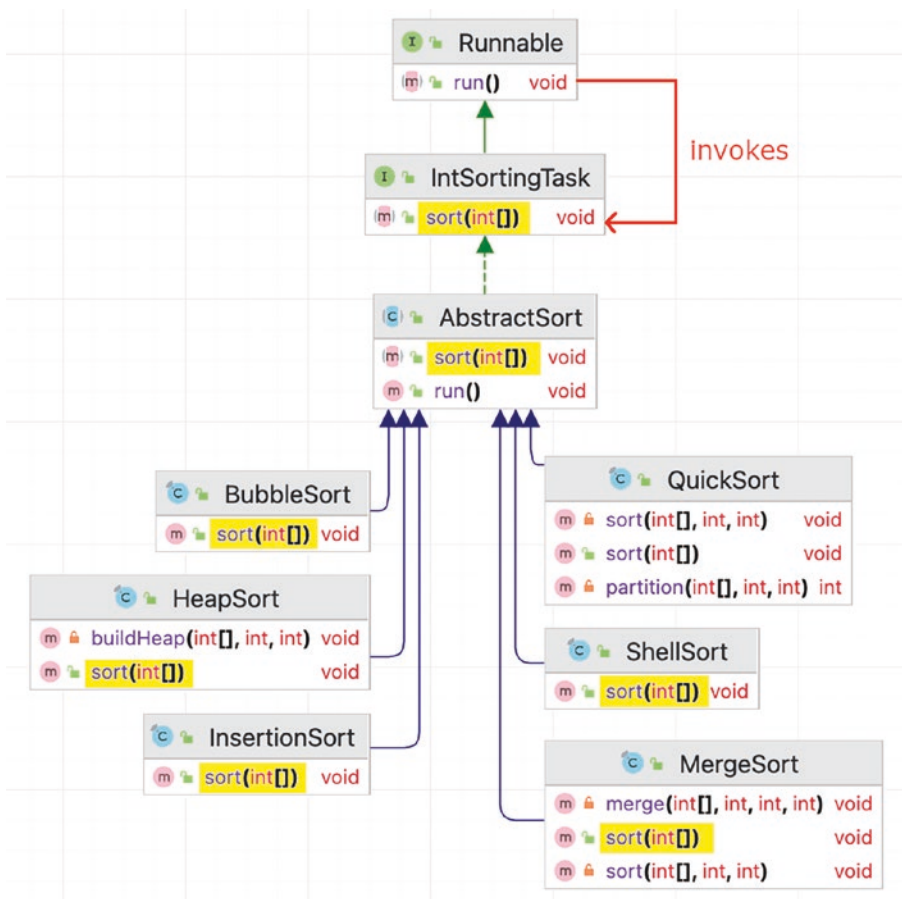
    @Override
    void execute(Runnable task);
}
```

The interface has a single method, `execute(Runnable task)`, that accepts a task for execution based on the semantics and configuration of the thread pool. Spring provides a few useful `TaskExecutor` implementations.

## Task Executing in Java

In Java there are quite a few `java.util.concurrent.Executor` implementations. Thread pools provide the advantage of improved performance when executing a large number of asynchronous tasks, because they provide a way of bounding and managing the resources, including threads when executing a collection of tasks. `ThreadPoolExecutor` maintains basic statistics as the number of active and completed tasks and one of my (Iuliana's) favorite implementations is to write a `ThreadPoolMonitor` class that implements `java.lang.Runnable` that prints those statistics.

This section introduces a hierarchy of classes that model various sorting algorithms, shown in Figure 12-1. These classes are suitable for creating sorting tasks that can be executed asynchronously by an executor.



**Figure 12-1.** Hierarchy of classes modeling various sorting algorithms

The implementation of these sorting algorithms is not important for this chapter, but running them in parallel managed by a `ThreadPoolExecutor` instance is.

All Java components specific to task executions can be found under the `java.util.concurrent` package. The `ThreadPoolExecutor` class is an implementation of `ExecutorService` that executes each submitted task using one of possibly several pooled threads, configured using `Executors` factory methods. The size of the thread pool and its maximum capacity are provided as arguments to its constructor. The tasks are provided as an argument of a type that implements the `BlockingQueue<Runnable>` interface, which avoids the same task being submitted more than once for execution, by being thread-safe. It also supports operations that wait for the queue to become non-empty before retrieving an element, which allows for tasks to be added to this list after the execution of its contents began.

The `ThreadPoolMonitor` class is a custom extension of `Thread` written specifically for this section to print statistics for a running `ThreadPoolExecutor`, and its code is shown in Listing 12-2.

*Listing 12-2.* The ThreadPoolMonitor Monitor Class

```

package com.apress.prospring6.twelve.classic;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;

import java.util.concurrent.ThreadPoolExecutor;

public class ThreadPoolMonitor implements Runnable {
    private static final Logger LOGGER = LoggerFactory.getLogger(ThreadPoolMonitor.class);

    protected ThreadPoolExecutor executor;
    protected int printInterval = 200;

    @Override
    public void run() {
        try {
            while (executor.getActiveCount() > 0) {
                monitorThreadPool();
                Thread.sleep(printInterval);
            }
        } catch (Exception e) {
            LOGGER.error(e.getMessage());
        }
    }

    private void monitorThreadPool() {
        String strBuff = "CurrentPoolSize : " + executor.getPoolSize() +
            " - CorePoolSize : " + executor.getCorePoolSize() +
            " - MaximumPoolSize : " + executor.getMaximumPoolSize() +
            " - ActiveTaskCount : " + executor.getActiveCount() +
            " - CompletedTaskCount : " + executor.getCompletedTaskCount() +
            " - TotalTaskCount : " + executor.getTaskCount() +
            " - isTerminated : " + executor.isTerminated();
        LOGGER.debug(strBuff);
    }

    public void setExecutor(ThreadPoolExecutor executor) {
        this.executor = executor;
    }
}

```

Notice that ThreadPoolMonitor class implements Runnable, which makes it a task too. A ThreadPoolMonitor instance can be started as a thread executing independently from the sorting tasks managed by the ThreadPoolExecutor.

Listing 12-3 shows the ClassicDemo class, which generates an array containing 100,000 elements with values between 0 and 500\_000 that is handed over to be sorted in parallel by the tasks in Figure 12-1. These tasks are managed and executed by an instance of ThreadPoolExecutor, which is monitored by an instance of ThreadPoolMonitor.

*Listing 12-3.* The ClassicDemo Monitor Class

```

package com.apress.prospring6.twelve.classic;

import java.util.List;
import java.util.Random;
import java.util.concurrent.LinkedBlockingQueue;
import java.util.concurrent.ThreadPoolExecutor;
import java.util.concurrent.TimeUnit;

public class ClassicDemo {

    public static void main(String... args) {
        int[] arr = new Random().ints(100_000, 0, 500_000).toArray(); // (1)
        // LOGGER.info("Starting Array: {} ", Arrays.toString(arr));

        var algsMonitor = new ThreadPoolMonitor(); // (2)
        var monitor = new Thread(algsMonitor);

        var executor = new ThreadPoolExecutor(2, 4, 0L, TimeUnit.MILLISECONDS,
            new LinkedBlockingQueue<>()); // (3)
        algsMonitor.setExecutor(executor);

        List.of(new BubbleSort(arr), // (4)
                new InsertionSort(arr),
                new HeapSort(arr),
                new MergeSort(arr),
                new QuickSort(arr),
                new ShellSort(arr))
            .forEach(executor::execute);

        monitor.start(); // (5)
        executor.shutdown();
        try {
            executor.awaitTermination(30, TimeUnit.MINUTES);
        } catch (InterruptedException e) {
            throw new RuntimeException(e);
        }
    }
}

```

The code has been split into sections by using empty lines. The sections are marked with numbers. Each section is responsible for the following:

- 1. The first section of the code creates the array. If you want to print it to check its values, feel free to un-comment the logging line.
- 2. The second section creates the `ThreadPoolMonitor` instance (`algsMonitor`) and the `Thread` that will execute it (`monitor`).
- 3. The third section creates the `ThreadPoolExecutor` (`executor`). Notice that while initializing the `ThreadPoolExecutor`, we are keeping initial pool size as 2 and maximum pool size to 4. The `algsMonitor` is configured to monitor the executor.

- 4. The fourth section creates the tasks and submits them for execution.
- 5. The fifth section starts the monitor thread. Then the executor is shut down, causing the finish execution of all the submitted tasks and termination of the thread pool.

When the `ClassicDemo` class is executed, the logs will make it obvious that tasks are being executed in parallel and that some complete faster than other...`BubbleSort` never had a chance in this competition, right? A log snippet is shown in Listing 12-4.

**Listing 12-4.** The `ClassicDemo` Console Log

```
DEBUG: ThreadPoolMonitor - CurrentPoolSize : 2 - CorePoolSize : 2 - MaximumPoolSize : 4 -
ActiveTaskCount : 2 - CompletedTaskCount : 0 - TotalTaskCount : 6 - isTerminated : false
INFO : AbstractSort - InsertionSort Sort Time: 0.8 seconds
DEBUG: ThreadPoolMonitor - MONITOR: [Sorting Algs Monitor] CurrentPoolSize : 2 -
CorePoolSize : 2 - MaximumPoolSize : 4 - ActiveTaskCount : 2 - CompletedTaskCount : 1 -
TotalTaskCount : 6 - isTerminated : false
INFO : AbstractSort - InsertionSort Sort Time: 0.847 seconds
INFO : AbstractSort - HeapSort Sort Time: 0.014 seconds
DEBUG: ThreadPoolMonitor - CurrentPoolSize : 2 - CorePoolSize : 2 - MaximumPoolSize : 4 -
ActiveTaskCount : 2 - CompletedTaskCount : 2 - TotalTaskCount : 6 - isTerminated : false
INFO : AbstractSort - MergeSort Sort Time: 0.226 seconds
INFO : AbstractSort - QuickSort Sort Time: 0.011 seconds
INFO : AbstractSort - ShellSort Sort Time: 0.017 seconds
DEBUG: ThreadPoolMonitor - CurrentPoolSize : 1 - CorePoolSize : 2 - MaximumPoolSize : 4 -
ActiveTaskCount : 1 - CompletedTaskCount : 5 - TotalTaskCount : 6 - isTerminated : false
...
DEBUG: ThreadPoolMonitor - CurrentPoolSize : 1 - CorePoolSize : 2 - MaximumPoolSize : 4 -
ActiveTaskCount : 1 - CompletedTaskCount : 5 - TotalTaskCount : 6 - isTerminated : false
INFO : AbstractSort - BubbleSort Sort Time: 19.991 seconds
```

The log clearly shows the change in active, completed, and total completed tasks counts of the executor. For this example, the `ThreadPoolExecutor` was created by explicitly invoking the constructor, but a similar result could be obtained by calling the factory method `Executors.newFixedThreadPool(6)`. There are other Java extensions of the `ExecutorService` that allow more granular control over task execution, such as the `ScheduledExecutorService`, so feel free to take a deeper look. Next we'll turn to how Spring does task execution.

## Task Executing in Spring

Spring's `TaskExecutor` interface was added in version 2.0. Similar to the JDK, out of the box, Spring provides a number of `TaskExecutor` implementations suited for different needs<sup>1</sup>. The most interesting are listed next:

- `org.springframework.core.task.SyncTaskExecutor`: Does not execute tasks asynchronously; invocation occurs in the calling thread.
- `org.springframework.core.task.SimpleAsyncTaskExecutor`: Creates new threads on each invocation; does not reuse existing threads.

<sup>1</sup><https://docs.spring.io/spring-framework/docs/current/javadoc-api/org/springframework/core/task/TaskExecutor.html>



- `org.springframework.scheduling.concurrent.ConcurrentTaskExecutor`: An adapter for a `java.util.concurrent.Executor` instance. Not usually used since there is a `ThreadPoolTaskExecutor` class, but it is useful if this one is not flexible enough.
- `org.springframework.scheduling.concurrent.ThreadPoolTaskExecutor`: `TaskExecutor` implementation providing the ability to configure `ThreadPoolExecutor` via bean properties and expose it as a Spring `TaskExecutor`.
- `org.springframework.scheduling.quartz.SimpleThreadPoolTaskExecutor`: Subclass of Quartz's `SimpleThreadPool`; used when you need to share a thread pool by both Quartz and non-Quartz components.

Each `TaskExecutor` implementation serves its own purpose, and all of them obviously have the same API. The only variation is in the configuration, when defining which `TaskExecutor` implementation you want to use and its properties, if any. Let's take a look at a simple example that prints out a number of random texts. The `TaskExecutor` implementation used is `SimpleAsyncTaskExecutor`. First let's create a bean class that holds the task execution logic, as shown in Listing 12-5.

**Listing 12-5.** The `RandomStringPrinter` Class

```
package com.apress.prospring6.twelve;
```

```
// some import statements omitted
```

```
import org.springframework.core.task.TaskExecutor;
```

```
import java.util.UUID;
```

```
@Component
```

```
public class RandomStringPrinter {
```

```
    private final Logger logger = LoggerFactory.getLogger(RandomStringPrinter.class);
```

```
    private final TaskExecutor taskExecutor;
```

```
    public RandomStringPrinter(TaskExecutor taskExecutor) {
```

```
        this.taskExecutor = taskExecutor;
```

```
    }
```

```
    public void executeTask() {
```

```
        for(int i=0; i < 10; ++ i) {
```

```
            final int index = i;
```

```
            taskExecutor.execute(() -> LOGGER.info("{}: {}", index , UUID.randomUUID().toString().substring(0, 8)));
```

```
        }
```

```
    }
```

```
}
```

This class is just a regular bean that needs `TaskExecutor` to be injected as a dependency and defines a method `executeTask()`. The `executeTask()` method calls the `execute` method of the provided `TaskExecutor` by creating a new `Runnable` instance containing the logic we want to execute for this task. This might not be obvious here, as a lambda expression is used to create the `Runnable` instance. The configuration is quite simple; it is similar to the configuration depicted in the previous section. The only thing we have to take into account here is that we need to provide a declaration for a `TaskExecutor` bean, which needs to be injected in the `RandomStringPrinter` bean.

Listing 12-6 shows the configuration class and the demo class named `SimpleAsyncTaskExecutorDemo`.

**Listing 12-6.** The `SimpleAsyncTaskExecutorDemo` and `AppConfig` Monitor Classes

```

package com.apress.prospring6.twelve;

// some import statements omitted
import org.springframework.scheduling.annotation.EnableAsync;

@Configuration
@EnableAsync
class AppConfig {
    @Bean
    TaskExecutor taskExecutor() {
        return new SimpleAsyncTaskExecutor();
    }
}

public class SimpleAsyncTaskExecutorDemo {

    public static void main(String... args) throws IOException {
        try (var ctx = new AnnotationConfigApplicationContext(AppConfig.class,
            RandomStringPrinter.class)) {
            var printer = ctx.getBean(RandomStringPrinter.class);
            printer.executeTask();

            System.in.read();
        }
    }
}

```

The most important bit in the class is the `@EnableAsync` annotation that enables Spring's asynchronous method execution capability, which means Spring will be searching for an associated thread pool definition, either a unique `org.springframework.core.task.TaskExecutor` bean in the context or an `java.util.concurrent.Executor` bean named `taskExecutor` otherwise. If none is found, a `org.springframework.core.task.SimpleAsyncTaskExecutor` will be used to process async method invocations.

When the `SimpleAsyncTaskExecutorDemo` class is run, the random strings are printed by each task in random order, since the tasks are executed asynchronously. This is obvious because each task has an associated number. Listing 12-7 shows sample output.

**Listing 12-7.** Log Sample Printed by the `SimpleAsyncTaskExecutorDemo` Class Execution

```

INFO : RandomStringPrinter - 6: 87548a56
INFO : RandomStringPrinter - 4: 019c9571
INFO : RandomStringPrinter - 3: a5cc57ef
INFO : RandomStringPrinter - 1: 8a6dc271
INFO : RandomStringPrinter - 5: 52fd6224
INFO : RandomStringPrinter - 8: 11810531
INFO : RandomStringPrinter - 2: 820b17a4
INFO : RandomStringPrinter - 7: 9e56cf1b
INFO : RandomStringPrinter - 0: eab9362a
INFO : RandomStringPrinter - 9: d24c2076

```

## Task Scheduling in Spring

Executing tasks is clearly easy, but enterprise applications often need to do so in a more controlled manner, which means tasks must be scheduled. In many applications, various tasks (such as sending e-mail notifications to customers, running day-end jobs, doing data housekeeping, and updating data in batches) need to be scheduled to run on a regular basis, either in a fixed interval (for example, every hour) or at a specific schedule (for example, at 8 p.m. every night, from Monday to Friday).

There are many ways to trigger the execution of a task in a Spring application. One way is to trigger a job externally from a scheduling system that already exists in the application deployment environment. For example, many enterprises use commercial systems, such as Control-M or CA AutoSys, for scheduling tasks. If the application is running on a Linux/Unix platform, the crontab scheduler can be used. The job triggering can be done by sending a RESTful-WS request to the Spring application and having Spring's MVC controller trigger the task.

Another way is to use the task scheduling support in Spring. Spring provides three options in terms of task scheduling:

- *Support of JDK Timer:* Spring supports JDK's Timer object for task scheduling.
- *Integration with Quartz:* Quartz Job Scheduler<sup>2</sup> is a popular open source scheduling library.
- *Spring's own Spring TaskScheduler abstraction:* Spring 3 introduced the TaskScheduler abstraction, which provides a simple way to schedule tasks and supports most typical requirements.

This section focuses on using Spring's TaskScheduler abstraction for task scheduling, the consequence of which is that the project is quite simple and the only Spring dependency necessary is the `spring-context.jar` library.

## Introducing the Spring TaskScheduler Abstraction

Spring's TaskScheduler abstraction provides a variety of methods for scheduling tasks to run at some point in the future and has mainly three participants:

- *The Trigger interface:* The `org.springframework.scheduling.Trigger` interface provides support for defining the triggering mechanism. Spring provides two Trigger implementations. The `CronTrigger` class supports triggering based on a cron expression, while the `PeriodicTrigger` class supports triggering based on an initial delay and then a fixed interval.
- *The task:* The task is the piece of business logic that needs to be scheduled. In Spring, a task can be specified as a method within any Spring bean.
- *The TaskScheduler interface:* The `org.springframework.scheduling.TaskScheduler` interface provides support for task scheduling. Spring provides three implementation classes of the TaskScheduler interface. The `ConcurrentTaskScheduler` and `ThreadPoolTaskScheduler` classes (both under the package `org.springframework.scheduling.concurrent`) wrap the `java.util.concurrent.ScheduledThreadPoolExecutor` class. Both classes support task execution from a shared thread pool. The `DefaultManagedTaskScheduler` class, also in package `org.springframework.scheduling.concurrent`, is commonly used in a Jakarta EE environment.

<sup>2</sup><https://www.quartz-scheduler.org/>

Figure 12-2 shows the relationships between the Trigger interface, the TaskScheduler interface, and the task that implements the `java.lang.Runnable` interface.

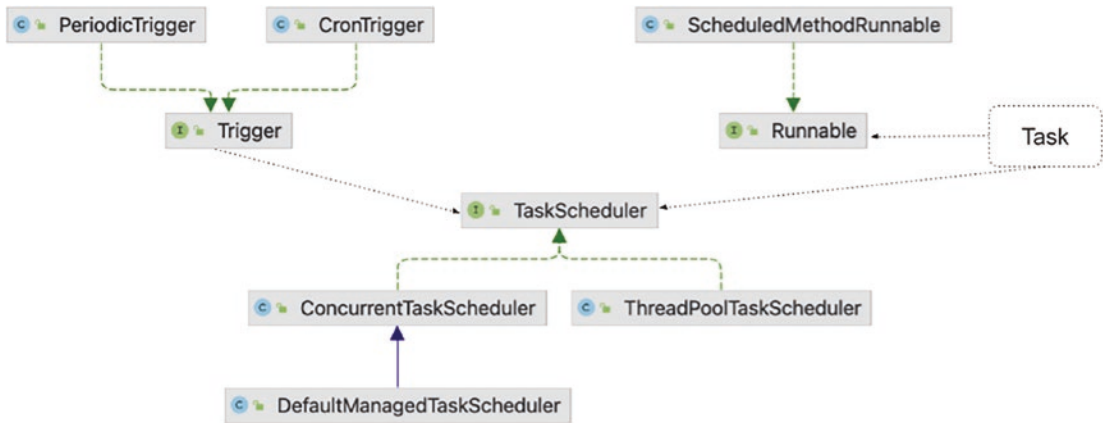


Figure 12-2. Relationship between trigger, task, and scheduler

Basically, task schedulers execute tasks based on a date, time, once, or repeatedly. Task executions are triggered by Trigger implementations, which provide granular control over the time tasks are executed, especially in relation to other task executions.

To schedule tasks by using Spring’s TaskScheduler abstraction, a few annotations are necessary, which are demonstrated and described in the following section.

## Exploring a Sample Task

To demonstrate task scheduling in Spring, let’s implement a simple job first, namely, an application maintaining a database of car information. Listing 12-8 shows the Car class, which is implemented as a JPA entity class.

Listing 12-8. Car Entity class

```

package com.apress.prospring6.twelve.entities;

import static jakarta.persistence.GenerationType.IDENTITY;
import jakarta.persistence.*;

import java.time.LocalDate;

@Entity
@Table(name="CAR")
public class Car {
    @Id
    @GeneratedValue(strategy = IDENTITY)
    @Column(name = "ID")
    private Long id;
}

```

```

@Column(name="LICENSE_PLATE")
private String licensePlate;

@Column(name="MANUFACTURER")
private String manufacturer;

@Column(name="MANUFACTURE_DATE")
private LocalDate manufactureDate;
@Column(name="AGE")
private int age;

@Version
private int version;

// getters and setters
}

```

This entity class is used as a model for the CAR table generated by Hibernate. The configuration for the data access and services layers is provided by the `BasicDataSourceCfgy` and the `JpaConfig` classes, just like shown in the data access chapters. To tell Hibernate to create the table, the `Environment.HBM2DDL_AUTO` property is set to `create-drop`. To make sure there is some data to work with, a class named `DBInitializer` is introduced. Creating a bean of this type adds three `Car` records to the table. The `DBInitializer` class is shown in Listing 12-9.

**Listing 12-9.** `DBInitializer` Class That Populates the CAR Table

```

package com.apress.prospring6.twelve.config;
// import statements omitted

@Service
public class DBInitializer {
    private static Logger LOGGER = LoggerFactory.getLogger(DBInitializer.class);

    private final CarRepository carRepository;

    public DBInitializer(CarRepository carRepository) {
        this.carRepository = carRepository;
    }

    @PostConstruct
    public void initDB() {
        LOGGER.info("Starting database initialization...");
        var car = new Car();
        car.setLicensePlate("GRAVITY-0405");
        car.setManufacturer("Ford");
        car.setManufactureDate(LocalDate.of(2006, 9, 12));
        carRepository.save(car);

        car = new Car();
        car.setLicensePlate("CLARITY-0432");
        car.setManufacturer("Toyota");
    }
}

```

```

        car.setManufactureDate(LocalDate.of(2003, 9, 9));
        carRepository.save(car);

        car = new Car();
        car.setLicensePlate("ROSIE-0402");
        car.setManufacturer("Toyota");
        car.setManufactureDate(LocalDate.of(2017, 4, 16));
        carRepository.save(car);

        // ...

        LOGGER.info("Database initialization finished.");
    }
}

```

The `CarRepository` bean injected in `DBInitializer` is a Spring Data typical repo, an interface extending `CrudRepository<Car, Long>`. The same bean is injected into the `CarServiceImpl` class depicted in Listing 12-10.

**Listing 12-10.** `CarServiceImpl` Class

```

package com.apress.prospring6.twelve.service;
// import statements omitted
import org.springframework.scheduling.annotation.Scheduled;

@Service("carService")
@Repository
@Transactional
public class CarServiceImpl implements CarService {
    public boolean done;

    final Logger LOGGER = LoggerFactory.getLogger(CarServiceImpl.class);

    private final CarRepository carRepository;

    public CarServiceImpl(CarRepository carRepository) {
        this.carRepository = carRepository;
    }

    @Override
    @Transactional(readOnly=true)
    public Stream<Car> findAll() {
        return StreamSupport.stream(carRepository.findAll().spliterator(), false);
    }

    @Override
    public Car save(Car car) {
        return carRepository.save(car);
    }

    @Override
    @Scheduled(fixedDelay=10000)

```

```

public void updateCarAgeJob() {
    var cars = findAll();

    var currentDate = LocalDate.now();
    LOGGER.info("Car age update job started");

    cars.forEach(car -> {
        var p = Period.between(car.getManufactureDate(), currentDate);
        int age = p.getYears();

        car.setAge(age);
        save(car);
        LOGGER.info("Car age update --> {}" , car);
    });

    LOGGER.info("Car age update job completed successfully");
    done = true;
}

@Override
public boolean isDone() {
    return done;
}
}

```

The `CarServiceImpl` class contains four methods:

- `Stream<Car> findAll()`: Retrieves the information about all cars.
- `Car save(Car car)`: Persists an updated Car object.
- `void updateCarAgeJob()`: The job that needs to be run regularly to update the age of the car based on the manufacture date of the car and the current date. Notice the `@Scheduled` annotation on it. It configures this method to be executed approximately every 10 seconds.
- `boolean isDone()`: A utility method designed to be used to know when the job ended, so that the application can be shut down gracefully.

The only thing missing is the Spring application configuration that enables task scheduling. The `TaskSchedulingConfig` class is shown in Listing 12-11.

*Listing 12-11.* TaskSchedulingConfig Class

```

package com.apress.prospring6.twelve.config;

import org.springframework.context.annotation.ComponentScan;
import org.springframework.context.annotation.Configuration;
import org.springframework.scheduling.annotation.EnableScheduling;

@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.twelve"})
@EnableScheduling
public class TaskSchedulingConfig {
}

```

The `@EnableScheduling` annotation used on a `@Configuration` class enables detection of `@Scheduled` annotations on any Spring-managed bean in the container or their methods. Methods annotated with `@Scheduled` may even be declared directly within `@Configuration` classes, since configuration classes are beans themselves. Since Spring 4.2, `@Scheduled` methods are supported on beans of any scope. This annotation tells Spring to look for an associated scheduler definition: either a unique `TaskScheduler` bean in the context or a `TaskScheduler` bean named `taskScheduler` or a `ScheduledExecutorService` bean. If none is found, a local single-threaded default scheduler will be created and used to execute scheduled tasks. To schedule a specific method in a Spring bean, the method must be annotated with `@Scheduled` and pass in the scheduling requirements.

The testing program is shown in Listing 12-12.

**Listing 12-12.** CarTaskSchedulerDemo Class

```
package com.apress.prospring6.twelve;
// import statements omitted

public class CarTaskSchedulerDemo {
    private static final Logger LOGGER = LoggerFactory.
        getLogger(CarTaskSchedulerDemo.class);

    public static void main(String[] args) throws IOException {
        try (var ctx = new AnnotationConfigApplicationContext(TaskSchedulingConfig.class)) {
            try {
                var taskScheduler = ctx.getBean(ScheduledAnnotationBeanPostProcessor.
                    DEFAULT_TASK_SCHEDULER_BEAN_NAME);
                LOGGER.info(" >>>> Task 'taskScheduler' found: {}", taskScheduler.
                    getClass());
            } catch (NoSuchBeanDefinitionException nbd) {
                LOGGER.debug("No 'taskScheduler' configured!");
            }
            System.in.read();
        }
    }
}
```

Since we want to check if we have a scheduler, we search for a scheduler bean named `taskScheduler` (this is the value of the `DEFAULT_TASK_SCHEDULER_BEAN_NAME` constant) in the demo code and print its class.

Scheduling tasks in Spring is implemented the same way as almost everything else is implemented, by proxying. The `@EnableScheduling` annotation adds a `org.springframework.scheduling.annotation.ScheduledAnnotationBeanPostProcessor` bean to the context that picks up methods annotated with `@Scheduled`. These methods are invoked by a `TaskScheduler` according to the `fixedRate`, `fixedDelay`, or `cron` expression configured via the `@Scheduled` annotation.

Since we need the main thread to continue its execution, so that we can see the `updateCarAgeJob()` method being executed repeatedly, the `System.in.read()` statement is used to wait for the developer to press any key before exiting. The log printed in the console might look a lot like the one shown in Listing 12-13.

**Listing 12-13.** CarTaskSchedulerDemo Log for execution with configuration in `TaskSchedulingConfig`

```
00:14:21.818 [main] INFO : ScheduledAnnotationBeanPostProcessor - No TaskScheduler/
ScheduledExecutorService bean found for scheduled processing
00:14:21.822 [main] DEBUG: CarTaskSchedulerDemo - No 'taskScheduler' configured!
```



```

00:14:21.900 [pool-1-thread-1] INFO : CarServiceImpl - Car age update job started
00:14:21.903 [pool-1-thread-1] INFO : CarServiceImpl - Car age update --> Car{id=1,
licensePlate='GRAVITY-0405', manufacturer='Ford', manufactureDate=2006-09-12, age=16,
version=0}
00:14:21.908 [pool-1-thread-1] INFO : CarServiceImpl - Car age update --> Car{id=2,
licensePlate='CLARITY-0432', manufacturer='Toyota', manufactureDate=2003-09-09, age=19,
version=0}
00:14:21.908 [pool-1-thread-1] INFO : CarServiceImpl - Car age update --> Car{id=3,
licensePlate='ROSIE-0402', manufacturer='Toyota', manufactureDate=2017-04-16, age=5,
version=0}
...
00:14:21.909 [pool-1-thread-1] INFO : CarServiceImpl - Car age update job completed
successfully
00:14:31.936 [pool-1-thread-1] INFO : CarServiceImpl - Car age update job started
00:14:31.936 [pool-1-thread-1] INFO : CarServiceImpl - Car age update --> Car{id=1,
licensePlate='GRAVITY-0405', manufacturer='Ford', manufactureDate=2006-09-12, age=16,
version=1}
00:14:31.937 [pool-1-thread-1] INFO : CarServiceImpl - Car age update --> Car{id=2,
licensePlate='CLARITY-0432', manufacturer='Toyota', manufactureDate=2003-09-09, age=19,
version=1}
00:14:31.937 [pool-1-thread-1] INFO : CarServiceImpl - Car age update --> Car{id=3,
licensePlate='ROSIE-0402', manufacturer='Toyota', manufactureDate=2017-04-16, age=5,
version=1}
00:14:31.938 [pool-1-thread-1] INFO : CarServiceImpl - Car age update job completed
successfully
...

```

The thread name is added to the log to make it obvious that the `updateCarAgeJob()` methods are executed in a thread pool, even if the default executor uses a single thread.

There are two ways to configure a task scheduler to be used: make the `TaskSchedulingConfig` class implement `org.springframework.scheduling.annotation.SchedulingConfigurer` and override the `configureTasks(..)` to set up a custom task scheduler, or declare a task scheduler custom bean.

Listing 12-14 shows the `TaskSchedulingConfig2` class that implements `SchedulingConfigurer`.

**Listing 12-14.** `TaskSchedulingConfig2` Configuration Class

```

package com.apress.prospring6.twelve.spring.config;

import org.springframework.context.annotation.FilterType;
import org.springframework.scheduling.annotation.EnableScheduling;
import org.springframework.scheduling.annotation.SchedulingConfigurer;
import org.springframework.scheduling.concurrent.ThreadPoolTaskScheduler;
import org.springframework.scheduling.config.ScheduledTaskRegistrar;

import java.util.concurrent.Executor;
import java.util.concurrent.ScheduledThreadPoolExecutor;
// import statements omitted

@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.twelve.spring"})
@EnableScheduling
public class TaskSchedulingConfig2 implements SchedulingConfigurer {

```

```

private static final Logger LOGGER = LoggerFactory.
    getLogger(TaskSchedulingConfig2.class);

@Override
public void configureTasks(ScheduledTaskRegistrar taskRegistrar) {
    taskRegistrar.setScheduler(taskExecutor());
}

@Bean(destroyMethod = "shutdown")
public Executor taskExecutor() {
    var tpts = new ThreadPoolTaskScheduler();
    tpts.setPoolSize(3);
    tpts.setThreadNamePrefix("tsc2-");
    return tpts;
}
}

```

The task scheduler is configured to name managed threads with the `tsc2-` to make it obvious that the tasks invoking `updateCarAgeJob()` are executed by it.

Listing 12-15 shows the demo program that checks the existence of a `taskExecutor` bean.

**Listing 12-15.** `CarTaskSchedulerDemo` Version Using `TaskSchedulingConfig2` Configuration Class

```

package com.apress.prospring6.twelve;
// import statements omitted

public class CarTaskSchedulerDemo {
    private static final Logger LOGGER = LoggerFactory.
        getLogger(CarTaskSchedulerDemo.class);

    public static void main(String[] args) throws IOException {
        try (var ctx = new AnnotationConfigApplicationContext(TaskSchedulingConfig2.
            class)) {
            try {
                var taskExecutor = ctx.getBean("taskExecutor");
                LOGGER.info(" >>>> 'taskExecutor' found: {}", taskExecutor.getClass());
            } catch (NoSuchBeanDefinitionException nbd) {
                LOGGER.debug("No 'taskExecutor' configured!");
            }
            System.in.read();
        }
    }
}

```

When run, this version of the `CarTaskSchedulerDemo` produces the output shown in Listing 12-16.

**Listing 12-16.** `CarTaskSchedulerDemo` Log for execution with configuration in `TaskSchedulingConfig2`

```

00:15:47.299 [main] DEBUG: CarTaskSchedulerDemo - No 'taskScheduler' configured!
00:15:47.299 [main] INFO : CarTaskSchedulerDemo - >>>> 'taskExecutor' found: class org.
springframework.scheduling.concurrent.ThreadPoolTaskScheduler
00:15:47.375 [tsc2-1] INFO : CarServiceImpl - Car age update job started

```

```

00:15:47.378 [tsc2-1] INFO : CarServiceImpl - Car age update --> Car{id=1,
licensePlate='GRAVITY-0405', manufacturer='Ford', manufactureDate=2006-09-12, age=16,
version=0}
00:15:47.383 [tsc2-1] INFO : CarServiceImpl - Car age update --> Car{id=2,
licensePlate='CLARITY-0432', manufacturer='Toyota', manufactureDate=2003-09-09, age=19,
version=0}
00:15:47.383 [tsc2-1] INFO : CarServiceImpl - Car age update --> Car{id=3,
licensePlate='ROSIE-0402', manufacturer='Toyota', manufactureDate=2017-04-16, age=5,
version=0}
00:15:47.384 [tsc2-1] INFO : CarServiceImpl - Car age update job completed successfully
...

```

The reason you do not see more than one thread is that the tasks take so little time to execute there is no need to use another thread from the pool.

The other way to do the same thing is by declaring the `TaskScheduler` bean directly as shown in Listing 12-17.

**Listing 12-17.** `TaskSchedulingConfig3` Configuration Class.

```

package com.apress.prospring6.twelve.spring.config;

@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.twelve.spring"})
@EnableScheduling
public class TaskSchedulingConfig3 {

    @Bean
    TaskScheduler taskScheduler() {
        var tpts = new ThreadPoolTaskScheduler();
        tpts.setPoolSize(3);
        tpts.setThreadNamePrefix("tsc3-");
        return tpts;
    }
}

```

The test program for the `TaskSchedulingConfig3` class is identical to the class shown in Listing 12-12, but the log shows that the new task scheduler bean is used, as you can see in Listing 12-18.

**Listing 12-18.** `CarTaskSchedulerDemo` Log for execution with configuration in `TaskSchedulingConfig3`

```

00:16:32.485 [main] INFO : CarTaskSchedulerDemo - >>>> 'taskScheduler' found: class org.
springframework.scheduling.concurrent.ThreadPoolTaskScheduler
00:16:32.558 [tsc3-1] INFO : CarServiceImpl - Car age update job started
00:16:32.560 [tsc3-1] INFO : CarServiceImpl - Car age update --> Car{id=1,
licensePlate='GRAVITY-0405', manufacturer='Ford', manufactureDate=2006-09-12, age=16,
version=0}
00:16:32.565 [tsc3-1] INFO : CarServiceImpl - Car age update --> Car{id=2,
licensePlate='CLARITY-0432', manufacturer='Toyota', manufactureDate=2003-09-09, age=19,
version=0}

```

```
00:16:32.565 [tsc3-1] INFO : CarServiceImpl - Car age update --> Car{id=3,
licensePlate='ROSIE-0402', manufacturer='Toyota', manufactureDate=2017-04-16, age=5,
version=0}
00:16:32.566 [tsc3-1] INFO : CarServiceImpl - Car age update job completed successfully
...
```

## Asynchronous Task Execution in Spring

Since version 3.0, Spring also supports using annotations to execute a task asynchronously. To do this, you just need to annotate the method with `@Async`. This means the caller returns immediately while the actual execution happens in a task submitted to Spring TaskExecutor.

This being said, Listing 12-19 shows the `AsyncServiceImpl` class that defines two simple methods that are invoked by asynchronous tasks.

*Listing 12-19.* `AsyncServiceImpl` Bean Class

```
package com.apress.prospring6.twelve.spring.async;

import java.util.concurrent.CompletableFuture;
import java.util.concurrent.Future;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.scheduling.annotation.Async;

public class AsyncServiceImpl implements AsyncService {
    private static final Logger LOGGER = LoggerFactory.getLogger(AsyncServiceImpl.class);

    @Async
    @Override
    public void asyncTask() {
        LOGGER.info("Start execution of async. task");

        try {
            Thread.sleep(10000);
        } catch (Exception ex) {
            LOGGER.error("Task Interruption", ex);
        }
        LOGGER.info("Complete execution of async. task");
    }

    @Async
    @Override
    public Future<String> asyncWithReturn(String name) {
        LOGGER.info("Start execution of async. task with return for {}",name);

        try {
            Thread.sleep(5000);
        } catch (Exception ex) {
            LOGGER.error("Task Interruption", ex);
        }
    }
}
```

```

    LOGGER.info("Complete execution of async. task with return for {}", name);
    return CompletableFuture.completedFuture("Hello: " + name);
}
}

```

The `AsyncService` interface defines two methods that `AsyncServiceImpl` provides implementations for. The `asyncTask()` method is a simple task that logs information to the logger. The method `asyncWithReturn()` accepts a `String` argument and returns an instance of the `java.util.concurrent.CompletableFuture<T>` that can be used by the caller to retrieve the result of the execution later.

The `@Async` annotation is picked up by enabling Spring's asynchronous method execution capability, and that is done by annotating a Java configuration class with `@EnableAsync`. Refining the configuration can be done by declaring the configuration class to implement `org.springframework.scheduling.annotation.AsyncConfigurer`.

Listing 12-20 shows the empty configuration class that enables asynchronous task execution.

**Listing 12-20.** `AsyncConfig` Bean Class

```

package com.apress.prospring6.twelve.spring.async;
// other import statements omitted
import org.springframework.scheduling.annotation.EnableAsync;

@Configuration
@EnableAsync
@ComponentScan
public class AsyncConfig {

    @Bean
    public AsyncService asyncService() {
        return new AsyncServiceImpl();
    }
}

```



The `AsyncService` bean was declared using `@Bean`, to avoid being picked up by the task scheduling configuration classes introduced previously and added into a context where it does not belong. This is a technical decision to avoid collision and log pollution, basically keeping the example scopes separate.

---

Testing this configuration requires explicit submission of tasks, especially since we need the results of the `asyncWithReturn()` invocation. The testing program is shown in Listing 12-21.

**Listing 12-21.** `AsyncDemo` Testing Class

```

package com.apress.prospring6.twelve.spring.async;
// other import statements omitted
import org.springframework.scheduling.annotation.EnableAsync;
import java.util.concurrent.ExecutionException;

public class AsyncDemo {
    private static final Logger LOGGER = LoggerFactory.getLogger(AsyncDemo.class);
}

```

```

public static void main(String... args) throws IOException, ExecutionException,
InterruptedException {
    try (var ctx = new AnnotationConfigApplicationContext(AsyncConfig.class)) {
        var asyncService = ctx.getBean("asyncService", AsyncService.class);

        for (int i = 0; i < 5; i++) {
            asyncService.asyncTask();
        }

        var result1 = asyncService.asyncWithReturn("John Mayer");
        var result2 = asyncService.asyncWithReturn("Eric Clapton");
        var result3 = asyncService.asyncWithReturn("BB King");
        Thread.sleep(6000);

        LOGGER.info(" >> Result1: " + result1.get());
        LOGGER.info(" >> Result2: " + result2.get());
        LOGGER.info(" >> Result3: " + result3.get());

        System.in.read();
    }
}

```

The `asyncTask()` method is invoked five times, then `asyncWithReturn()` method is invoked three times with different arguments, and then we retrieve the results after the main thread sleeps for six seconds. Running the program produces the output shown in Listing 12-22.

**Listing 12-22.** AsyncDemo Log Sample

```

00:11:28.937 [main] INFO : AsyncExecutionAspectSupport - No task executor bean found for
async processing: no bean of type TaskExecutor and no bean named 'taskExecutor' either
00:11:28.944 [SimpleAsyncTaskExecutor-1] INFO : AsyncServiceImpl - Start execution of
async. task
00:11:28.944 [SimpleAsyncTaskExecutor-3] INFO : AsyncServiceImpl - Start execution of
async. task
00:11:28.944 [SimpleAsyncTaskExecutor-4] INFO : AsyncServiceImpl - Start execution of
async. task
00:11:28.944 [SimpleAsyncTaskExecutor-5] INFO : AsyncServiceImpl - Start execution of
async. task
00:11:28.944 [SimpleAsyncTaskExecutor-2] INFO : AsyncServiceImpl - Start execution of
async. task
00:11:28.945 [SimpleAsyncTaskExecutor-8] INFO : AsyncServiceImpl - Start execution of async.
task with return for BB King
00:11:28.945 [SimpleAsyncTaskExecutor-7] INFO : AsyncServiceImpl - Start execution of async.
task with return for Eric Clapton
00:11:28.945 [SimpleAsyncTaskExecutor-6] INFO : AsyncServiceImpl - Start execution of async.
task with return for John Mayer
00:11:33.951 [SimpleAsyncTaskExecutor-7] INFO : AsyncServiceImpl - Complete execution of
async. task with return for Eric Clapton
00:11:33.951 [SimpleAsyncTaskExecutor-6] INFO : AsyncServiceImpl - Complete execution of
async. task with return for John Mayer

```

```

00:11:33.951 [SimpleAsyncTaskExecutor-8] INFO : AsyncServiceImpl - Complete execution of
async. task with return for BB King
00:11:34.949 [main] INFO : AsyncDemo - >> Result1: Hello: John Mayer
00:11:34.949 [main] INFO : AsyncDemo - >> Result2: Hello: Eric Clapton
00:11:34.949 [main] INFO : AsyncDemo - >> Result3: Hello: BB King
00:11:38.949 [SimpleAsyncTaskExecutor-5] INFO : AsyncServiceImpl - Complete execution of
async. task
00:11:38.949 [SimpleAsyncTaskExecutor-2] INFO : AsyncServiceImpl - Complete execution of
async. task
00:11:38.949 [SimpleAsyncTaskExecutor-3] INFO : AsyncServiceImpl - Complete execution of
async. task
00:11:38.949 [SimpleAsyncTaskExecutor-4] INFO : AsyncServiceImpl - Complete execution of
async. task
00:11:38.949 [SimpleAsyncTaskExecutor-1] INFO : AsyncServiceImpl - Complete execution of
async. task

```

From the output, you can see that all the calls were started at the same time. The three invocations with return values complete first, and are displayed on the console output. Finally, the five `asyncTask()` methods called are completed too.

Customizing this configuration is as simple as customizing the scheduled configuration—just make the configuration class implement `AsyncConfigurer` and override the `getAsyncExecutor()` method, as shown in Listing 12-23.

**Listing 12-23.** `AsyncDemo` with Custom Async Executor

```

package com.apress.prospring6.twelve.spring.async;
// other import statements omitted
import org.springframework.scheduling.annotation.AsyncConfigurer;
import org.springframework.scheduling.concurrent.ThreadPoolTaskExecutor;

@Configuration
@EnableAsync
@ComponentScan
public class AsyncConfig implements AsyncConfigurer {

    @Override
    public Executor getAsyncExecutor() {
        var tpts = new ThreadPoolTaskExecutor();
        tpts.setCorePoolSize(2);
        tpts.setMaxPoolSize(10);
        tpts.setThreadNamePrefix("tpte2-");
        tpts.setQueueCapacity(5);
        tpts.initialize();
        return tpts;
    }

    @Bean
    public AsyncService asyncService() {
        return new AsyncServiceImpl();
    }
}

```

If more than one task executor is configured in the same application context, tasks can be assigned to a specific executor by using its name as a parameter for the `@Async` annotation, such as `@Async("otherExecutor")`.

Both task executions and schedulers can be configured to handle situations in which tasks end with an exception being thrown using special exception handlers. As shown in Listing 12-24, the `ThreadPoolTaskScheduler` can be configured with an instance of `org.springframework.util.ErrorHandler` to handle errors that occur during asynchronous execution of tasks, and a task executor can be configured with an instance of type `java.util.concurrent.RejectedExecutionHandler` to handle rejected tasks.

*Listing 12-24.* `TaskSchedulingConfig4` Example with an `ErrorHandler` and a `RejectedExecutionHandler`

```
package com.apress.prospring6.twelve.spring.config;

import org.springframework.scheduling.annotation.EnableScheduling;
import org.springframework.scheduling.concurrent.ThreadPoolTaskScheduler;
import org.springframework.util.ErrorHandler;

import java.util.concurrent.ConcurrentHashMap;
import java.util.concurrent.RejectedExecutionHandler;
import java.util.concurrent.ThreadPoolExecutor;

@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.twelve.spring"})
@EnableScheduling
public class TaskSchedulingConfig4 {

    @Bean
    TaskScheduler taskScheduler() {
        var tpts = new ThreadPoolTaskScheduler();
        tpts.setPoolSize(3);
        tpts.setThreadNamePrefix("tsc4-");
        tpts.setErrorHandler(new LoggingErrorHandler("tsc4"));
        tpts.setRejectedExecutionHandler(new RejectedTaskHandler());
        return tpts;
    }
}

class LoggingErrorHandler implements ErrorHandler {

    private static final Logger LOGGER = LoggerFactory.getLogger(LoggingErrorHandler.class);
    private final String name;

    public LoggingErrorHandler(String name) {
        this.name = name;
    }

    @Override
    public void handleError(Throwable t) {
        LOGGER.error("[{}]: task failed because {}", name, t.getCause(), t);
    }
}
```



```

class RejectedTaskHandler implements RejectedExecutionHandler {

    private static final Logger LOGGER = LoggerFactory.getLogger(RejectedTaskHandler.class);

    private Map<Runnable, Integer> rejectedTasks = new ConcurrentHashMap<>();

    @Override
    public void rejectedExecution(Runnable r, ThreadPoolExecutor executor) {
        LOGGER.info(">> check for resubmission.");
        boolean submit = true;
        if (rejectedTasks.containsKey(r)) {
            int submittedCnt = rejectedTasks.get(r);
            if (submittedCnt > 5) {
                submit = false;
            } else {
                rejectedTasks.put(r, rejectedTasks.get(r) + 1);
            }
        } else {
            rejectedTasks.put(r, 1);
        }
        if(submit) {
            executor.execute(r);
        } else {
            LOGGER.error(">> Task {} cannot be re-submitted.", r.toString());
        }
    }
}

```

The `LoggingErrorHandler` simply logs with the `ERROR` level the exception thrown by a task being processed. The `RejectedTaskHandler` resubmits a rejected task and keeps count of the number of resubmissions. If a task has been resubmitted more than five times, an exception is thrown and the task is not submitted anymore.

Listing 12-10 earlier in the chapter shows the `CarServiceImpl` throwing an `IllegalStateException` every time the internal time divides perfectly by 5. The stacktrace of this exception is shown in the console and the `LoggingErrorHandler` intercepts it and prints the task name, so we know which task failed.

There are two situations in which a task is rejected: when the task is submitted after `shutdown()` is invoked, and when the thread pool doesn't have any available threads for the task to execute in. For the first scenario, an implementation of `RejectedExecutionHandler` can only submit a notification or write a log with the details of the failed task. For the second scenario, an implementation like the one in `RejectedTaskHandler` tries to resubmit the task a few times back to the executor until a final rejection, if the task was still not executed. Unfortunately, this situation is difficult to reproduce with tasks that barely do anything, like the one in `CarServiceImpl`.

Feel free to run the examples in the `chapter12` project and notice the exception handling specific to the `TaskSchedulingConfig4` configuration.

Listing 12-19 shows the `AsyncServiceImpl` throwing an `IllegalStateException` every time the internal time divides perfectly by 5. For a Spring asynchronous task executor, a bean of type `org.springframework.aop.interceptor.SimpleAsyncUncaughtExceptionHandler` (that implements `org.springframework.aop.interceptor.AsyncUncaughtExceptionHandler`) simply logs the exception. To override this behavior, we have to implement this interface and override the default one by implementing the `getAsyncUncaughtExceptionHandler()` method from the `AsyncConfigurer` interface.

Listing 12-25 shows the custom `AsyncExceptionHandler` class and the new asynchronous executor configuration.

**Listing 12-25.** `TaskSchedulingConfig4` Example with an `ErrorHandler` and a `RejectedExceptionHandler`

```

package com.apress.prospring6.twelve.spring.async;

import org.springframework.aop.interceptor.AsyncUncaughtExceptionHandler;
// other import statements omitted

class AsyncExceptionHandler implements AsyncUncaughtExceptionHandler {
    private static final Logger LOGGER = LoggerFactory.
        getLogger(AsyncExceptionHandler.class);
    @Override
    public void handleUncaughtException(Throwable t, Method method, Object... obj) {
        LOGGER.error("[{}]: task method '{}' failed because {}", Thread.currentThread(),
            method.getName() , t.getMessage(), t);
    }
}

@Configuration
@EnableAsync
@ComponentScan
class Async2Config implements AsyncConfigurer {

    @Override
    public Executor getAsyncExecutor() {
        var tpts = new ThreadPoolTaskExecutor();
        tpts.setCorePoolSize(2);
        tpts.setMaxPoolSize(10);
        tpts.setThreadNamePrefix("tpte2-");
        tpts.setQueueCapacity(5);
        tpts.initialize();
        return tpts;
    }

    @Bean
    public AsyncService asyncService() {
        return new AsyncServiceImpl();
    }

    @Override
    public AsyncUncaughtExceptionHandler getAsyncUncaughtExceptionHandler() {
        return new AsyncExceptionHandler();
    }
}

```

```

public class Async2Demo {
    private static final Logger LOGGER = LoggerFactory.getLogger(Async2Demo.class);

    public static void main(String... args) throws IOException, ExecutionException,
    InterruptedException {
        try (var ctx = new AnnotationConfigApplicationContext(Async2Config.class)) {
            var asyncService = ctx.getBean("asyncService", AsyncService.class);
            // code to invoke tasks is omitted for duplicate
        }
    }
}

```

Again, feel free to run the examples in the chapter12 project and notice the exception handling specific to the Async2Config configuration.

## Summary

In this chapter, we briefly covered Spring's TaskExecutor and common implementations. We also covered Spring's support for task scheduling. We focused on Spring's built-in TaskScheduler abstraction and demonstrated how to use it to fulfill task scheduling needs with a sample batch data update job. We also covered how Spring supports annotation for executing tasks asynchronously.

A Spring Boot section is not needed in this chapter because the annotations used for marking tasks for scheduling and asynchronous execution are part of the spring-context library and available with a basic Spring Boot configuration. Plus, configuring scheduled and asynchronous tasks is already as easy as it can be with Spring; there is not much Spring Boot could do to improve on this topic. If you are curious and want to convert the provided project to Spring Boot, you can find inspiration in previous chapters or in this brief tutorial: <https://spring.io/guides/gs/scheduling-tasks>.

Since the future seems to be serverless, there will be no servers to be up to run tasks at scheduled intervals. The current approach on cloud applications is to design microservices that run within containers that are scheduled for deployment (or to use scheduled lambdas in AWS, for example). Task execution and scheduling is not a complex subject, so it is time to move on to something more interesting, Spring Remoting.

## CHAPTER 13



# Spring Remoting

In the previous chapters of this book, the projects have been relatively simple, insofar as they can be run on a single VM and the only component they exchange data with is a database, which can be local or remote. These types of applications are called *monolithic applications* and this type of communication is also referred to as **inter-process communication**.

Most enterprise applications, however, are complex, are composed of multiple parts, and communicate with other applications. Take, for example, a company selling products; when a customer places an order, an order-processing system processes that order and generates a transaction. During order processing, an inquiry is made to the inventory system to check whether the product is in stock. Upon order confirmation, a notification is sent to the fulfillment system to deliver the product to the customer. Finally, the information is sent to the accounting system, an invoice is generated, and the payment is processed.

This business process is not fulfilled by a single application, but by several applications working together. Some applications may be developed in-house, and others may be purchased from external vendors. Moreover, the applications may be running on different machines in different locations and implemented with different technologies and programming languages (for example, Java, .NET, or C++). Performing the handshaking between applications in order to build an efficient business process is always a critical task when architecting and implementing an application. As a result, remoting support via various protocols and technologies is needed for an application to participate well in an enterprise environment.

In earlier times, communication between applications was achieved via *remoting* and *web services*. In remoting, the applications involved in the communication process may be located on the same computer or on different computers (either in the same network or a different network). In remoting, both applications know about each other. A proxy of an application object is created in the other application, and this allows to make the execution of a foreign (remote) method to look like the invocation of a local method.

In the Java world, remoting support has existed since Java was first created. In the early days (Java 1.x), most remoting requirements were implemented by using traditional TCP sockets or Java Remote Method Invocation (RMI). After J2EE came on the scene, EJB (Enterprise Java Beans) and JMS (Java Messaging System) became common choices for inter-application server communications.

The rapid evolution of XML and the Internet gave rise to remote support using XML over HTTP, also known as *web services*. This is a term that includes any kind of remoting technology that sits on HTTP, including the Java API for XML-based RPC (JAX-RPC), the Java API for XML Web Services (JAXWS), and HTTP-based technologies (for example, Hessian<sup>1</sup> and Burlap<sup>2</sup>). Spring used to have its own HTTP-based remoting support, called the Spring HTTP Invoker. In the following years, to cope with the explosive growth of the Internet and more responsive web application requirements (for example, via Ajax), more lightweight

---

<sup>1</sup><http://hessian.caucho.com/doc/hessian-overview.xtp>

<sup>2</sup><http://hessian.caucho.com/doc/burlap.xtp>

and efficient remoting support of applications has become critical for the success of an enterprise. Consequently, the Java API for RESTful Web Services (JAX-RS) was created and quickly gained popularity. Other protocols, such as Comet and HTML5 WebSocket, also attracted a lot of developers. Needless to say, remoting technologies keep evolving at a rapid pace.

Nowadays, the most popular application architecture style is *microservices*, small modules/elements that are independent of each other. At times, microservices are interdependent on other microservices or even a database. Breaking down applications into smaller elements brings scalability and efficiency to the structure. It also requires efficient communication between the services, which if not considered ahead of time can wreak havoc. Communication between the components of a microservices application is also referred to as **inter-service communication**.

The outright leader when choosing how services will communicate with each other tends to be *HTTP*. Communication via HTTP can be *synchronous*, which is when a service has to wait for another service to complete before it returns; this introduces a strong coupling of the two services. Communication via HTTP can also be *asynchronous*, which is when the service takes the request from the first service and immediately returns a URL. An alternative to HTTP is *gRPC*<sup>3</sup> a modern open source high-performance Remote Procedure Call (RPC) framework that can run in any environment. Unfortunately, there is no Spring module for working with gRPC.

The second communication pattern leveraged in microservices applications is *message-based communication*. The most popular protocol for this is Advanced Message Queuing Protocol (AMQP). Unlike HTTP, the services involved do not directly communicate with each other, but interact via a message broker (Kafka, RabbitMQ, ActiveMQ, SNS, etc.).

Thus, the title of this chapter is somewhat misleading. Its content will cover a few ways to communicate between Spring applications remotely, but *Spring Remoting* is a term that is somewhat deprecated.

## Communication via HTTP Using Spring REST

Using HTTP for communication obviously implies that the applications have to be web applications or expose some REST API to support those calls. To show how two Spring applications can communicate with each other via HTTP, a single application is used that models a person sending and receiving letters, as depicted in Figure 13-1. The application is started twice with different properties to model Evelyn and Tom, two pen pals sending letters to each other using POST requests and saving them into their own respective H2 database. The application representing Evelyn is started on port 8080, and the application representing Tom is started on port 8090.

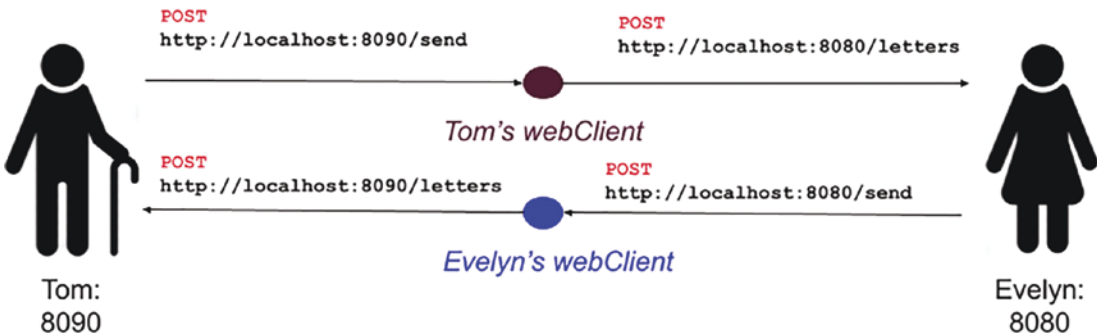


Figure 13-1. Abstract representation of the two pen pals applications

<sup>3</sup><https://grpc.io>

To make Evelyn send a letter to Tom, a POST event is sent to `http://localhost:8080/send` with a body representing a letter. Internally, the `LetterSender` bean will make a POST call to Tom's exposed REST API at `http://localhost:8090/letters` using an instance of `webClient`.



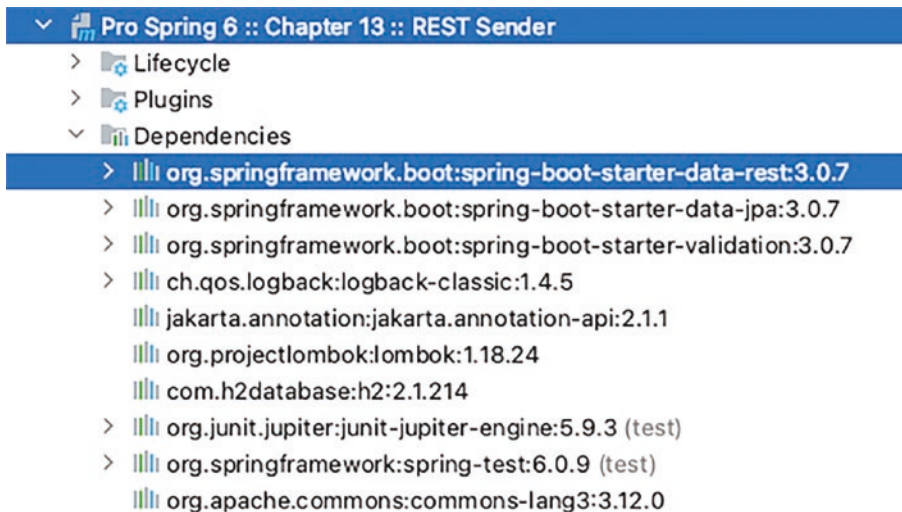
To keep the discussion and examples simple in this chapter, maintaining secure communications between applications won't be a focus.

To make Tom send a letter to Evelyn, the same thing will be done, as already shown in Figure 13-1.

The `webClient` mentioned is an instance of Spring's `org.springframework.web.client.RestTemplate`, the web client class used to make REST calls in non-reactive applications. There is also an implementation for reactive applications, which is introduced in **Chapter 20**.

To keep things easy, only Spring Boot applications are used in this chapter. To keep things even simpler for the letter correspondence application over HTTP, Spring Data REST repositories are used. Spring Data REST takes the features of Spring HATEOAS (Hypermedia as the Engine of Application State) and Spring Data JPA and automatically combines them together, allowing us to expose REST APIs to manage entities without declaring a controller to interact with the Spring Repository.

Figure 13-2 shows the dependencies needed for project `chapter13-sender-boot` to model the behavior we are interested in.



**Figure 13-2.** Project `chapter13-sender-boot` dependencies

Let's build the project step by step, starting with the entity class. The class that models a letter is shown in Listing 13-1.

*Listing 13-1.* The Letter Class

```

package com.apress.prospring6.thirteen;

import jakarta.persistence.*;
import lombok.*;

import java.io.Serial;
import java.io.Serializable;
import java.time.LocalDate;
import jakarta.validation.constraints.NotEmpty;

@Data
@Entity
public class Letter implements Serializable {
    @Serial
    private static final long serialVersionUID = 1L;
    @Id
    @GeneratedValue(strategy = GenerationType.AUTO)
    private Long id;
    @NotEmpty
    private String title;

    private String sender;

    private LocalDate sentOn;
    @Enumerated(EnumType.STRING)
    private Category category = Category.MISC;
    @NotEmpty
    private String content;
}

```

Notice that the Lombok `@Data` annotation used on the `Letter` entity class is a shortcut annotation that bundles the features of Lombok's `@ToString`, `@EqualsAndHashCode`, `@Getter`, `@Setter`, and `@RequiredArgsConstructor` together, thus generating all the boilerplate that is associated with simple entity classes (POJOs).



Using Lombok<sup>4</sup> was avoided in this book until this chapter, because it was important to show the data classes as Hibernate needs them to be modeled, with default constructors and setter and getters for all properties. Project Lombok is a Java library that automatically plugs into your editor and build tools, spicing up your Java. It generates a lot of code for you: constructors, getters, setters, hashcode, equals, and configures loggers, reducing the boilerplate code and allowing you to focus on pure functionality.

---

<sup>4</sup><https://projectlombok.org>



Lombok is closely tied to the Java compiler. Since the annotation processor API only allows creation of new files during the compilation (and not the modification of existing files), Lombok uses that API as an entry point to modify the Java compiler. Unfortunately, these modifications of the compiler make heavy usage of non-public APIs. Using Lombok may be a good idea, but you must be aware that upgrading your compiler may break your code.

The Category enum is used to categorize letters based on tier scope. This enum has various values, and to ensure correct serialization and deserialization when letters are sent, CategorySerializer and CategoryDeserializer classes are declared as shown in Listing 13-2.

**Listing 13-2.** The Category Enum and Its CategorySerializer and CategoryDeserializer Classes

```
package com.apress.prospring6.thirteen;

import com.fasterxml.jackson.core.JsonGenerator;
import com.fasterxml.jackson.core.JsonParser;
import com.fasterxml.jackson.databind.JsonDeserializer;
import com.fasterxml.jackson.databind.JsonSerializer;
import lombok.Getter;
import lombok.RequiredArgsConstructor;
// other import statements omitted

@JsonSerialize(using = Category.CategorySerializer.class)
@JsonDeserialize(using = Category.CategoryDeserializer.class)
@Getter
@RequiredArgsConstructor
public enum Category {
    PERSONAL("Personal"),
    FORMAL("Formal"),
    MISC("Miscellaneous")
    ;
    private final String name;

    public static Category eventOf(final String value) {
        var result = Arrays.stream(Category.values()).filter(m -> m.getName().
            equalsIgnoreCase(value)).findAny();
        return result.orElse(null);
    }

    public static final class CategorySerializer extends JsonSerializer<Category> {
        @Override
        public void serialize(final Category enumValue, final JsonGenerator gen, final
            SerializerProvider serializer) throws IOException {
            gen.writeString(enumValue.getName());
        }
    }
}
```



```

public final static class CategoryDeserializer extends JsonSerializer<Category> {
    @Override
    public Category deserialize(final JsonParser parser, final DeserializationContext
    context) throws IOException, JsonProcessingException
    {
        final String jsonValue = parser.getText();
        return Category.eventOf(jsonValue);
    }
}

```

Now that we have the entity class in place, we can write the Spring Data REST repository. This repository is just like a Spring Data Repository, either `JpaRepository<T, ID>`, `CrudRepository<T, ID>`, or `PagingAndSortingRepository<T, ID>`, but the class and its methods are decorated with special Spring Data REST annotations that tell Spring MVC (the topic of [Chapter 14](#)) to create RESTful endpoints for managing entities. The `LetterRepository` interface is shown in [Listing 13-3](#).

*Listing 13-3.* The `LetterRepository` Spring Data REST Repository

```

package com.apress.prospring6.thirteen;

import org.springframework.data.jpa.repository.JpaRepository;
import org.springframework.data.repository.query.Param;
import org.springframework.data.rest.core.annotation.RepositoryRestResource;
import org.springframework.data.rest.core.annotation.RestResource;

import java.time.LocalDate;
import java.util.List;

@RepositoryRestResource(collectionResourceRel = "mailbox", path = "letters")
public interface LetterRepository extends JpaRepository<Letter, Long> {

    @RestResource(path = "byCategory", rel = "customFindMethod")
    List<Letter> findByCategory(@Param("category") Category category);
    List<Letter> findBySentOn(@Param("date") LocalDate sentOn);

    @Override
    @RestResource(exported = false)
    void deleteById(Long id);
}

```

The `@RepositoryRestResource` annotation tells Spring MVC to create RESTful endpoints at `/letters`. This annotation is not necessary when the `spring-boot-starter-data-rest` is on the project classpath, but it is useful to customize the path all the management endpoints are relative to. The default root path for managing `Letter` instances is `letters`, the same one used in the example. When the `http://localhost:8090/letters` is accessed, a JSON construct similar to the one depicted in [Listing 13-4](#) is shown.

**Listing 13-4.** The JSON Representation Returned When Accessing the `http://localhost:8090/letters` Endpoint

```
{
  "_embedded" : {
    "mailbox" : [ {
      "title" : "Salutations from England",
      "sender" : "Evelyn",
      "sentOn" : "2022-12-05",
      "category" : "Personal",
      "content" : "I would love to visit. Let's discuss dates.",
      "_links" : {
        "self" : {
          "href" : "http://localhost:8090/letters/1"
        },
        "letter" : {
          "href" : "http://localhost:8090/letters/1"
        }
      }
    }
  ]
},
  "_links" : {
    "self" : {
      "href" : "http://localhost:8090/letters"
    },
    "profile" : {
      "href" : "http://localhost:8090/profile/letters"
    },
    "search" : {
      "href" : "http://localhost:8090/letters/search"
    }
  },
  "page" : {
    "size" : 20,
    "totalElements" : 2,
    "totalPages" : 1,
    "number" : 0
  }
}
```

The `collectionResourceRel` attribute declares the relative value to use when generating links to the collection resource. This means all `Letter` instances will be returned as part of the collection named `mailbox` that is a member of the JSON representation accessible at the `http://localhost:8090/letters` endpoint. (Look at the highlighted text in Listing 13-4, that is the mentioned collection, that is empty when the application starts.)

The `@RestResource` annotation tells Spring MVC what the value of the path of a resource is, and the value of the `rel` attribute will be in links. By executing a `curl` to `http://localhost:8090/letters/search` (or opening the URL in the browser), we can see our new methods listed with other resources, parameters names included as shown in Listing 13-5.

**Listing 13-5.** The JSON Representation Returned When Accessing the `http://localhost:8090/letters/search` Endpoint

```
## curl http://localhost:8090/letters/search
{
  "_links" : {
    "findBySentOn" : {
      "href" : "http://localhost:8090/letters/search/findBySentOn{?date}",
      "templated" : true
    },
    "customFindMethod" : {
      "href" : "http://localhost:8090/letters/search/byCategory{?category}",
      "templated" : true
    },
    "self" : {
      "href" : "http://localhost:8090/letters/search"
    }
  }
}
```

In Listing 13-3 the `deleteById(..)` method is annotated with `@RestResource(exported = false)`. The `exported` attribute value decides if the resource is exported or not. In this example, the effect of this configuration is that there will be no REST endpoint created for the `deleteById(..)` method. However, there are two links matching the two custom search methods declared in `LetterRepository` shown in Listing 13-3. The `{?category}` construct represents the request parameter name, thus the search by category actual URL is something like:

```
GET http://localhost:8090/letters/search/byCategory?category=PERSONAL
```

The purpose of the `LetterRepository` interface is to expose REST API endpoints to be invoked by a `RestTemplate` instance.

The next class to be analyzed is `LetterSenderController`. This class is a REST controller exposing a single POST handler used to trigger the sending letter operation on the current application. The handler method uses the `RestTemplate` bean to send a POST request to the other instance of the application representing letter destination. The `LetterSenderController` class is depicted in Listing 13-6.

**Listing 13-6.** The `LetterSenderController` Class

```
package com.apress.prospring6.thirteen;

import org.springframework.beans.factory.annotation.Value;
import org.springframework.http.HttpEntity;
import org.springframework.http.HttpMethod;
import org.springframework.http.MediaType;
import org.springframework.web.bind.annotation.PostMapping;
import org.springframework.web.bind.annotation.RequestBody;
import org.springframework.web.bind.annotation.RestController;
import org.springframework.web.client.RestTemplate;
import java.time.LocalDate;
```

```

@RestController
public class LetterSenderController {

    private final RestTemplate webClient;
    private final String correspondentAddress;
    private final String sender;

    public LetterSenderController(RestTemplate webClient,
        @Value("#{senderApplication.correspondentAddress}") String
        correspondentAddress,
        @Value("#{senderApplication.sender}") String sender) {
        this.webClient = webClient;
        this.correspondentAddress = correspondentAddress;
        this.sender = sender;
    }

    @PostMapping(path = "send", consumes = MediaType.APPLICATION_JSON_VALUE)
    public void sendLetter(@RequestBody Letter letter){
        letter.setSender(sender);
        letter.setSentOn(LocalDate.now());
        var request = new HttpEntity<>(letter);
        webClient.exchange(correspondentAddress + "/letters", HttpMethod.POST, request,
            Letter.class);
    }
}

```

**Chapter 3** introduced stereotype annotations. The `@RestController` annotation is a convenience annotation that is itself annotated with `@Controller` and `@ResponseBody`. If `@Controller` is used to mark beans destined for web use, containing methods mapped to URLs, `@RestController` is used to mark beans destined for REST use, containing methods mapped to REST endpoints. Since neither Spring MVC support (**Chapter 14**) nor Spring REST support (**Chapter 15**) were introduced so far in the book, this explanation should suffice for now.

The `RestTemplate` class is a Spring class used to create synchronous clients to perform HTTP requests. It exposes a very simple set of methods used to set request content and headers and also exposes a simple, template method API over underlying HTTP client libraries such as the `JDK HttpURLConnection`, `Apache HttpComponents`, and others. `RestTemplate` is typically used as a shared component; a single bean is declared in the application and injected wherever necessary. Starting with Spring version 5.0, this class is in maintenance mode, with only minor requests for changes and bugs to be accepted going forward. The recommendation is to use `org.springframework.web.reactive.client.WebClient`, which has a more modern API and supports sync, async, and streaming scenarios, but for non-reactive applications, the reactive `WebClient` is not suitable.

The `LetterSenderController` class is configured with a `sender` property which is set to the name of the person sending the letter. The `sender` value is injected from the main Spring Boot application class, referenced here using a SpEL expression: `#{senderApplication.sender}`. The same is valid for the person the letters are sent to, represented here by the `correspondentAddress` property that is populated from a Spring Boot property as well. The values for these properties are read from the Spring Boot configuration file, the `application.yaml` file in this example. Its contents are shown in Listing 13-7.

**Listing 13-7.** The application.yaml File for the chapter13-sender-boot Project

```
# Spring Boot application name
spring:
  application:
    name: chapter13-sender-app

# datasource config
datasource:
  url: "jdbc:h2:mem:testdb"
  driverClassName: "org.h2.Driver"
  username: sa
  password: password

# jpa config
jpa:
  database-platform: "org.hibernate.dialect.H2Dialect"
  hibernate:
    ddl-auto: create-drop
    # Uppercase Table Names
    naming:
      physical-strategy: org.hibernate.boot.model.naming.
        PhysicalNamingStrategyStandardImpl

# enabling the H2 web console
h2:
  console:
    enabled: true

# application config
app:
  sender:
    name: "default"
  correspondent:
    address: "http://localhost:8090"

# server config
server:
  port: 8090
  compression:
    enabled: true
  address: 0.0.0.0
```

```
# Logging config
logging:
  pattern:
    console: "%-5level: %class{0} - %msg%n"
  level:
    root: INFO
    org.springframework: DEBUG
    com.apress.prospring6.thirteen: INFO
```

This configuration is split into seven sections, some of which are already familiar to you if you've read the previous chapter. Each section is described in the following list:

- # `Spring Boot application name`: This section configures a value for the Spring `ApplicationContext` ID.
- # `datasource config`: This section configures the data source connection details; in this case the underlying database is an in-memory H2 database.
- # `jpa config`: This section configures the JPA details, such as the dialect used to communicate with the database, whether the database should be created, and how the tables should be named; in this case, all table names are generated using uppercase letters.
- # `enabling the H2 web console`: As the section name indicates, sometimes to check if the application is doing the right thing, we might want to check the database and generated table. This property enables exposing the `/h2-console` endpoint that points to a web console for managing the H2 database (similar to `phpMyAdmin`<sup>5</sup>, but way simpler). The login window and the console dashboard are shown in [Figure 13-3](#).

---

<sup>5</sup><https://www.phpmyadmin.net>

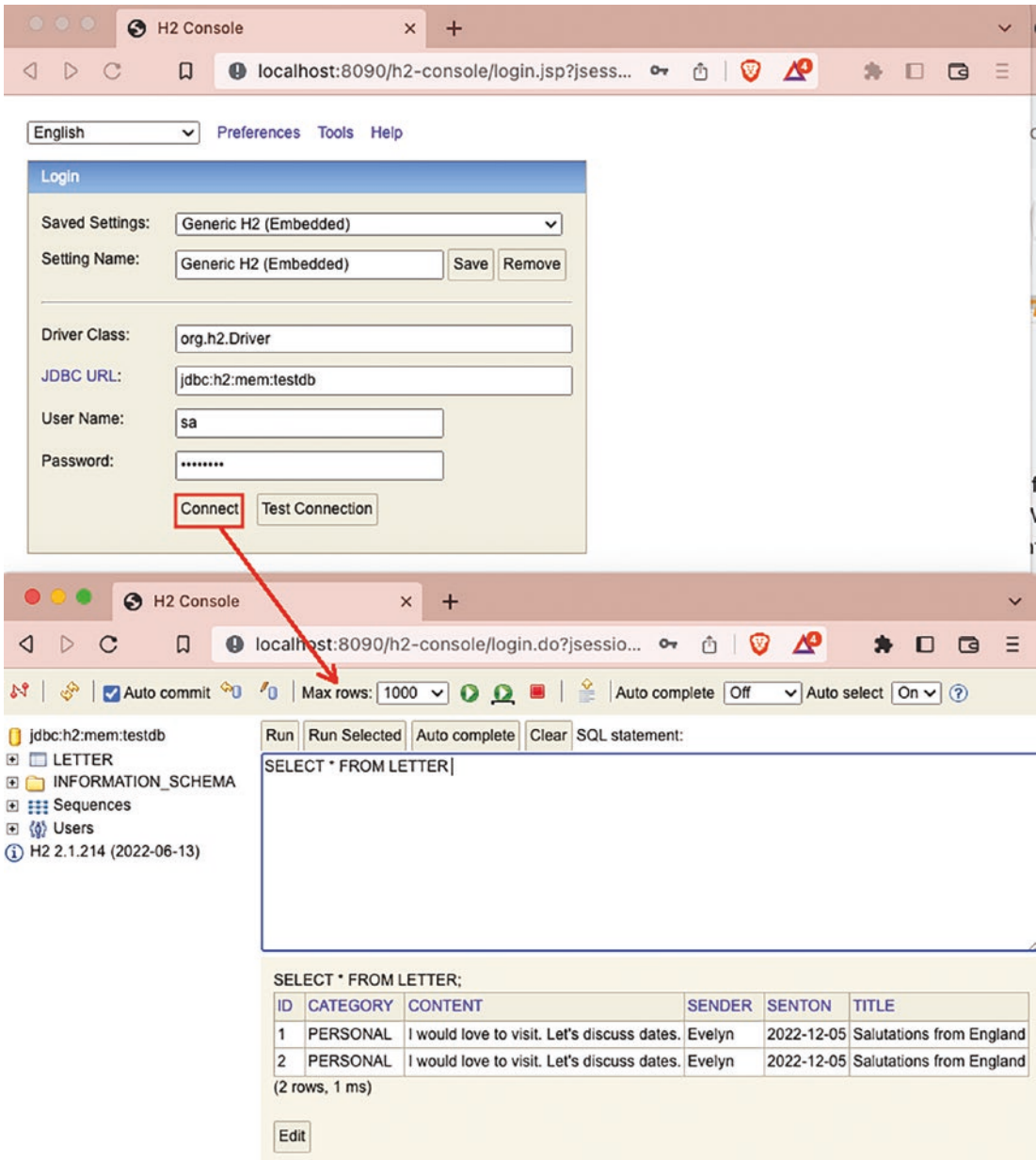


Figure 13-3. H2 Console login and dashboard

- # application config: This section configures the user sending the letters and the address which the letters are being sent. The default configuration is to configure an application where the letter sender and the correspondence address represent the same application.

- `# server config`: This section configures the URL where the application is available. Setting the address to `0.0.0.0` allows the application to be accessible on all network addresses associated with the computer the application runs in (e.g., `http://localhost:8090/letters`, `http://127.0.0.1:8090/letters`, etc.).
- `# Logging config`: This section configures the logging levels for packages and classes in the application.

Based on this configuration and a Spring Boot main class, an application that can communicate via HTTP with another one can be started. The Spring Boot main class is shown in Listing 13-8.

**Listing 13-8.** The Spring Boot Main Class for the `chapter13-sender-boot` Project

```

package com.apress.prospring6.thirteen;

import lombok.extern.slf4j.Slf4j;
import org.springframework.boot.CommandLineRunner;
// other import statements omitted

@SpringBootApplication
@Slf4j
public class SenderApplication {

    public static void main(String... args) {
        ConfigurableApplicationContext ctx = SpringApplication.run(SenderApplication.
            class, args);
    }

    @Value("${app.sender.name}")
    public String sender;

    @Value("${app.correspondent.address}")
    public String correspondentAddress;

    @Bean
    RestTemplate restTemplate(){
        return new RestTemplate();
    }

    @Bean
    public CommandLineRunner initCmd(){
        return (args) -> log.info(" >>> Sender {} ready to send letters to {}", sender,
            correspondentAddress);
    }
}

```

As you can see from this example, Lombok can also help declare the logger for classes, by using the `@Slf4j` annotation.

The `app.sender.name` is read from the `application.yaml` file and injected into the `sender` property. The `app.correspondent.address` is read from the `application.yaml` file and injected into the `correspondentAddress` property. The `SenderApplication` configuration declares a bean named `senderApplication`, and the properties of this bean are injected in the `LetterSenderController` class using SpEL expressions as shown previously in Listing 13-6.



Now that all beans and configurations have been explained, let's start the two applications, named Tom and Evelyn, and start sending letters. To start two instances of the application, you can use IntelliJ IDEA launchers, but the easiest way is to build the application and start it twice, with different configurations for Tom and Evelyn using the generated JAR.

To build the project, go to the `pro-spring-6/chapter13-sender-boot` and run `gradle clean build`. The project is built and the executable is generated at `chapter13-sender-boot/build/libs/chapter13-sender-boot-6.0-SNAPSHOT.jar`.

To start the Tom application, open a terminal and run the command shown in Listing 13-9.

**Listing 13-9.** Starting the Tom Application

```
java -jar \
build/libs/chapter13-sender-boot-6.0-SNAPSHOT.jar \
--server.port=8090 \
--app.sender.name=Tom \
--app.correspondent.address=http://localhost:8080 # Evelyn's address
```

The application starts and the last two log entries printed should be as follows:

```
INFO: SenderApplication - >>> Sender Tom ready to send letters to http://localhost:8080
DEBUG: ApplicationAvailabilityBean - Application availability state ReadinessState changed
to ACCEPTING_TRAFFIC
```

The INFO log is printed by the `CommandLineRunner` bean.

To start the Evelyn application, open a terminal and run the command shown in Listing 13-10.

**Listing 13-10.** Starting the Evelyn Application

```
java -jar \
build/libs/chapter13-sender-boot-6.0-SNAPSHOT.jar \
--server.port=8080 \
--app.sender.name=Evelyn \
--app.correspondent.address=http://localhost:8090 # Tom's address
```

The application starts and the last two log entries printed should be as follows:

```
INFO : SenderApplication - >>> Sender Evelyn ready to send letters to http://
localhost:8090
DEBUG: ApplicationAvailabilityBean - Application availability state ReadinessState changed
to ACCEPTING_TRAFFIC
```

To make Tom send a letter to Evelyn, a POST request must be made to `http://localhost:8090/send`. The easiest way to do so is by executing the requests in the `chapter13-sender-boot/src/test/resources/Sender.http` file, using the HTTPie<sup>6</sup> client embedded in IntelliJ IDEA. For example, the request to send a letter from Tom to Evelyn (one of the requests in the `Sender.http` file) is shown in Listing 13-11.

**Listing 13-11.** HTTPie POST Request to Make Tom Send a Letter to Evelyn

```
### Tom sending letter to Evelyn
POST http://localhost:8090/send
Content-Type: application/json
```

<sup>6</sup><https://httpie.io>

```
{
  "title": "Salutations from Scotland",
  "category": "Personal",
  "content" : "Scotland is rather lovely this time of year. Would you like to visit?"
}
```

How do we know this worked? We look in Tom's log and look for the log entries that report that the `restTemplate` bean has performed the request. The log entries should look very similar to the ones shown in Listing 13-12.

**Listing 13-12.** Application Log Entries for Sending Requests Using a `restTemplate` Bean

```
DEBUG: LogFormatUtils - POST "/send", parameters={}
DEBUG: AbstractHandlerMapping - Mapped to com.apress.prospring6.thirteen.LetterSender
Controller#sendLetter(Letter)
DEBUG: CompositeLog - HTTP POST http://localhost:8080/letters
DEBUG: CompositeLog - Accept=[application/json, application/*+json]
DEBUG: CompositeLog - Writing [Letter(id=null, title=Salutations from Scotland,
sender=Tom, sentOn=2022-12-06, category=PERSONAL, content=Scotland is rather lovely this
time of year. Would you like to visit?)] with org.springframework.http.converter.json.
MappingJackson2HttpMessageConverter
DEBUG: CompositeLog - Response 201 CREATED
DEBUG: CompositeLog - Reading to [com.apress.prospring6.thirteen.Letter]
```

On the Evelyn application, you can see a matching log, depicted in Listing 13-13.

**Listing 13-13.** Application Log Entries for Receiving a POST Request

```
DEBUG: LogFormatUtils - POST "/letters", parameters={}
DEBUG: AbstractMessageConverterMethodProcessor - Using 'application/json', given
[application/json, application/*+json] and supported [application/hal+json, application/
json, application/prs.hal-forms+json]
DEBUG: LogFormatUtils - Writing [EntityModel { content: Letter(id=1, title=Salutations from
Scotland, sender=Tom, sentOn=2022-12-06, (truncated)...}]
DEBUG: FrameworkServlet - Completed 201 CREATED
```

And to be really convinced, you can open `http://localhost:8080/letters` in a browser (or use the GET request in the `Sender.http` file). The returned JSON representation for Evelyn should now have the mailbox populated with the letter sent by Tom. The JSON representation is shown in Listing 13-14.

**Listing 13-14.** JSON Representation of Letter Resources for the Evelyn Application

**### Root JSON representation of Evelyn's letters**

**GET http://localhost:8080/letters**

**Accept: application/json**

**###**

```
{
  "_embedded" : {
    "mailbox" : [ {
      "title" : "Salutations from Scotland",
      "sender" : "Tom",
      "sentOn" : "2022-12-06",
```

```

        "category" : "Personal",
        "content" : "Scotland is rather lovely this time of year. Would you like to visit?",
        "_links" : {
            "self" : {
                "href" : "http://localhost:8080/letters/1"
            },
            "letter" : {
                "href" : "http://localhost:8080/letters/1"
            }
        }
    } ]
},
"_links" : {
    "self" : {
        "href" : "http://localhost:8080/letters"
    },
    "profile" : {
        "href" : "http://localhost:8080/profile/letters"
    },
    "search" : {
        "href" : "http://localhost:8080/letters/search"
    }
},
"page" : {
    "size" : 20,
    "totalElements" : 1,
    "totalPages" : 1,
    "number" : 0
}
}
}

```

By default, `RestTemplate` registers all built-in message converters, depending on classpath checks that help to determine what optional conversion libraries are present. Since we have two copies of the same application communicating, they can both covert between `Letter` and its JSON representation and vice versa with no problem. You can also set the message converters to use explicitly if you need too.

However, `RestTemplate` can be used to communicate with any other application, written in any language, as long as the right converters are registered. For example, in Listing 13-15 a method is added to `LetterSenderController` to perform a request to <https://jsonplaceholder.typicode.com/users>, an endpoint provided by a free fake API for testing and prototyping.

**Listing 13-15.** `RestTemplate` Being Used to Perform a GET to <https://jsonplaceholder.typicode.com/users>

```

package com.apress.prospring6.thirteen;
// other imports omitted

@RestController
@Slf4j
public class LetterSenderController {

    @GetMapping(path = "misc", produces = MediaType.APPLICATION_JSON_VALUE)
    public String getMiscData(){

```

```

    var response = webClient.getForObject("https://jsonplaceholder.typicode.com/users",
    String.class);
    log.info("Random info from non-java application: {} ", response);
    return response;
}
}

```

The returned result is an array of user objects in JSON representation. If the application had a User POJO definition matching the JSON representation, a converter would ensure a correct conversion.

The `RestTemplate` class used to submit the requests is quite versatile, but as previously mentioned, it is set to be deprecated. The future seems to be reactive, and `WebClient` and the new declarative HTTP interface are the replacements.

Starting with Spring 6 and Spring Boot 3, the Spring Framework supports proxying a remote HTTP service as a Java interface with annotated methods for HTTP exchanges, also called a *declarative HTTP interface*<sup>7</sup>. A declarative HTTP interface is a Java interface that helps reduce the boilerplate code, generates a proxy implementing this interface, and performs the exchanges at the framework level.

## Using JMS in Spring

Using message-oriented middleware, generally referred to as a message queue (MQ) server, is another popular way to support communication between applications. The main benefits of an MQ server are that it provides an asynchronous and loosely coupled way for application integration. In the Java world, JMS is the standard for connecting to an MQ server for sending or receiving messages. An MQ server maintains a list of queues and topics for applications to connect to for sending and receiving messages. The following is a brief description of the difference between a queue and a topic:

- *Queue*: A queue is used to support a point-to-point message exchange model. When a producer sends a message to a queue, the MQ server keeps the message within the queue and delivers it to one, and only one, consumer the next time the consumer connects.
- *Topic*: A topic is used to support the publish-subscribe model. Any number of clients can subscribe to the message within a topic. When a message arrives for that topic, the MQ server delivers it to all clients that have subscribed to the message. This model is particularly useful when you have multiple applications that will be interested in the same piece of information (for example, a news feed).

In JMS, a producer connects to an MQ server and sends a message to a queue or topic. A consumer also connects to the MQ server and listens to a queue or topics for messages of interest. In JMS 1.1, the API was unified, so the producer and consumer didn't need to deal with different APIs for interacting with queues and topics. As of Spring Framework 5, Spring's JMS package fully supports JMS 2.0 and requires the JMS 2.0 API to be present at runtime. Thus, a JMS 2.0-compatible provider is required. Starting with Spring 6, the JMS API specification used is the Jakarta Messaging API version 3.x, because the JMS API is one of the Java EE products that Oracle outsourced.

<sup>7</sup><https://docs.spring.io/spring-framework/docs/current/reference/html/integration.html#rest-http-interface>

This chapter demonstrates how to use Apache ActiveMQ Artemis<sup>8</sup>, which has a Jakarta JMS-compatible version, and there is a Spring Boot starter for it, which will make things a lot easier.

The core of JMS communication in Spring is the `JmsTemplate`, which simplifies creation and release of resources when sending and receiving synchronous messages. For convenience, `JmsTemplate` also exposes a basic request-reply operation that allows for sending a message and waiting for a response. `JmsTemplate` is similar to `RestTemplate`; they are both used in remote communication between applications, and they both expose practical APIs for developers to use. Instances of both types are thread-safe once configured, and thus a single `JmsTemplate` bean is necessary in an application, and it can be injected wherever necessary.

## Working with Apache ActiveMQ Artemis

Using Spring Boot makes development of JMS applications more practical since it autoconfigures a `jakarta.jms.ConnectionFactory` bean when it detects ActiveMQ Artemis is available on the classpath.

Listing 13-16 shows an example of the `application.yml` configuration file for native use (local or remote, referenced by IP) of the ActiveMQ Artemis server.

**Listing 13-16.** `application.yml` Configuration for native use of the ActiveMQ Artemis Server

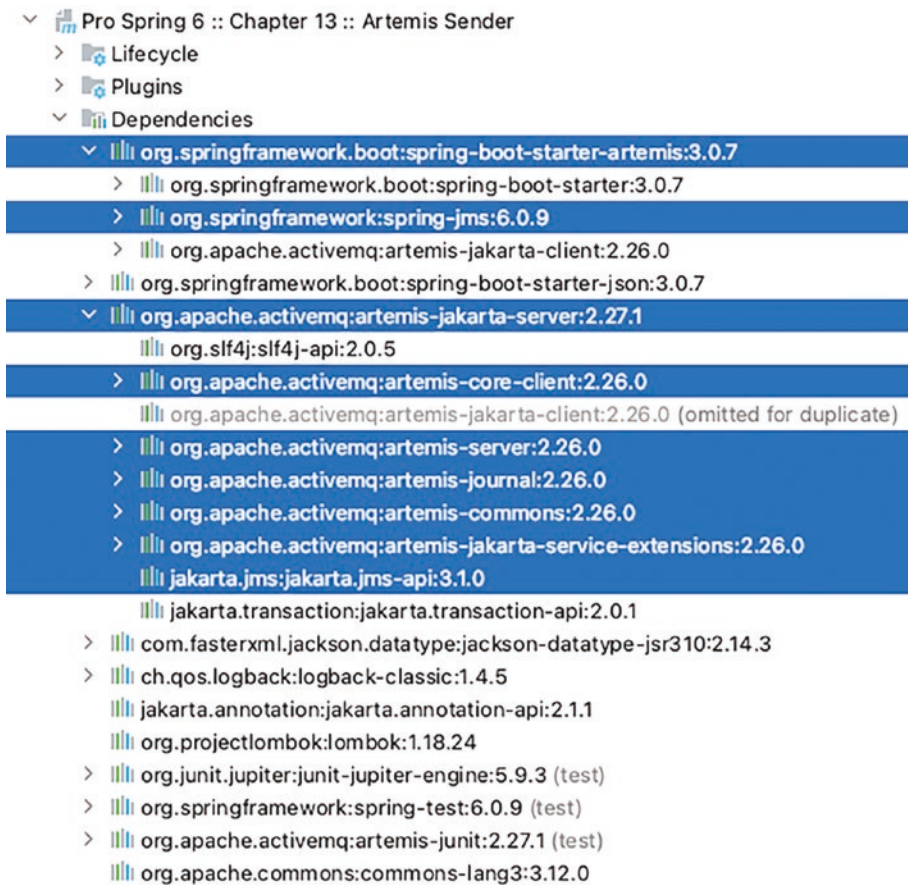
```
spring:
  artemis:
    mode: native
    host: IP_ADDRESS
    port: 61617
    user: prospring6
    password:prospring6
# or
spring:
  artemis:
    mode: native
    broker-url: tcp://${IP_ADDRESS}:61617
    user: prospring6
    password:prospring6
```

Starting with Spring Boot 3.x, properties `spring.artemis.host` and `spring.artemis.port` are marked as deprecated and the recommendation is to use `spring.artemis.broker-url`.

Installing ActiveMQ Artemis is not the focus of this book, so for the code samples, the embedded version is used. To use ActiveMQ Artemis embedded in a Spring Boot application, three things are necessary: `spring-boot-starter-artemis` on the classpath, `artemis-jakarta-server` on the classpath, and the Spring Boot embedded configuration. Figure 13-4 shows all the dependencies of the project specific to this section, `chapter13-artemis-boot`.

---

<sup>8</sup><https://activemq.apache.org/components/artemis>



**Figure 13-4.** Spring Boot Artemis JMS project dependencies

The Spring Boot application configuration that uses an embedded ActiveMQ Artemis server is shown in Listing 13-17.

**Listing 13-17.** application.yaml Configuration for an Embedded ActiveMQ Artemis Server

```
spring:
  artemis:
    mode: embedded
    embedded:
      queues: prospring6
      enabled: true
```

Using Spring Boot is very practical, because there is no need to declare a `jakarta.jms.ConnectionFactory` bean; it is automatically set up. The `spring.artemis.embedded.queues` property configures a comma-separated list of queues to create on startup. By default, Spring Boot configures a bean of type `org.springframework.jms.connection.CachingConnectionFactory`. This type is an extension of `org.springframework.jms.connection.SingleConnectionFactory`. This is a special class that ensures

a single JMS connection is opened and shared between all objects needing to communicate with the JMS server. The `CachingConnectionFactory` adds caching behavior for message producers and consumers. Figure 13-5 shows the most common implementations of the `jakarta.jms.ConnectionFactory`.

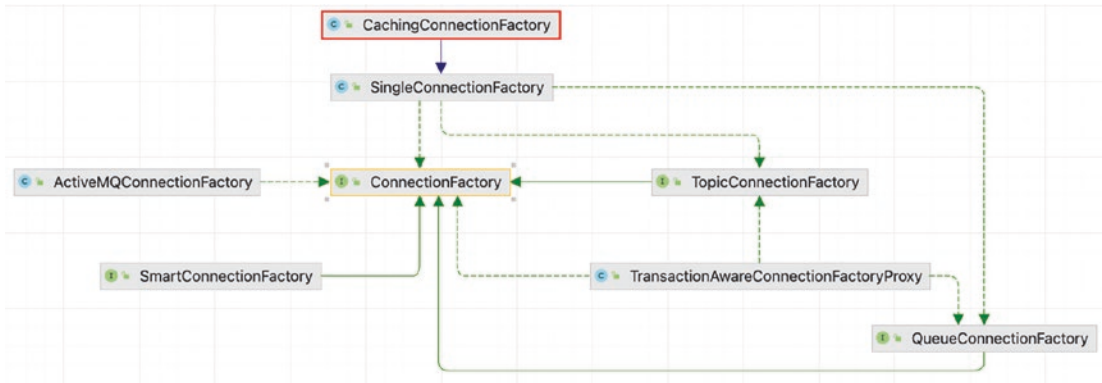


Figure 13-5. `jakarta.jms.ConnectionFactory` hierarchy

In the previous section we sent `Letter` instances between two applications, so in this section the same object will be sent to a JMQ queue by a Sender and read by a Receiver. Since Spring Boot is using an embedded Apache MQ Artemis server, we cannot start two applications and exchange messages between them. So, the functionality is simple and matches the schema shown in Figure 13-6.

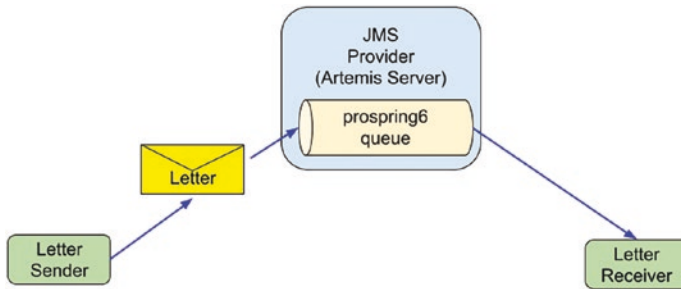


Figure 13-6. Spring Boot JMS application abstract schema

The Sender bean uses a `JmsTemplate` bean to send a `Letter` instance. The `JmsTemplate` bean is autoconfigured by Spring Boot too, so all we must do is inject it in the Sender bean declaration and use it. The Sender class and bean declaration is shown in Listing 13-18.

Listing 13-18. The JMS Producer, the Sender Class

```

package com.apress.prospring6.thirteen;

import org.springframework.jms.core.JmsTemplate;
// other import statements omitted

@Component
@S1f4j

```

```

@RequiredArgsConstructor
public class Sender {
    private final JmsTemplate jmsTemplate;

    @PostConstruct
    public void init(){
        jmsTemplate.setDeliveryDelay(2000L);
    }

    @Value("${spring.artemis.embedded.queues}")
    private String queueName;

    public void send(Letter letter) {
        log.info(" >> sending letter='{}'", letter);
        jmsTemplate.convertAndSend(queueName, letter);
    }
}

```

Notice that the queue name is extracted from the Spring Boot configuration file using `@Value("${spring.artemis.embedded.queues}")`. The Receiver is even simpler, as shown in Listing 13-19.

**Listing 13-19.** The JMS Consumer, the Receiver Class

```

package com.apress.prospring6.thirteen;

import org.springframework.jms.annotation.JmsListener;
// other import statements omitted

@Component
@Slf4j
public class Receiver {

    @JmsListener(destination = "${spring.artemis.embedded.queues}")
    public void receive(Letter letter) {
        log.info(" >> received letter='{}'", letter);
    }
}

```

The most important thing in this bean declaration is the method annotated with `@JmsListener`. This annotation marks a method to be the target of a JMS message listener on the specified destination. This annotation can also specify a custom JMS `ConnectionFactory` using the `connectionFactory` attribute. Without it, it uses the default `ConnectionFactory` configured by Spring Boot.

Processing `@JmsListener` is the responsibility of a `org.springframework.jms.annotation.JmsListenerAnnotationBeanPostProcessor` bean that Spring Boot automatically configures. Without Spring Boot to configure this bean, the `@EnableJms` annotation (from package `org.springframework.jms`, annotation) needs to be placed on a configuration class.

To test that letters sent by the Sender bean are received by the Receiver bean through the `prospring6` queue, managed by the embedded Artemis server, we can write the program shown in Listing 13-20.



**Listing 13-20.** Program to Test JMS Message Handling

```

package com.apress.prospring6.thirteen;

import java.util.UUID;
// other import statements omitted

@SpringBootApplication
@Slf4j
public class ArtemisApplication {

    public static void main(String... args) {
        try (var ctx = SpringApplication.run(ArtemisApplication.class, args)){
            var sender = ctx.getBean(Sender.class);
            for (int i = 0; i < 10; ++i) {
                var letter = new Letter("Letter no. " + i, "Test", LocalDate.now(), UUID.
                    randomUUID().toString());
                sender.send(letter);
            }
            System.in.read();
        } catch (IOException e) {
            log.error("Problem reading keystrokes.");
        }
    }
}

```

In Listing 13-20, the application context is created, and then the `Sender` bean is retrieved from the context and used to send ten `Letter` instances. The `Receiver` bean automatically reacts to `Letter` instances found in the queue, and “consumes” them, which in this case means they are just logged. When running this program, you might notice that it does not work as expected and the following message is printed in the console:

```

Exception in thread "main"
org.springframework.jms.support.converter.MessageConversionException:
Cannot convert object of type [com.apress.prospring6.thirteen.Letter] to JMS message.
Supported message payloads are: String, byte array, Map<String,?>, Serializable object.
at org.springframework.jms.support.converter.SimpleMessageConverter.toMessage(SimpleMess
ageConverter.java:79)
at org.springframework.jms.core.JmsTemplate.lambda$convertAndSend$5(JmsTemplate.
java:661)
...
at com.apress.prospring6.thirteen.Sender.send(Sender.java:56)
at com.apress.prospring6.thirteen.ArtemisApplication.main(ArtemisApplication.java:70)

```

So, what is the problem here? By default, as the message states, only a few types of messages can be written to the queue, and all of them are represented by types implementing `jakarta.jms.Message`, as shown in Figure 13-7.

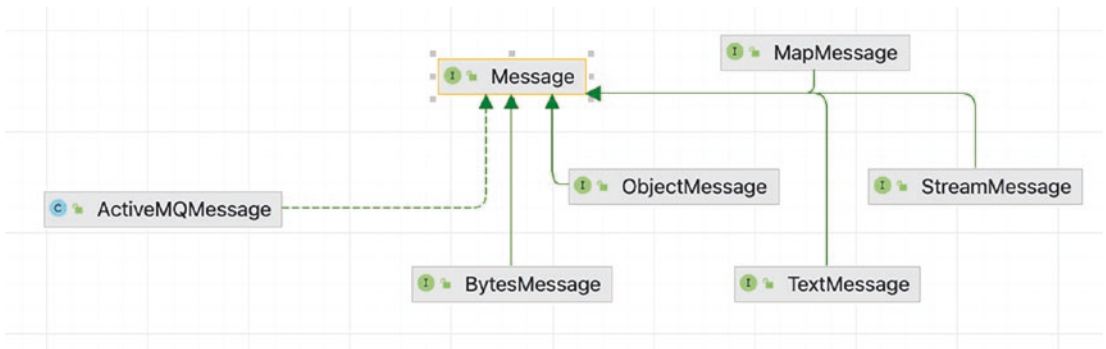


Figure 13-7. Hierarchy of available implementations for the `jakarta.jms.Message` interface



The `ActiveMQMessage` class is the message implementation that is part of the `active-server.jar` library, but it is not really necessary in a Spring application.

So, how do we add support for a different type? There is a hint in the error message: since there is no message converter, we need a message converter. The easiest way is to provide a converter that transforms a `Letter` to JSON text representation, so the Sender writes a `jakarta.jms.TextMessage` to the queue, and transforms a JSON representation to a `Letter` so the Receiver can read it. And since we are working in a Spring context, the most suitable way is to declare a bean doing that, and because this is a Spring Boot application, the bean will be automatically used where needed. The JMS converter bean is shown in Listing 13-21, and it is configured using the Jackson library.

Listing 13-21. JMS Converter Bean

```

package com.apress.prospring6.thirteen;

import com.fasterxml.jackson.databind.json.JsonMapper;
import com.fasterxml.jackson.datatype.jsr310.JavaTimeModule;
import org.springframework.jms.support.converter.MappingJackson2MessageConverter;
import org.springframework.jms.support.converter.MessageConverter;
import org.springframework.jms.support.converter.MessageType;
//other import statements omitted

@SpringBootApplication
@Slf4j
public class ArtemisApplication {
    @Bean
    public MessageConverter messageConverter() {
        var converter = new MappingJackson2MessageConverter();
        converter.setTargetType(MessageType.TEXT); // (1)
        converter.setTypeIdPropertyName("_type"); // (2)
        var mapper = new JsonMapper();
        mapper.registerModule(new JavaTimeModule()); // (3)
    }
}
  
```

```

        converter.setObjectMapper(mapper);
        return converter;
    }

    // main method omitted
}

```

There are three lines marked in Listing 13-21, which are needed to configure the following:

- 1. `converter.setTargetType(MessageType.TEXT)`: Specifies that the object should be marshalled to a `TextMessage` by being invoked with the `MessageType.TEXT` enum value. Other possible values are `BYTES`, `MAP`, or `OBJECT`.
- 2. `converter.setTypeIdPropertyName("_type")`: Specifies the name of the JMS message property that carries the type ID for the contained object. This property needs to be set in order to allow the conversion from an incoming message to a Java object.
- 3. `mapper.registerModule(new JavaTimeModule())`: This is needed because the `Letter` record contains a field named `sentOn` of type `java.time.LocalDate`.

With this bean in the configuration, now the application behaves as it should. If we run the `main(..)` method and analyze the console, the log messages printed by the `Sender` before sending a `Letter` instance and the log messages printed by the `Receiver` after receiving a `Letter` instance are printed in the console. A sample log snippet is shown in Listing 13-22.

**Listing 13-22.** Spring Boot Console Log Snippet Showing JMS Messages Being Processed

```

INFO : ActiveMQServerLogger_impl - AMQ221007: Server is now live
INFO : ActiveMQServerLogger_impl - AMQ221001: Apache ActiveMQ Artemis Message Broker version
2.27.1 [localhost, nodeID=62e0a32a-7a73-11ed-b408-3e5b0a7a3878]
...
INFO : Sender - >> sending letter='Letter[title=Letter no. 0, sender=Test,
sentOn=2022-12-12, content=95e3c388-37b5-499d-a720-c6b77b8cb99c]'
INFO : AuditLogger_impl - AMQ601267: User anonymous@invm:0 is creating a core session
on target resource ActiveMQServerImpl::name=localhost with parameters: [63310d25-7a73-
11ed-b408-3e5b0a7a3878, null, ****, 102400, RemotingConnectionImpl [ID=631dfa50-7a73-
11ed-b408-3e5b0a7a3878, clientID=null, nodeID=62e0a32a-7a73-11ed-b408-3e5b0a7a3878, tra
nsportConnection=InVMConnection [serverID=0, id=631dfa50-7a73-11ed-b408-3e5b0a7a3878]],
true, true, false, false, null, org.apache.activemq.artemis.core.protocol.core.impl.
CoreSessionCallback@4a09407d, true, {}]
...
INFO : Sender - >> sending letter='Letter[title=Letter no. 1, sender=Test,
sentOn=2022-12-12, content=c9490fb3-49d3-4678-af76-a3c2fff3de21]'
...
INFO : Receiver - >> received letter='Letter[title=Letter no. 0, sender=Test,
sentOn=2022-12-12, content=95e3c388-37b5-499d-a720-c6b77b8cb99c]'
INFO : AuditLogger_impl - AMQ601759: User anonymous@invm:0 added acknowledgement of a
message from prospring6: CoreMessage[messageID=17,durable=true,userID=6337eaf6-7a73-
11ed-b408-3e5b0a7a3878,priority=4,timestamp=Mon Dec 12 23:19:12 GMT 2022,expiration=0,
durable=true, address=prospring6,size=588,properties=TypedProperties[__AMQ_
CID=63296c02-7a73-11ed-b408-3e5b0a7a3878,_type=com.apress.prospring6.thirteen.Letter,_AMQ_
SCHED_DELIVERY=1670887154279,_AMQ_ROUTING_TYPE=1]]@489572349 to transaction: TransactionImpl

```

```
[xid=null, txID=30, xid=null, state=ACTIVE, createTime=1670887154268(Mon Dec 12 23:19:14 GMT
2022), timeoutSeconds=300, nr operations = 1]@16eb0e22
INFO : Receiver - >> received letter='Letter[title=Letter no. 1, sender=Test,
sentOn=2022-12-12, content=c9490fb3-49d3-4678-af76-a3c2fff3de21]'
...
```

Among the custom log messages confirming sending (producing) and receiving (consuming) of messages, there are Artemis-specific logs. Since the server is an embedded one, each message is sent using an anonymous user, which is confirmed by the logs. As you can see from the logs, sending and receiving JMS messages is done in a JMS transaction, which Spring Boot manages by default.

More advanced behavior, like message consumption prioritization and handling errors, can be easily configured by customizing the Spring Boot configuration. Feel free to enrich your knowledge of Spring Boot JMS support by reading the official documentation<sup>9</sup>.

## Using Spring for Apache Kafka

In this section, we focus on the point-to-point style for using queues, which is a more commonly used pattern within an enterprise, and not on any queueing technology. We are going to show you how to write Spring Boot applications using Apache Kafka<sup>10</sup>.

In a world where the quantity of data to manage increases exponentially from year to year, and where making data accessible with lightning speed is essential for productivity, classical queuing technologies have difficulties adapting. Enter open source Apache Kafka, a distributed event streaming platform renowned for being used to build high-performance data pipelines, streaming analytics, data integration, and mission-critical applications by thousands of companies. Apache Kafka is known for its excellent performance, low latency, fault tolerance, and high throughput. It's capable of handling thousands of messages per second. So, of course, integrating with it was a priority for the Spring Team. The Spring for Apache Kafka (`spring-kafka`) project applies core Spring concepts to the development of Kafka-based messaging solutions.



Notice that the project is named *Spring for Apache Kafka*, not *Spring Kafka*, the reason being that the Apache Foundation wanted to avoid confusion in regard to Kafka ownership. All open source Apache projects have their name prefixed with “Apache,” and any project donated to the Apache Foundation gets renamed as such. For example, the Brooklyn orchestration server became Apache Brooklyn when it was donated to the Apache Foundation.

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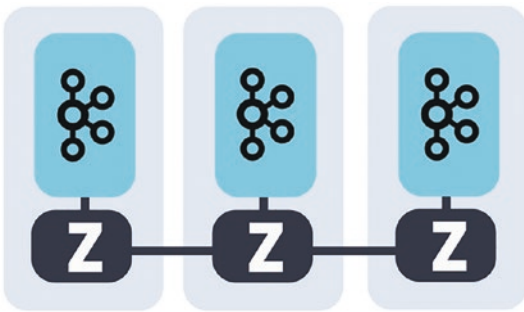
As stated in the official documentation: “Apache Kafka is a distributed system consisting of servers and clients that communicate via a high-performance TCP network protocol. It can be deployed on bare-metal hardware, virtual machines, and containers in on-premises as well as cloud environments.” For the example in this book, Apache Kafka is deployed on-premises in a Docker runtime.

<sup>9</sup><https://docs.spring.io/spring-boot/docs/3.0.0/reference/htmlsingle/#messaging>

<sup>10</sup><https://kafka.apache.org>

The containers needed to run Apache Kafka locally are configured via a `docker-compose.yml` file, and Docker Compose<sup>11</sup> is used to start up and shut down the containers. This configuration is provided by Bitnami<sup>12</sup>, a library of installers or software packages for web applications and software stacks as well as virtual appliances. The full library is shared via GitHub and all container configurations are available here: <https://github.com/bitnami/containers>. The configuration necessary for the example in this book was downloaded from this repository<sup>13</sup>. The instructions to start the containers can be found in the `chapter13-kafka-boot/CHAPTER13-KAFKA-BOOT.adoc` document.

In production environments, Apache Kafka is run as a cluster, and somebody must manage the instances. This is where Zookeeper comes in. Zookeeper is software developed by Apache that acts as a centralized service and is used to maintain naming and configuration data and to provide flexible and robust synchronization within distributed systems. This means in a production environment you might see a setup like the one shown in Figure 13-8, where instances of Zookeeper coordinate with each other and each one of them is responsible for its own Apache Kafka server.



**Figure 13-8.** *Apache Kafka production setup*

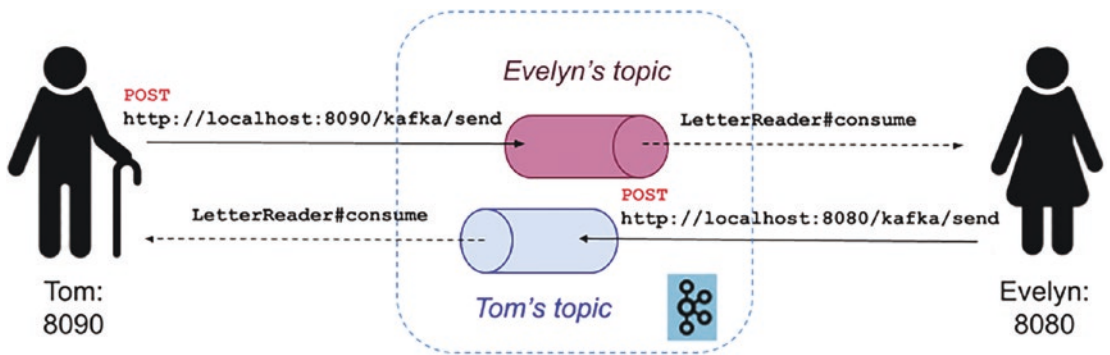
In a production system, multiple instances of Zookeeper work together to manage Kafka data that is divided across multiple collections of nodes, and this is how Kafka achieves its high availability and consistency. In Figure 13-8 each gray rectangle is a node, the bubbles labeled with Z represent Zookeeper instances, and the black “grape” logos represent Apache Kafka instances. (For a development Docker setup though, one Zookeeper instance and one Apache Kafka instance is sufficient.)

Since we are using an Apache Kafka instance that is external to our application, we can write another application that can be started twice and simulate a communication between instances. As we did in the beginning of this chapter, an application will be started for Tom to send letter messages to Evelyn, and one for Evelyn to send letters to Tom. Tom and Evelyn have their own queues they receive messages on. Each application is a web application that will expose a single `/kafka/send` endpoint, and a POST method is used to trigger a message to be sent to the queue of the other person, as described in Figure 13-9.

<sup>11</sup> <https://github.com/docker/compose>

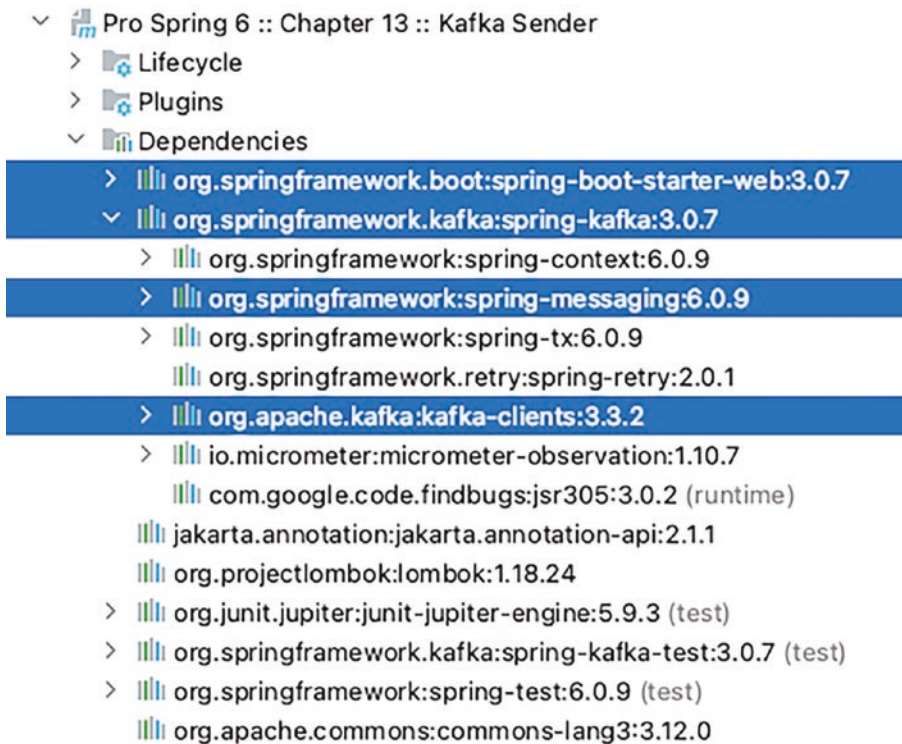
<sup>12</sup> <https://bitnami.com>

<sup>13</sup> <https://github.com/bitnami/containers/blob/main/bitnami/kafka/docker-compose.yml>



**Figure 13-9.** Abstract representation of the two pen pals applications using Apache Kafka

There is no Spring Boot starter for Apache Kafka, since you cannot start Kafka in embedded mode, but it is quite easy to create a Spring Boot web application, add `spring-kafka` as a dependency, and configure it using Spring properties. Figure 13-10 shows the dependencies of the `chapter13-kafka-boot` project.



**Figure 13-10.** Gradle configuration for a Spring Boot application using Apache Kafka

Not that we have the desired behavior and the dependencies, let's build this application. First we need to tell Spring Boot where Apache Kafka is running, so that its API can be called so that queues are created, and messages can be sent and received. Listing 13-23 shows the Spring Boot application configuration (the contents of the `application.yaml` file).

**Listing 13-23.** Spring Boot with Apache Kafka Application Configuration

```
# web config
server:
  port: 8090
  compression:
    enabled: true
  address: 0.0.0.0

# kafka config
spring:
  kafka:
    bootstrap-servers: localhost:9092
    consumer:
      group-id: letters-group-id

# custom config
app:
  sending:
    topic:
      name: default # topic where letters are sent
  receiving:
    topic:
      name: self # topic where letters are received

# logging config
logging:
  pattern:
    console: "%-5level: %class{0} - %msg%n"
  level:
    root: INFO
    org.springframework: DEBUG
    com.apress.prospring6.thirteen: INFO
```

The YAML configuration has been split in sections per scope, and the sections are explained in the following list:

- `# web config`: This section configures web application details, like the port, and if the application is exposed on all network IPs (0.0.0.0 means the application will be accessible at `http://localhost:8090`, `http://127.0.0.1:8090`, etc.).
- `# kafka config`: This section configures the location and port where the Apache Kafka cluster is available. The `consumer.group-id` is a Kafka abstraction that enables supporting both point-to-point and publish-subscribe messaging. This property can be used to group multiple consumers and customize the behavior per-group, such as priority when consuming messages, parallelism, and so on.

- # custom config: This section configures the topic where messages are sent (`app.topic.sending.name`) and the topic where messages are received (`app.topic.receiving.name`). The `app.topic.receiving.name` property also identifies the application: Tom or Evelyn.
- # logging config: This section configures log levels.

Second, we need a Java type to model the information sent to the topics. On the two topics, Letter instances will be written. The record declaration is shown in Listing 13-24.

*Listing 13-24.* Letter Record Declaration

```
package com.apress.prospring6.thirteen;

import com.fasterxml.jackson.annotation.JsonFormat;
import com.fasterxml.jackson.annotation.JsonProperty;

import java.time.LocalDate;

public record Letter (@JsonProperty("title") String title,
                    @JsonProperty("sender") String sender,
                    @JsonFormat(shape = JsonFormat.Shape.STRING, pattern = "yyyy-MM-dd")
                    @JsonProperty("sentOn") LocalDate sentOn,
                    @JsonProperty("content") String content ) {}
```

Since we do not plan to edit the received Letter instances, a Java record is suitable for this application.

The Apache Kafka cluster doesn't know what topics we need, so we have to configure them. This is the third thing we need: a configuration class for Kafka. It doesn't know what kind of object we plan to produce and consume from the topics, so we have to configure that as well. To keep it simple, we'll group all these configurations in a class named `KafkaConfig` that is shown in Listing 13-25.

*Listing 13-25.* `KafkaConfig` Configuration Class

```
package com.apress.prospring6.thirteen;

import org.apache.kafka.clients.admin.NewTopic;
import org.apache.kafka.clients.consumer.ConsumerConfig;
import org.apache.kafka.clients.producer.ProducerConfig;
import org.apache.kafka.common.serialization.StringDeserializer;
import org.apache.kafka.common.serialization.StringSerializer;
import org.springframework.boot.autoconfigure.kafka.KafkaProperties;
// some import statements omitted

@SuppressWarnings({"unchecked", "rawtypes"})
@Configuration
@RequiredArgsConstructor
public class KafkaConfig {

    private final KafkaProperties kafkaProperties;

    @Value(value = "${spring.kafka.bootstrap-servers}")
    private String bootstrapAddress;
```



```

@Value(value = "${spring.kafka.consumer.group-id}")
private String groupId;

@Value("#{kafkaApplication.sendingTopic}")
private String sendingTopicName;

@Value("#{kafkaApplication.receivingTopic}")
private String receivingTopicName;

@Bean // configs for the LetterSender
public Map<String, Object> producerConfigs() {
    Map<String, Object> props = new HashMap<>(kafkaProperties.
        buildProducerProperties());
    props.put(ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG, StringSerializer.class);
    props.put(ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG, JsonSerializer.class);
    return props;
}

@Bean
public ProducerFactory<String, Object> producerFactory() {
    return new DefaultKafkaProducerFactory<>(producerConfigs());
}

@Bean
public KafkaTemplate<String, Object> kafkaTemplate() {
    return new KafkaTemplate<>(producerFactory());
}

@Bean // topic where Letters are sent
public NewTopic sendingTopic() {
    return new NewTopic(sendingTopicName, 1, (short) 1);
}

@Bean // topic where to read letters from
public NewTopic receivingTopic() {
    return new NewTopic(receivingTopicName, 1, (short) 1);
}

@Bean // configs for the LetterReader
public ConsumerFactory<String, Object> consumerFactory() {
    final org.springframework.kafka.support.serializer.JsonDeserializer<Object>
        jsonDeserializer = new JsonDeserializer<>();
    jsonDeserializer.addTrustedPackages("*");
    return new DefaultKafkaConsumerFactory<>(kafkaProperties.buildConsumerProperties(),
        new StringDeserializer(), jsonDeserializer);
}

@Bean
public ConcurrentKafkaListenerContainerFactory<String, Object>
    kafkaListenerContainerFactory() {

```

```

    ConcurrentKafkaListenerContainerFactory<String, Object> factory = new
    ConcurrentKafkaListenerContainerFactory<>();
    factory.setConsumerFactory(consumerFactory());
    return factory;
}
}

```

In a Spring Boot application, all the Kafka-specific properties from the configuration are loaded into a `KafkaProperties` configuration bean. This bean is injected into the `KafkaConfig` class, so it can be extended with properties specific for a `ProducerFactory<String, Object>` or a `ConsumerFactory<String, Object>`—in this example, serializers and deserializers, which are used to convert a `Letter` instance to a JSON representation before writing it to the topic, and vice versa when the message is consumed. Notice that the `Letter` type is not mentioned anywhere. The `ProducerFactory` only needs to know what to use to convert the message key and the message, because every message has to be identified uniquely by a unique key.

Before the application is started, the Apache Kafka cluster does not have any topics defined. A `NewTopic` bean is declared for each topic we need, which ensures a topic with the configured name is created if it doesn't already exist. A topic can be configured to be divided into multiple partitions and replicated across brokers. In our very simple example, both the number of partitions and the replication factor are set to 1.

The `KafkaTemplate` class is similar to `JmsTemplate` (and `RestTemplate` too), and a bean of this type is needed to execute high-level operations with Apache Kafka. The bean is thread-safe, and to produce messages, the configured `ProducerFactory<K, V>` bean is used.

The `ConsumerFactory<K, V>` is needed to consume messages from a topic. For this simple scenario, we use Spring's `DefaultKafkaConsumerFactory<K, V>` implementation with a minimal configuration.

For messages to be consumed, they need to be picked up by a listener. To create one of those, beside the `@KafkaListener` annotation attached to a consuming method, a `ConcurrentKafkaListenerContainerFactory<K, V>` is needed.



The reason why none of the beans for producing and consuming messages are restricted to a certain type of message is that multiple types of messages can be written on the same queue, and read by different listeners, created by different `ConcurrentKafkaListenerContainerFactory<K, V>`.

---

Notice that Kafka properties are extracted from the Spring Boot configuration files and injected using `@Value(value = "${spring.kafka.*}")`, but custom properties like `app.topic.sending.name` need to first be declared as properties of the Spring Boot main configuration class and injected using SpEL.

The beans in this configuration must be injected in the beans used to produce and consume `Letter` instances. The class used to model a message producer is named `LetterSender`, because its responsibility is to send letters. The class is shown in Listing 13-26.

**Listing 13-26.** `LetterSender` Class and Bean Configuration

```

package com.apress.prospring6.thirteen;

import lombok.RequiredArgsConstructor;
import lombok.extern.slf4j.Slf4j;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.kafka.core.KafkaTemplate;
import org.springframework.stereotype.Service;

```

```

@RequiredArgsConstructor
@Service
@Slf4j
public class LetterSender {

    @Value("#{kafkaApplication.sendingTopic}")
    public String sendingToTopicName;

    @Value("#{kafkaApplication.receivingTopic}")
    private String sender; // who is sending the letter

    private final KafkaTemplate<String, Object> kafkaTemplate;

    // make application configurable
    public void send(Letter letter) {
        log.info(">>> -> [{}] Sending letter -> {}", sender, letter);
        kafkaTemplate.send(sendingToTopicName, letter);
    }
}

```

The `LetterSender` bean needs the `KafkaTemplate` bean to send messages and the name of the topic the messages are sent to. There are multiple versions of the `send(...)` message that include parameters for choosing a partition and the time when the message was produced. There is also a version that returns a `CompletableFuture<SendResult<K, V>>`, which allows declaring a callback to be executed after the message is sent successfully.

`kafkaApplication.receivingTopic` is also the name of the application sending the messages and is injected in this bean for logging purposes.

The `LetterSender` bean is injected into the `KafkaController`, so sending a letter can be triggered via a POST request. The `KafkaController` class and bean configuration are shown in Listing 13-27.

**Listing 13-27.** `KafkaController` Class and Bean Configuration

```

package com.apress.prospring6.thirteen;

import lombok.RequiredArgsConstructor;
import org.springframework.web.bind.annotation.*;

@RequiredArgsConstructor
@RestController
@RequestMapping(path = "/kafka")
public class KafkaController {

    private final LetterSender sender;

    @PostMapping(value = "/send")
    public void sendMessageToKafkaTopic(@RequestBody Letter letter) {
        this.sender.send(letter);
    }
}

```

Now that we know how to send `Letter` instances to a topic, let's see how we can consume them. We already mentioned the `@KafkaListener`, but where do we put it? The answer is on a method in a class called `LetterReader`, which is shown in Listing 13-28.

*Listing 13-28.* LetterReader Class and Bean Configuration

```

package com.apress.prospring6.thirteen;

import lombok.extern.slf4j.Slf4j;

import org.springframework.beans.factory.annotation.Value;
import org.springframework.kafka.annotation.KafkaListener;
import org.springframework.messaging.handler.annotation.Payload;
import org.springframework.stereotype.Service;

@Service
@Slf4j
public class LetterReader {

    @Value("#{kafkaApplication.receivingTopic}")
    private String receivingTopicName;

    @KafkaListener(topics = "#{kafkaApplication.receivingTopic}",
        groupId = "${spring.kafka.consumer.group-id}",
        containerFactory = "kafkaListenerContainerFactory")
    public void consume(@Payload Letter letter) {
        log.info("<<<< [{}] Reading letter -> {}", receivingTopicName, letter);
    }
}

```

The `@KafkaListener` annotation marks a method to be the target of a Kafka message listener. A listener needs to know the topics (yes, it can read messages from multiple topics) to read messages from, and this is configured using the `topics` attribute. If multiple groups are used, and we want a listener to read messages only from a single group of topics, the `groupId` attribute is useful for that.

And, since we want to make sure the message is converted correctly, we need to make sure the suitable listener is created, and this means specifying the suitable `ConcurrentKafkaListenerContainerFactory<K,V>` to use via the `containerFactory` method.

The `consume(..)` method can have various signatures, as long as Spring knows what to do with the message once consumed from the topic. The `@Payload` annotation from the `org.springframework.messaging.handler` annotation package binds the body of a Kafka message to this method parameter and converts it to the appropriate type, in this case `Letter`.

The last class to be shown is the `KafkaApplication` class, the main Spring Boot configuration class and runner, shown in Listing 13-29.

*Listing 13-29.* KafkaApplication Spring Boot Class

```

package com.apress.prospring6.thirteen;

@SpringBootApplication
@Slf4j
public class KafkaApplication {

    public static void main(String... args) {
        SpringApplication.run(KafkaApplication.class, args);
    }
}

```

```

@Value("${app.sending.topic.name}")
public String sendingTopic;

@Value("${app.receiving.topic.name}")
public String receivingTopic;

@Bean
public CommandLineRunner initCmd(){
    return (args) -> log.info(" >>> Sender {} ready to send letters to {} ",
        receivingTopic, sendingTopic);
}
}

```

Since this application is going to be started twice, once for Evelyn and once for Tom, a `CommandLineRunner` bean is created to show which application is running. The name of the topic where Letters are received is also the name of the application. As shown earlier in Figure 13-9, the application for Evelyn is started on port 8080, and the Tom application is started on 8090.

To start the two application instances, the way to go is either to configure different IntelliJ IDEA launchers, or to build the application and start two instances using the JAR in different terminal windows, using the commands shown in Listing 13-30.

**Listing 13-30.** Bash Commands to Start Two Instances of the Application

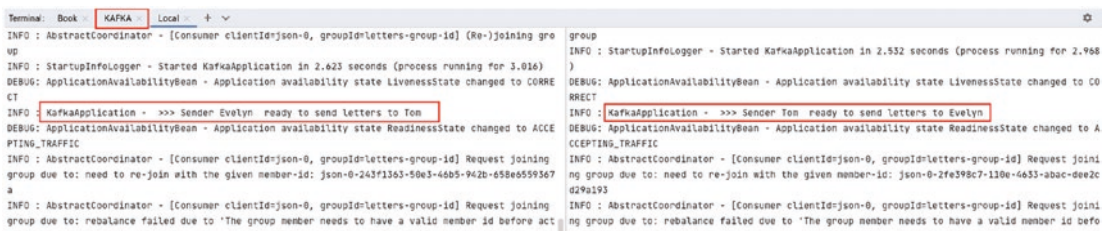
```

# starting Evelyn
java -jar build/libs/chapter13-kafka-boot-6.0-SNAPSHOT.jar --app.sending.topic.name=Tom --app.receiving.topic.name=Evelyn --server.port=8080

# starting Tom
java -jar build/libs/chapter13-kafka-boot-6.0-SNAPSHOT.jar --app.sending.topic.name=Evelyn --app.receiving.topic.name=Tom --server.port=8090

```

A practical approach when using IntelliJ IDEA to develop applications with multiple pieces is to have it all in separate IntelliJ terminals. In Figure 13-11, there is a terminal where we run Docker Compose to start the Apache Kafka server, and another terminal with two windows where the Evelyn and Tom applications can be seen running at the same time.



**Figure 13-11.** IntelliJ IDEA terminals with Apache Kafka and two Spring Boot applications running

Requests can be made using `curl`<sup>14</sup> or `Postman`<sup>15</sup>, or if you are using IntelliJ IDEA, you can use the HTTPie client. The request body to send a Letter from Evelyn to Tom, and vice versa, is shown in Listing 13-31.

**Listing 13-31.** POST Requests in HTTPie to Send Letter Instances Between the Two Applications to Each Other

**### Evelyn sending letter message to Tom**  
**POST `http://localhost:8080/kafka/send`**  
**Content-Type: `application/json`**

```
{
  "title": "To my Dear Friend",
  "sender": "HTTPIE",
  "sentOn" : "2022-12-04",
  "content" : "Haven't read anything written by you in a while. Miss you!"
}
```

**### Tom sending letter message to Evelyn**  
**POST `http://localhost:8090/kafka/send`**  
**Content-Type: `application/json`**

```
{
  "title": "Miss you too",
  "sender": "HTTPIE",
  "sentOn" : "2022-12-05",
  "content" : "Scotland is rather lovely this time of year. Would you like to visit?"
}
```

If you run the two requests, you will see both applications printing logs confirming the sending of a Letter and receiving one, as shown in Listing 13-32.

**Listing 13-32.** Evelyn Logs Confirming a Letter Is Sent and One Is Received

```
INFO : LetterSender - >>>> [Evelyn] Sending letter -> Letter[title=To my Dear Friend,
sender=HTTPIE, sentOn=2022-12-04, content=Haven't read anything written by you in a while.
Miss you!]
DEBUG: FrameworkServlet - Completed 200 OK
...
DEBUG: LogAccessor - Received: 1 records
INFO : LetterReader - <<<< [Evelyn] Reading letter ->
  Letter[
    title=Miss you too,
    sender=HTTPIE,
    sentOn=2022-12-05,
    content=Scotland is rather lovely this time of year. Would you like to visit?
  ]
```

<sup>14</sup><https://curl.se>

<sup>15</sup><https://www.postman.com>

The Tom application prints something similar.

It was mentioned previously that the method annotated with `@KafkaListener` can have a different signature, and all details of a message can be inspected, not only the body (payload). To achieve this, the method can be written as shown in Listing 13-33.

**Listing 13-33.** Method annotated with `@KafkaListener` that inspects the contents of a `ConsumerRecord`

```
package com.apress.prospring6.thirteen;

import org.apache.kafka.clients.consumer.ConsumerRecord;
// other import statements omitted

@Service
@Slf4j
public class LetterReader {

    @KafkaListener(topics = "#{kafkaApplication.receivingTopic}",
        groupId = "${spring.kafka.consumer.group-id}",
        clientIdPrefix = "json",
        containerFactory = "kafkaListenerContainerFactory")
    public void consume(ConsumerRecord<String, String> cr) {
        log.info("<<<< Receiving message at -> {}", cr.timestamp());
        log.info("<<<< Receiving message on topic -> {}", cr.topic());
        log.info("<<<< Receiving message on partition -> {}", cr.partition());
        log.info("<<<< Receiving message with headers -> {}", cr.headers());
        log.info("<<<< Receiving message with key -> {}", cr.key());
        log.info("<<<< Receiving message with value -> {}", cr.value());
    }
}
```

The `ConsumerRecord<K, V>` is part of the `kafka-clients.jar` library and, as you can see, it is a key/pair value mapping to the message identifier and payload, but also includes other useful information such as the topic name and partition number for where the message is received.

Listing 13-34 shows the output of this method when letters are being sent after this change.

**Listing 13-34.** Evelyn Logs Confirming a Letter Is Received As a `ConsumerRecord<String, Letter>`

```
INFO : LetterReader - <<<< Receiving message at -> 1671403710391
INFO : LetterReader - <<<< Receiving message on topic -> Evelyn
INFO : LetterReader - <<<< Receiving message on partition -> 0
INFO : LetterReader - <<<< Receiving message with headers -> RecordHeaders(headers = [],
isReadOnly = false)
INFO : LetterReader - <<<< Receiving message with key -> dcccbbe7-3b5f-4447-9c15-0272f45591a9
INFO : LetterReader - <<<< Receiving message with value ->
Letter[
    title=Miss you too,
    sender=HTTPIE,
    sentOn=2022-12-05,
    content=Scotland is rather lovely this time of year. Would you like to visit?
]
```

## Summary

In this chapter, we covered the most commonly used remoting techniques in Spring-based applications. For each scenario in this chapter, you've been shown how to send and receive messages. Communication between remote applications is a vast subject, and there are multiple technologies that can be used for this purpose. This chapter's purpose was to introduce you to the most common of them and give you an overall idea of how Spring applications can be designed to communicate with other applications, written with Spring or not.

Spring Boot was exclusively used for this chapter, as the focus was on the integration of Spring with each of the technologies, REST, JMS, and Apache Kafka.

In the next chapter, we discuss using Spring for writing web applications.



## CHAPTER 14



# Spring MVC

In an enterprise application, the presentation layer critically affects users' level of acceptance of the application. The presentation layer is the front door into your application. It lets users perform business functions provided by the application, as well as presents a view of the information that is being maintained by the application. How the user interface performs greatly contributes to the success of the application. Because of the explosive growth of the Internet (especially these days), as well as the rise of different kinds of devices that people are using, developing an application's presentation layer is a challenging task.

The following are some major considerations when developing web applications:

- *Performance*: Performance is always the top requirement of a web application. If users choose a function or click a link, and it takes a long time to execute (in the world of the Internet, three seconds is like a century!), users will definitely not be happy with the application.
- *User-friendliness*: The application should be easy to use and easy to navigate, with clear instructions that don't confuse the user.
- *Interactivity and richness*: The user interface should be highly interactive and responsive. In addition, the presentation should be rich in terms of visual presentation, such as charting, a dashboard type of interface, and so on.
- *Accessibility*: Nowadays, users require that the application is accessible from anywhere via any device. In the office, they will use their desktop to access the application. On the road, users will use various mobile devices (including laptops, tablets, and smartphones) to access the application.

Developing a web application to fulfill the previous requirements is not easy, but they are considered mandatory for business users. Fortunately, many new technologies and frameworks have been developed to address those needs. Many web application frameworks and libraries—such as Spring MVC (Spring Web Flow), Apache Struts, Tapestry, Java/Jakarta Server Faces (JSF), Google Web Toolkit (GWT), jQuery, React, and Dojo, to name a few—provide tools and rich component libraries that can help you develop highly interactive web front ends. Spring Web Flow<sup>1</sup> provides a JSF integration that lets you use the JSF UI Component Model with Spring Web Flow controllers. In addition, many frameworks provide tools

---

<sup>1</sup><https://spring.io/projects/spring-webflow>

or corresponding widget libraries targeting mobile devices such as smartphones and tablets. The rise of the HTML5<sup>2</sup> and CSS3<sup>3</sup> standards and the support of these latest standards by most web browsers and mobile device manufacturers also help ease the development of web applications that need to be available anywhere, from any device.

In parallel with Spring MVC, starting with version 5.0 Spring Framework introduced a reactive-stack web framework whose name named Spring WebFlux<sup>4</sup>. This stack will be covered succinctly in **Chapter 20**.

In terms of web application development, Spring provides comprehensive and intensive support. The Spring MVC module provides a solid infrastructure and Model View Controller (MVC) framework for web application development. When using Spring MVC, you can use various view technologies (for example, JSP or Velocity). In addition, Spring MVC integrates with many common web frameworks and toolkits (for example, Struts and GWT). Other Spring projects help address specific needs for web applications. For example, Spring MVC, when combined with the Spring Web Flow project and its Spring Faces module, provides comprehensive support for developing web applications with complex flows and for using JSF as the view technology. Simply speaking, there are many choices out there in terms of presentation layer development. This chapter focuses on Spring MVC and discusses how we can use the powerful features provided by Spring MVC to develop highly performing web applications.

Specifically, this chapter covers the following topics:

- *Spring MVC*: We discuss the main concepts of the MVC pattern and introduce Spring MVC. We present Spring MVC's core concepts, including its `WebApplicationContext` hierarchy and the request-handling life cycle.
- *i18n, locale, and theming*: Spring MVC provides comprehensive support for common web application requirements, including i18n (internationalization), locale, and theming. We discuss how to use Spring MVC to develop web applications that support those requirements.
- *View support*: The use of view technologies in Spring MVC is pluggable. In this chapter, we focus on using Thymeleaf as the view part of the web application, because it allows development of simple web pages without explicit use of JavaScript and other dynamic technologies. Anything else that you might want to use that is supported by Spring, such as Groovy markup templates and JSPs, can be easily plugged in just with simple configuration changes.
- *File upload support*: Instead of integration with Apache Commons FileUpload, we discuss how to use Spring MVC with the Jakarta Servlet 5.0 container's built-in multipart support for file upload.

## Setting Up the Data and Lower-Level Layers

A web application must provide access to manipulate data that is stored in a remote location, on a certain type of storage, usually a database. Up to this chapter, you were introduced to how to configure a Spring application to manage data using Spring Data repositories and declare transactional beans to manage data within a transaction. These are the two data layers of an application; in this chapter, you will be introduced to configuring the last layer of an application: the presentation layer, which is the web application or the web console the end user works with, unaware of which kind of application is doing the heavy lifting in the backend.

<sup>2</sup><https://html.spec.whatwg.org/multipage>

<sup>3</sup><https://developer.mozilla.org/en-US/docs/Web/CSS>

<sup>4</sup><https://docs.spring.io/spring-framework/docs/current/reference/html/web-reactive.html>

This chapter uses the same database structure used in previous chapters, but a new column, PHOTO, is added to the SINGER table. The new SINGER table creation script is shown in Listing 14-1.

**Listing 14-1.** The Updated SINGER Table

```
CREATE TABLE SINGER (
    ID INT NOT NULL AUTO_INCREMENT
    , VERSION INT NOT NULL DEFAULT 0
    , FIRST_NAME VARCHAR(60) NOT NULL
    , LAST_NAME VARCHAR(40) NOT NULL
    , BIRTH_DATE DATE
    , PHOTO LONGBLOB NULL
    , UNIQUE (FIRST_NAME, LAST_NAME)
    , PRIMARY KEY (ID)
);
```

The PHOTO column, of the binary large object (LONGBLOB) data type, will be used to store the photo of a singer using file upload. To create the database and the tables in it, a Docker container is needed. Creating the image for it and running it is described in the chapter14/CHAPTER14.adoc file that is part of the project for this chapter.

To manage SINGER records as Java objects, we use Singer instances. This class is configured as a Jakarta Persistence entity, shown in Listing 14-2.

**Listing 14-2.** The Updated Singer Entity

```
package com.apress.prospring6.fourteen.entities;

import jakarta.persistence.*;
import jakarta.validation.*;
import org.springframework.format.annotation.DateTimeFormat;

@Entity
@Table(name = "SINGER")
public class Singer extends AbstractEntity {
    @Serial
    private static final long serialVersionUID = 2L;

    @NotNull
    @Size(min = 2, max = 30)
    @Column(name = "FIRST_NAME")
    private String firstName;

    @NotNull
    @Size(min = 2, max = 30)
    @Column(name = "LAST_NAME")
    private String lastName;

    @DateTimeFormat(pattern = "yyyy-MM-dd")
    @Column(name = "BIRTH_DATE")
    private LocalDate birthDate;
    @OneToMany(mappedBy = "singer")
    private Set<Album> albums = new HashSet<>();
```

```

@Basic(fetch= FetchType.LAZY)
@Lob
@Column(name = "PHOTO")
private byte[] photo;

// other code omitted
}

```

AbstractEntity is an abstract class containing fields common to all entity classes used in the application (id and version). Notice that most fields have validation annotations on them, which are useful to validate user-provided data. The @DateTimeFormat annotation is a Spring annotation that configures a field or method parameter to be formatted as a date or time according to the format provided as an attribute.



The ALBUM and INSTRUMENT tables and the entities for them are part of the project, but there is enough ground to cover on Spring MVC by only working with Singer instances, so they won't be mentioned in this chapter.

---

For managing Singer instances, a simple Spring Data Repository interface is necessary, as shown in Listing 14-3.

*Listing 14-3.* The SingerRepo Interface

```

package com.apress.prospring6.fourteen.repos;

import com.apress.prospring6.fourteen.entities.Singer;
import org.springframework.data.jpa.repository.JpaRepository;
import org.springframework.data.jpa.repository.Query;
import org.springframework.data.repository.query.Param;
import org.springframework.stereotype.Repository;

import java.time.LocalDate;

public interface SingerRepo extends JpaRepository<Singer, Long> {

    @Query("select s from Singer s where s.firstName=:fn")
    Iterable<Singer> findByFirstName(@Param("fn") String firstName);

    @Query("select s from Singer s where s.firstName like %?1%")
    Iterable<Singer> findByFirstNameLike(String firstName);

    @Query("select s from Singer s where s.lastName=:ln")
    Iterable<Singer> findByLastName(@Param("ln") String lastName);

    @Query("select s from Singer s where s.lastName like %?1%")
    Iterable<Singer> findByLastNameLike(String lastName);
}

```

```

@Query("select s from Singer s where s.birthDate=:date")
Iterable<Singer> findByBirthDate(@Param("date") LocalDate date);
}

```

All the extra methods are invoked by the `SingerService` bean, to perform various operations with `Singer` instances. The `SingerService` interface declaring all the methods available in the implementation is shown in Listing 14-4.

*Listing 14-4.* The `SingerService` Interface

```

package com.apress.prospring6.fourteen.services;

import com.apress.prospring6.fourteen.entities.Singer;
import com.apress.prospring6.fourteen.problem.InvalidCriteriaException;
import com.apress.prospring6.fourteen.util.CriteriaDto;
import org.springframework.data.domain.Page;
import org.springframework.data.domain.Pageable;

import java.util.List;

public interface SingerService {

    List<Singer> findAll();

    Singer findById(Long id);

    Singer save(Singer singer);

    void delete(Long id);

    Page<Singer> findAllByPage(Pageable pageable);

    List<Singer> getByCriteriaDto(CriteriaDto criteria)
        throws InvalidCriteriaException;
}

```

The `SingerServiceImpl` class that implements `SingerService` is transactional and mostly wraps around `SingerRepo` methods, except for the `getByCriteriaDto(..)` method. This method is used to delegate to one of the customized `find*` methods in `SingerRepo` based on the `CriteriaDto` instance passed as an argument; its code will be shown later in the chapter when the context is more relevant.

The configuration for the first two layers is provided by two classes. The `BasicDataSourceCfg` class, introduced in [Chapter 8](#), provides a way to interact with the MariaDB database. The `TransactionCfg` class, introduced in [Chapter 9](#), provides the details for database operations to happen in a transactional environment. Feel free to review those two chapters if these two configuration classes that are part of the chapter-14 project look foreign.

Now that the two lower layers are set up, we are ready to start covering Spring MVC.

Before moving on to implement the presentation layer, let's go through some major concepts of MVC as a pattern in web applications and how Spring MVC provides comprehensive support in this area.

In the following sections, we present these high-level concepts one by one. First, we give a brief introduction to MVC. Second, we present a high-level view of Spring MVC and its `WebApplicationContext` hierarchy. Finally, we discuss the request life cycle within Spring MVC.

## Introducing MVC

MVC is a commonly used pattern in implementing the presentation layer of an application. The main principle of the MVC pattern is to define an architecture with clear responsibilities for different components. As its name implies, there are three participants within the MVC pattern.

- *Model*: A model represents the business data as well as the “state” of the application within the context of the user. For example, in an e-commerce website, the model usually includes the user profile information, shopping cart data, and order data if users purchase goods on the site.
- *View*: This presents the data to the user in the desired format, supports interaction with users, and supports client-side validation, i18n, styles, and so on.
- *Controller*: The controller handles requests for actions performed by users in the front end, interacting with the service layer, updating the model, and directing users to the appropriate view based on the result of execution.

Figure 14-1 illustrates a commonly used web application pattern, which can be treated as an enhancement to the traditional MVC pattern because of the introduction of Spring as a main component.

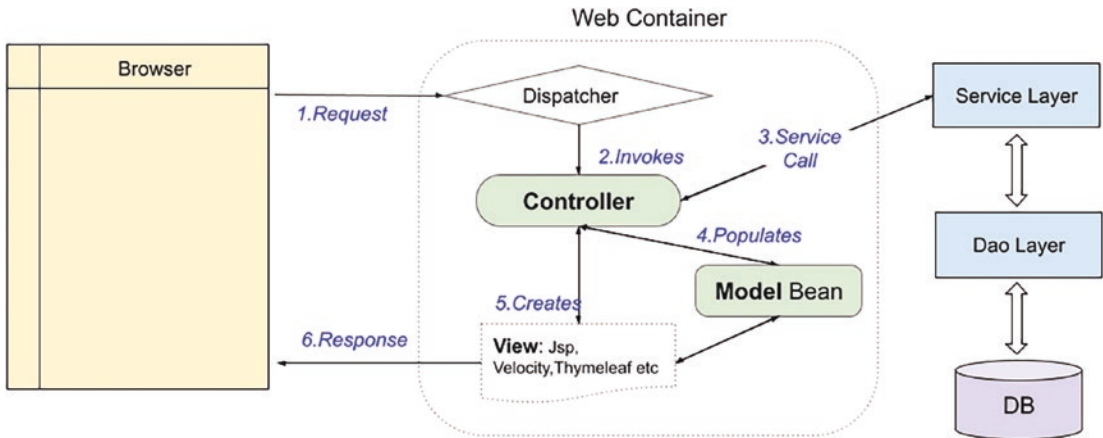


Figure 14-1. The MVC pattern in a typical web application

A normal view request is handled as follows:

1. *Request:* A request is submitted to the server. On the server side, most frameworks (for example, Spring MVC or Struts) have a dispatcher (in the form of a servlet) to handle the request.
2. *Invokes:* The dispatcher dispatches the request to the appropriate controller based on the HTTP request information and the web application configuration.
3. *Service call:* The controller interacts with the service layer.
4. *Model is populated:* The information obtained from the service layer is used by the controller to populate a model.
5. *View is created:* Based on the model, a view is created.
6. *Response:* The controller returns the corresponding view to the user.

## Introducing Spring MVC

In the Spring Framework, the Spring MVC module provides comprehensive support for the MVC pattern, with support for other features (for example, theming, i18n, validation, and type conversion and formatting) that ease the implementation of the presentation layer.

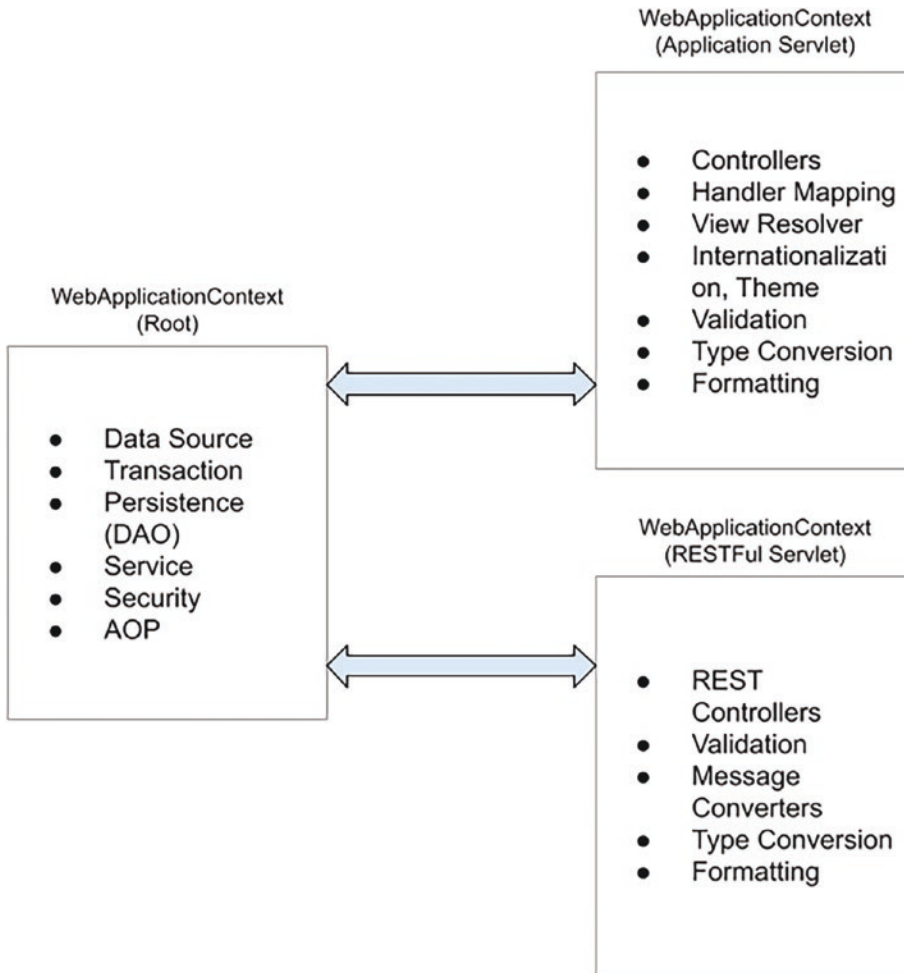
In the following sections, we discuss the main concepts of Spring MVC. Topics include Spring MVC's `WebApplicationContext` hierarchy, a typical request-handling life cycle, and configuration.

## Spring MVC `WebApplicationContext` Hierarchy

In Spring MVC, `DispatcherServlet` is the central servlet that receives requests and dispatches them to the appropriate controllers. In a Spring MVC application, there can be any number of `DispatcherServlet` instances for various purposes (for example, handling user interface requests and RESTful-WS requests), and each `DispatcherServlet` instance has its own `WebApplicationContext` configuration, which defines the servlet-level characteristics, such as controllers supporting the servlet, handler mapping, view resolving, i18n, theming, validation, and type conversion and formatting.

Underneath the servlet-level `WebApplicationContext` configurations, Spring MVC maintains a root `WebApplicationContext`, which includes the application-level configurations such as the back-end data source, security, and service and persistence layer configuration. The root `WebApplicationContext` will be available to all servlet-level `WebApplicationContexts`.

Let's consider an example. Say we have two `DispatcherServlet` instances in an application. One servlet supports the user interface (called the *application servlet*), and the other provides services in the form of RESTful-WS to other applications (called the *RESTful servlet*). In Spring MVC, we will define the configurations for both the root `WebApplicationContext` instance and the `WebApplicationContext` instance for the two `DispatcherServlet` instances. Figure 14-2 shows the `WebApplicationContext` hierarchy that will be maintained by Spring MVC for this scenario.

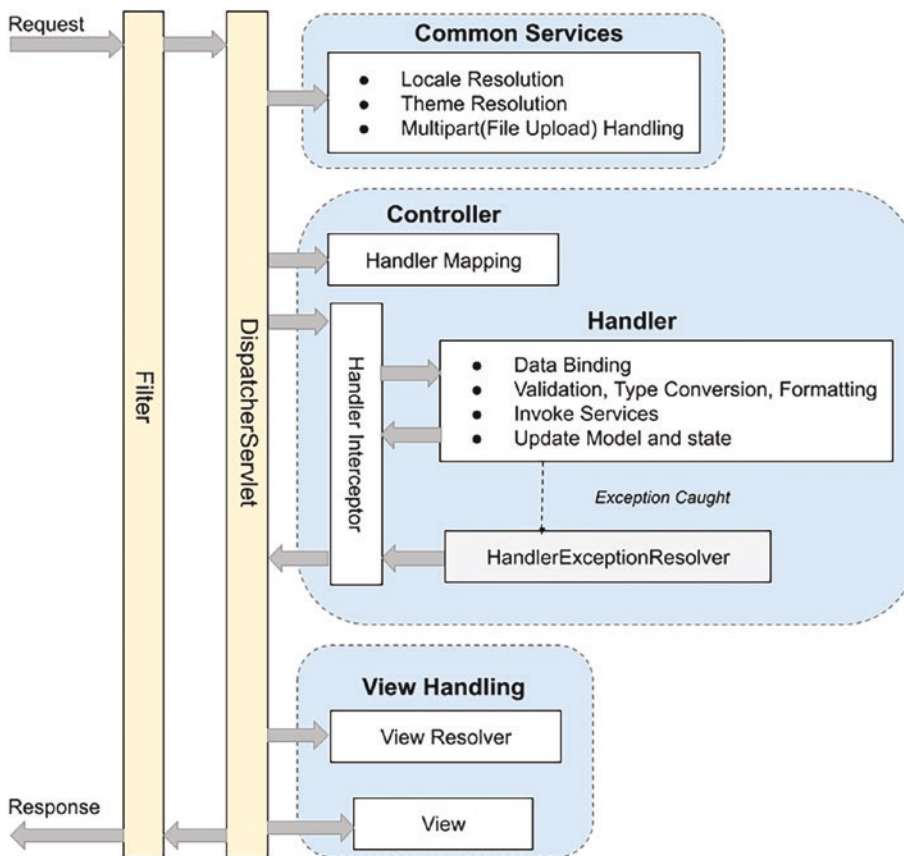


*Figure 14-2. Spring MVC WebApplicationContext hierarchy*

## Spring MVC Request Life Cycle

Let's see how Spring MVC handles a request. Figure 14-3 shows the main components involved in handling a request in Spring MVC.





**Figure 14-3.** Spring MVC Request Handling Components

The main components and their purposes are as follows:

- **Filter**: The filter applies to every request. Several commonly used filters and their purposes are described in the next section.
- **DispatcherServlet**: The servlet analyzes the requests and dispatches them to the appropriate controller for processing.
- **Common services**: The common services will apply to every request to provide support including i18n, theme, and file upload. Their configuration is defined in the DispatcherServlet's `WebApplicationContext`.
- **Handler Mapping**: This maps incoming requests to handlers (a method within a Spring MVC controller class). Since Spring 2.5, in most situations the configuration is not required because Spring MVC will automatically register a `HandlerMapping` implementation out of the box that maps handlers based on HTTP paths expressed through the `@RequestMapping` annotation (and its extensions) at the type or method level within controller classes.



In Spring 2.5, `DefaultAnnotationHandlerMapping` was the default implementation. Starting with Spring 3.1, `RequestMappingHandlerMapping` has become the default implementation, which supports request mapping to handlers defined without annotations also, as long as the Spring conventions of naming controllers and methods are respected.

- *Handler Interceptor*: In Spring MVC, you can register interceptors for the handlers for implementing common checking or logic. For example, a handler interceptor can check to ensure that the handlers can only be invoked during office hours.
- *HandlerExceptionResolver*: In Spring MVC, the `HandlerExceptionResolver` interface (defined in package `org.springframework.web.servlet`) is designed to deal with unexpected exceptions thrown during request processing by handlers. By default, `DispatcherServlet` registers the `DefaultHandlerExceptionResolver` class (from package `org.springframework.web.servlet.mvc.support`). This resolver handles certain standard Spring MVC exceptions by setting a specific response status code. You can also implement your own exception handler by annotating a controller method with the `@ExceptionHandler` annotation and passing in the exception type as the attribute.
- *ViewResolver*: Spring MVC's `ViewResolver` interface (from package `org.springframework.web.servlet`) supports view resolution based on a logical name returned by the controller. There are many implementation classes to support various view-resolving mechanisms. For example, the `UrlBasedViewResolver` class supports direct resolution of logical names to URLs. The `ContentNegotiatingViewResolver` class supports dynamic resolving of views depending on the media type supported by the client (such as XML, PDF, and JSON). There also exists a number of implementations to integrate with different view technologies, such as Thymeleaf<sup>5</sup> (`ThymeleafViewResolver`), FreeMarker<sup>6</sup> (`FreeMarkerViewResolver`), Velocity<sup>7</sup> (`VelocityViewResolver`), and JasperReports<sup>8</sup> (`JasperReportsViewResolver`).

These descriptions cover only a few commonly used handlers and resolvers. For a full description, please refer to the Spring Framework reference documentation and its Javadoc.

## Spring MVC Configuration

To enable Spring MVC within a web application, some initial configuration is required, especially for the web deployment descriptor `web.xml`. Since Spring 3.1, support has been available for code-based configuration within a Servlet 3.0 web container. This provides an alternative to the XML configuration required in the web deployment descriptor file (`web.xml`).

<sup>5</sup><https://www.thymeleaf.org>

<sup>6</sup><https://freemarker.apache.org>

<sup>7</sup><https://velocity.apache.org>

<sup>8</sup><https://community.jaspersoft.com>



If you are interested in using XML configuration, check out *Pro Spring 4*, the fourth edition of this book.

To configure Spring MVC support for web applications, we need to perform the following configurations for the web deployment descriptor:

- Configure the root `WebApplicationContext`
- Configure the servlet filters required by Spring MVC
- Configure the dispatcher servlets within the application

There are many ways to do this in Spring, but the easiest way is to extend `AbstractAnnotationConfigDispatcherServletInitializer`, a Spring utility class from the `org.springframework.web.servlet.support`, as shown in Listing 14-5.

*Listing 14-5.* Configuration Class for a Spring Web Application Context

```
package com.apress.prospring6.fourteen;

import org.springframework.web.filter.CharacterEncodingFilter;
import org.springframework.web.filter.HiddenHttpMethodFilter;
import org.springframework.web.servlet.support.
AbstractAnnotationConfigDispatcherServletInitializer;

import jakarta.servlet.Filter;
import java.nio.charset.StandardCharsets;

public class WebInitializer
    extends AbstractAnnotationConfigDispatcherServletInitializer {

    @Override
    protected Class<?>[] getRootConfigClasses() {
        return new Class[]{BasicDataSourceCfg.class, TransactionCfg.class};
    }

    @Override
    protected Class<?>[] getServletConfigClasses() {
        return new Class[]{WebConfig.class};
    }

    @Override
    protected String[] getServletMappings() {
        return new String[]{"/"};
    }

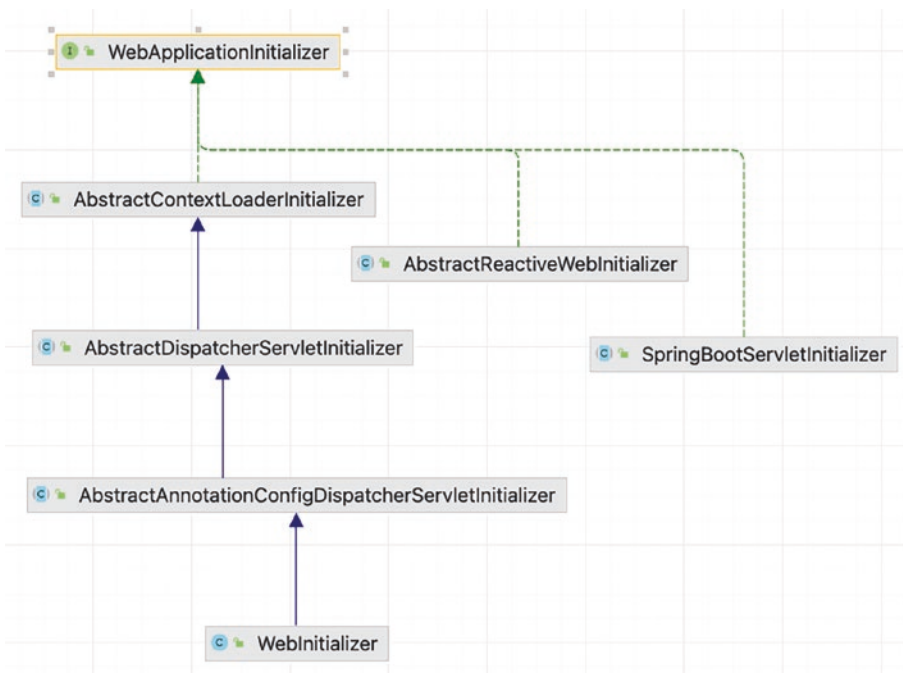
    @Override
    protected Filter[] getServletFilters() {
        final CharacterEncodingFilter cef = new CharacterEncodingFilter();
        cef.setEncoding(StandardCharsets.UTF_8.name());
    }
}
```

```

        cef.setForceEncoding(true);
        return new Filter[] { new HiddenHttpMethodFilter(), cef };
    }
}

```

The `AbstractAnnotationConfigDispatcherServletInitializer` class implements the `org.springframework.web.WebApplicationInitializer` class. This interface needs to be implemented in servlet environments in order to configure the `ServletContext` programmatically. Spring provides more than one implementation, as shown in Figure 14-4, depending on how complex the user customization needs to be.



**Figure 14-4.** *SpringWebApplicationInitializer implementations*

In the previous example, the Spring class `AbstractAnnotationConfigDispatcherServletInitializer` is used because it contains concrete implementations of methods needed for the configuration of Spring web applications that use Java-based Spring configuration.

All classes implementing the `WebApplicationInitializer` interface are automatically detected by the `org.springframework.web.SpringServletContainerInitializer` class. Starting with Spring 6, this class implements Servlet 3.0's `jakarta.servlet.ServletContainerInitializer` interface, which bootstraps automatically in any Servlet 3.0 containers. As shown in Listing 14-5, the following methods were overridden to plug in customized configurations:

- `getRootConfigClasses()`: A root application context of type `AnnotationConfigWebApplicationContext` will be created using the configuration classes returned by this method.
- `getServletConfigClasses()`: A web application context of type `AnnotationConfigWebApplicationContext` will be created using the configuration classes returned by this method.

- `getServletMappings()`: The `DispatcherServlet`'s mappings (context) are specified by the array of strings returned by this method.
- `getServletFilters()`: This method returns an array of implementations of `jakarta.servlet.Filter` that will be applied to every request.

Returning to the filters, Table 14-1 describes each of the filters in the array returned by `getServletFilters()`.

**Table 14-1.** *Commonly Used Spring MVC Servlet Filters*

Filter Class Full Name	Description
<code>org.springframework.web.filter.CharacterEncodingFilter</code>	This filter is used to specify the character encoding for the request.
<code>org.springframework.web.filter.HiddenHttpMethodFilter</code>	This filter provides support for HTTP methods other than GET and POST (for example, PUT).



Although not needed here (and thus not used in the configuration), there is a filter implementation that should be mentioned: `org.springframework.orm.jpa.support.OpenEntityManagerInViewFilter`. This implementation binds a JPA `EntityManager` to the thread for the entire processing of the request. It is intended for the Open `EntityManager` in View pattern, allowing for lazy loading in web views despite the original transactions already being completed. Although practical, it is quite dangerous, as multiple requests might end up consuming all database-allowed open connections. Also, if the data set to load is big, the application might freeze. That is why developers prefer not to use it, instead having specific handlers called via Ajax requests to load the data in web-specific view objects (instead of entities).

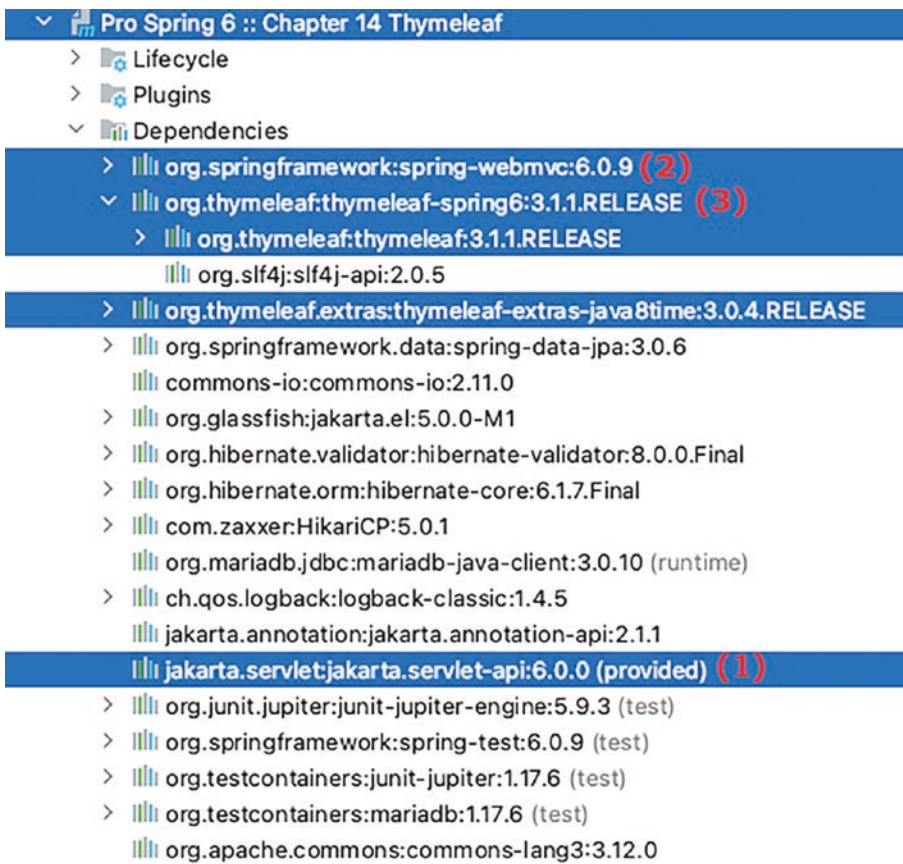
## Creating the First View in Spring MVC

Having the service layer and Spring MVC configuration in place, we can start to implement our first view. In this section, we will implement a simple view to display all singers that are saved in the `SINGER` table.

As mentioned at the beginning of chapter, Thymeleaf is used to design HTML pages. Thymeleaf is a modern server-side Java template engine for both web and stand-alone environments, and it integrates smoothly with Spring applications since it was created specifically for them. To integrate Thymeleaf with a Spring Web application, the Thymeleaf library needs to be on the classpath. And it is about time to list the dependencies of the chapter-14 project, which represents a Spring MVC application that is packed as a war and deployed on an Apache Tomcat 10<sup>9</sup> server.

Figure 14-5 shows the dependencies of the chapter-14 project in the Gradle View.

<sup>9</sup><https://tomcat.apache.org/download-10.cgi>



**Figure 14-5.** Gradle View showing dependencies of the chapter-14 project

The library marked with (1), `jakarta.servlet-api`<sup>10</sup>, is part of the Jakarta project and contains all the required interfaces, classes, and methods to develop a web application. To develop a Spring web application, we need to build on top of it. Version 6.0.0 of this library is suitable for a web application compatible with Apache Tomcat 10.

The library marked with (2), `spring-webmvc`, contains all the interfaces and classes used to develop a Spring Web application. Spring Web MVC is built on top of Servlet API and is part of the Spring Framework. Version 6.x is compatible with Jakarta EE 9.

The library marked with (3), `thymeleaf-spring6`, provides all interfaces and classes to integrate Thymeleaf with Spring.

## Configuring DispatcherServlet

The next step is to configure `DispatcherServlet`. This is done by creating a configuration class that defines all infrastructure beans needed for a Spring web application. The Java Config–based class for the chapter-14 project is depicted in Listing 14-6.

<sup>10</sup><https://projects.eclipse.org/projects/ee4j.servlet>

*Listing 14-6.* Configuration Class for Spring's DispatcherServlet

```

package com.apress.prospring6.fourteen;

import org.springframework.context.annotation.Description;
import org.springframework.web.servlet.DispatcherServlet;
import org.springframework.web.servlet.ViewResolver;
import org.springframework.web.servlet.config.annotation.*;
import org.thymeleaf.extras.java8time.dialect.Java8TimeDialect;
import org.thymeleaf.spring6.SpringTemplateEngine;
import org.thymeleaf.spring6.templateresolver.SpringResourceTemplateResolver;
import org.thymeleaf.spring6.view.ThymeleafViewResolver;
import org.thymeleaf.templatemode.TemplateMode;

@Configuration
@EnableWebMvc
@ComponentScan(basePackages = {"com.apress.prospring6.fourteen"})
public class WebConfig implements WebMvcConfigurer {

    @Bean
    @Description("Thymeleaf Template Resolver")
    public SpringResourceTemplateResolver templateResolver(){
        var resolver = new SpringResourceTemplateResolver();
        resolver.setApplicationContext(this.applicationContext);
        resolver.setPrefix("/WEB-INF/views/");
        resolver.setSuffix(".html");
        resolver.setTemplateMode(TemplateMode.HTML);
        resolver.setCacheable(false);
        return resolver;
    }

    @Bean
    @Description("Thymeleaf Template Engine")
    public SpringTemplateEngine templateEngine() {
        var engine = new SpringTemplateEngine();
        engine.addDialect(new Java8TimeDialect());
        engine.setTemplateResolver(templateResolver());
        engine.setEnableSpringELCompiler(true);
        return engine;
    }

    @Bean
    @Description("Thymeleaf View Resolver")
    public ViewResolver viewResolver() {
        var viewResolver = new ThymeleafViewResolver();
        viewResolver.setTemplateEngine(templateEngine());
        viewResolver.setOrder(1);
        return viewResolver;
    }
}

```

```

@Override
public void addResourceHandlers(final ResourceHandlerRegistry registry) {
    WebMvcConfigurer.super.addResourceHandlers(registry);
    registry.addResourceHandler("/images/**", "/styles/**")
        .addResourceLocations("/images/", "/styles/");
}

@Override
public void configureDefaultServletHandling(final DefaultServletHandlerConfigurer
configurer) {
    configurer.enable();
}

@Override
public void addViewControllers(ViewControllerRegistry registry) {
    registry.addRedirectViewController("/", "/home");
}
}

```

The interface `WebMvcConfigurer` defines callback methods to customize the Java-based configuration for Spring MVC enabled by using `@EnableWebMvc`. Although there can be more than one Java-based configuration class in a Spring application, only one is allowed to be annotated with `@EnableWebMvc`. In Listing 14-6, you can observe that several methods are overridden to customize the configuration:

- `addResourceHandlers(..)`: Adds handlers that are used to serve static resources such as images, JavaScript, and CSS files from specific locations under the web application root, the classpath, and others. In this customized implementation, any request with the URL containing resources will be treated by a special handler that bypasses all filters. The method defines the locations of the static resource files, which enables Spring MVC to handle the files within those folders efficiently. Within the tag, the location attribute defines the folders for the static resources. The `WebMvcConfigurer.super.addResourceHandlers(registry)` invocation indicates the root folder for the web application, which is by default `/src/main/webapp`. The resource handler path, `/styles/**`, defines the URL for mapping to CSS resources; as an example, for the URL `http://localhost:8080/ch14/styles/standard.css`, Spring MVC will retrieve the file `standard.css` from the folder `/src/main/webapp/styles`.
- `configureDefaultServletHandling(..)`: Enables the mapping of `DispatcherServlet` to the web application's root context URL, while still allowing static resource requests to be handled by the container's default servlet.
- `addViewControllers(..)`: Defines simple automated controllers preconfigured with the response status code and/or a view to render the response body. These views have no controller logic and are used to render a welcome page, perform simple site URL redirects, return a 404 status, and more. In Listing 14-6, we are using this method to perform a redirection to the home view, when the root (`/`) of the site is accessed, which basically turns the home page into a front page.
- `viewResolver(..)`: Declares a view resolver of type `ThymeleafViewResolver` that matches symbolic view names to `*.html` templates under `/WEB-INF/views`. Thymeleaf is a templating tool, generating views per logical



names by combining more fragments; this job is being performed by the `SpringResourceTemplateResolver` bean declared in this configuration. The final view is a HTML page built by replacing Thymeleaf special constructs with HTML elements compiled together with Spring view data, and this is being taken care of by the `SpringTemplateEngine`.

## Implementing Spring Controllers

The home view is simple and is the best example to introduce Spring controllers. *Spring controllers* are special beans annotated with the special stereotype annotation `@Controller` and its extensions like `@RestController`, covered in **Chapter 15**.

The `HomeController` class is depicted in Listing 14-7.

*Listing 14-7.* `HomeController` Class and Bean Declaration

```
package com.apress.prospring6.fourteen.controllers;

import org.springframework.stereotype.Controller;
import org.springframework.ui.Model;
import org.springframework.web.bind.annotation.RequestMapping;
import org.springframework.web.bind.annotation.RequestMethod;

@Controller
public class HomeController {

    @RequestMapping(path = "home", method = RequestMethod.GET)
    public String home(Model model) {
        model.addAttribute("message", "Spring MVC ThymeleafExample!!");
        return "home";
    }
}
```

The annotation `@Controller` is applied to the class, indicating that it's a Spring MVC controller. The `@RequestMapping` annotation indicates the URL that will be handled by the method the annotation is placed on. The controller class is sometimes called a *handler*, because it handles requests, and the methods are called *handler methods*, because they handle requests too. Usually the handler methods handle requests that have a common root path declared using a `@RequestMapping` annotation at the class level; the controller class is just a way of grouping them together.

The `@RequestMapping` annotation placed on the `home(..)` method is mapped to the HTTP GET method via the `method` attribute. This means that any GET request to the URL `/home` will be handled by this method. Within the body of this method, `"Spring MVC ThymeleafExample!!"` is set as a value for the `message` property on the `Model` object. In the `DispatcherServlet` configuration, `ThymeleafViewResolver` is configured as the view resolver, with the file prefix `/WEB-INF/views/` and the suffix `.html`. As a result, Spring MVC will pick up the file `/WEB-INF/views/singers/home.html` as the view and render it using the data in the `Model` object.

## Implementing the View

The `home.html` Thymeleaf template is quite simple, as you can see in Listing 14-8.

**Listing 14-8.** The Contents of the `/WEB-INF/views/singers/home.html` Thymeleaf View File

```
<!DOCTYPE HTML>
<html xmlns:th="http://www.thymeleaf.org">

  <head th:replace=~{templates/layout :: pageTitle('Singers Home Page')}></head>

  <body>
    <div class="container">
      <header th:replace=~{templates/layout :: pageHeader}" ></header>

      <header th:replace=~{templates/layout :: pageMenu}" ></header>

      <section th:fragment=~{templates/layout :: pageContent}">
        <p th:text="Home Page" ></p>
        <p th:text="{message}" ></p>
      </section>

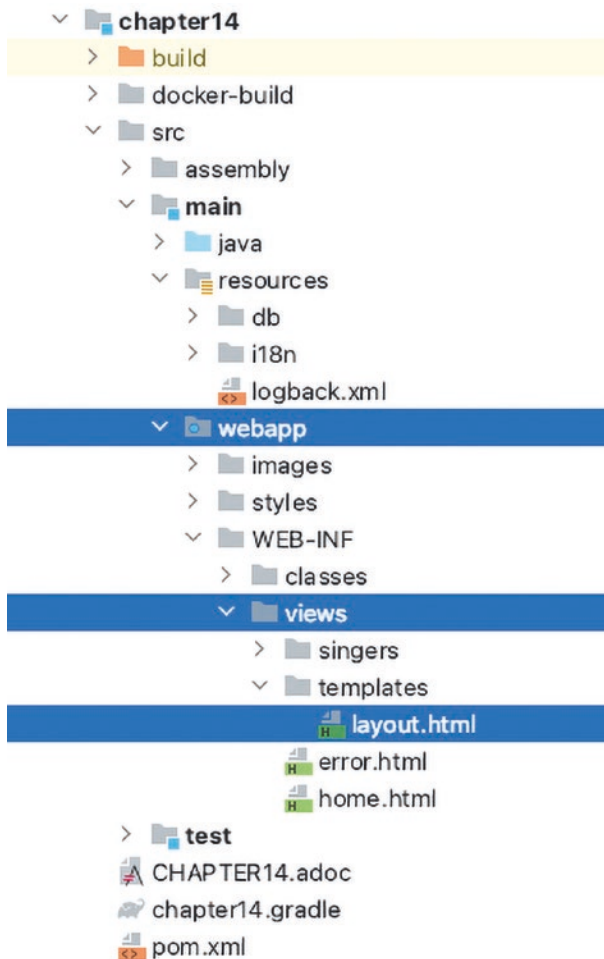
      <footer th:replace=~{templates/layout :: pageFooter}" ></footer>
    </div>
  </body>
</html>
```

This template should look pretty familiar to anyone who has seen HTML code. The only extra parts are all the elements prefixed with `th:`. The reason this template looks so simple is that the biggest parts are in a different template called a *layout*. This template contains the general layout of the site, and for each view, Thymeleaf replaces pieces of it with scoped ones. The general template of the site is located under `chapter14/src/main/webapp/WEB-INF/views/templates/` and is named `layout.html`. Since the focus of this book is Spring, not Thymeleaf, and `layout.html` is quite big, it won't be shown here (feel free to check it out yourself in the book's project repo); only small Thymeleaf constructs are explained. The Thymeleaf constructs in Listing 14-8 are explained here:

- `th:replace`: Substitutes the `<head>` tag in the `home.html` template with the fragment from `templates/layout.html`, but substitutes the title with the one provided as a parameter for the custom function `pageTitle(..)`.
- `th:fragment`: Substitutes the fragment from `templates/layout.html` with the fragment declared in `home.html`. In this example the `pageContent` section declared in `templates/layout.html` is a very simple generic one, so in each inheriting view it needs to be replaced with an appropriate one.

## Testing the Home View

The view files are located under the `WEB-INF` directory located under the `webapp` directory that groups all the web resources. The internal structure of the project is the typical Maven one for a web project, and various plug-ins are configured for Maven and Gradle to build the project into a Web Archive (*WAR*) that can be deployed on an Apache Tomcat server. The structure of the project is displayed in Figure 14-6.



**Figure 14-6.** The internal structure of *chapter-14* project

Testing the `home.html` view can be done in two ways:

- Write a Spring MVC test to test the mapping of the view and the population of the model.
- Build the project, deploy the resulting war to a local Apache Tomcat, and check the home page.

Writing a test for a very simple view and controller is pretty simple. When the application context becomes more complex and more dependencies must be wired, it might be more complicated but not impossible. Listing 14-9 shows the test class and method that check the proper mapping of the `/home` path to the `HomeController#home(..)` method and the population of the model for the `home.html` view.

*Listing 14-9.* Testing the HomeController and the home.html View

```

package com.apress.prospring6.fourteen.controllers;

import com.apress.prospring6.fourteen.WebConfig;
import org.junit.jupiter.api.Test;
import org.springframework.test.context.junit.jupiter.web.SpringJUnitWebConfig;
import org.springframework.test.web.servlet.MockMvc;
import org.springframework.test.web.servlet.request.MockMvcRequestBuilders;
import org.springframework.test.web.servlet.setup.MockMvcBuilders;
import org.springframework.web.context.WebApplicationContext;

import static org.hamcrest.Matchers.containsString;
import static org.springframework.test.web.servlet.result.MockMvcResultHandlers.print;
import static org.springframework.test.web.servlet.result.MockMvcResultMatchers.*;

@SpringJUnitWebConfig(classes = WebConfig.class)
public class HomeControllerTest {

    MockMvc mockMvc;

    public HomeControllerTest(WebApplicationContext wac) {
        this.mockMvc = MockMvcBuilders.webAppContextSetup(wac).build();
    }

    @Test
    void testHome() throws Exception {
        mockMvc.perform(MockMvcRequestBuilders.get("/home"))
            .andExpect(print())
            .andExpect(status().isOk())
            .andExpect(view().name("home"))
            .andExpect(content().string(containsString("Spring MVC
            ThymeleafExample!!")));
    }
}

```

MockMvc is built on Servlet API mock implementations from the `spring-test` module and does not rely on a running container, but it still needs the `servlet-api` dependency. This is not an end-to-end test, and it works because the `HomeController` does not invoke a service and/or a repository.

The `MockMvcRequestBuilders.get(..)` method creates a `MockHttpServletRequest` instance that is configured with the parameters set for it to create a valid request. `MockMvc` performs the request on the context configured via the `@SpringJUnitWebConfig` annotation. This annotation is a special Spring Test annotation used to configure test context for Spring web applications. It is meta-annotated with `@ExtendWith(SpringExtension.class)` used to register the `SpringExtension` that integrates the Spring TestContext Framework into JUnit 5's Jupiter programming model. It is meta-annotated with `@ContextConfiguration` used to determine how to load and configure an `ApplicationContext` for integration tests. And it is meta-annotated with `@WebAppConfiguration` used to configure that a `WebApplicationContext` should be loaded for the test using a default for the path to the root of the web application.

The test checks all the important parts of a response:

- That the HTTP response code is the expected one through the `.andExpect(status().isOk())` matcher
- That the logical view name is the expected one through the `.andExpect(view().name("home"))` matcher
- That the attribute set on the Spring Model instance was added to the rendered view through the `.andExpect(content().string(containsString("Spring MVC ThymeleafExample!!")))` matcher

The other method of checking that the home page is rendered correctly is by actually deploying the application. For this you have to do the following:

- Build the project, which generates the `build/libs/chapter14-6.0-SNAPSHOT.war`.
- Download and install Apache Tomcat 10.



On Unix-based systems you might need to make all scripts under `$TOMCAT_HOME/bin` executable.

---

- Deploy the `chapter14-6.0-SNAPSHOT.war`, by using an IntelliJ IDEA Tomcat launcher.

To create an Apache Tomcat launcher, follow the instructions on the IntelliJ official page<sup>11</sup>. In Figure 14-7 you can see that the Deployment tab is used to add the web artifact to the launcher. When added in exploded form, the launcher can be started in Debug mode and breakpoints from the code will pause the application to allow runtime debugging.

---

<sup>11</sup><https://www.jetbrains.com/help/idea/configuring-and-managing-application-server-integration.html>

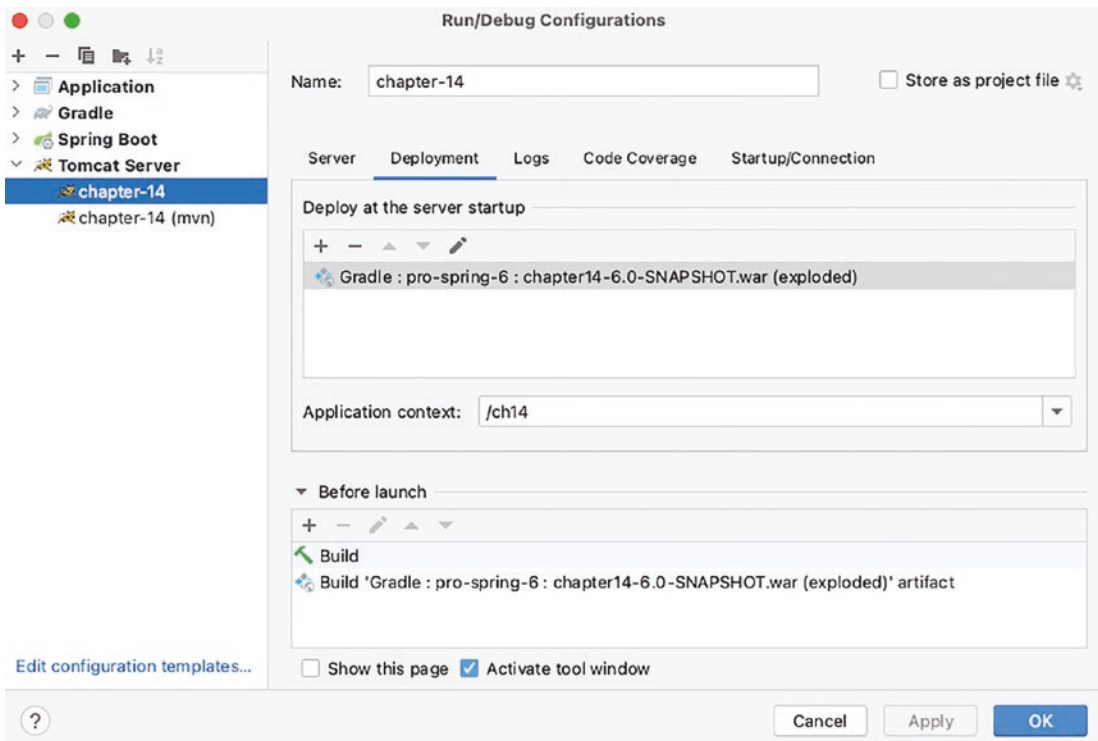


Figure 14-7. IntelliJ IDEA launcher for the chapter-14 project

Once a launcher is in place, you can start the application, and when the application is fully deployed, IntelliJ tries to open a web page with the `http://localhost:8080/ch14/home` location. If the page is loaded correctly, you should see a page that look like the one shown in Figure 14-8.

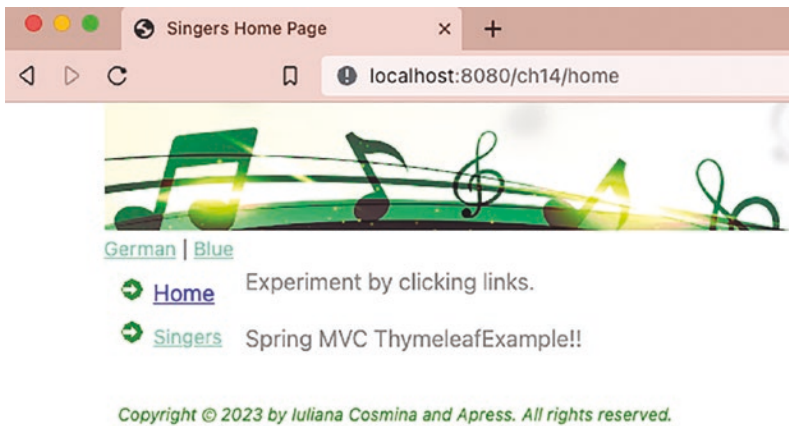


Figure 14-8. chapter-14 project main web page

Now we have our first view working. In the upcoming sections, we will enrich the application with more views and enable support of i18n, themes, error handling, and so on.

## Understanding the Spring MVC Project Structure

Before diving into the implementation of the various aspects of a web application, let's take a look at what the project structure in the sample web application developed in this chapter looks like.

Typically, in a web application, a lot of files are required to support various features. For example, there are a lot of static resource files, such as style sheets, JavaScript files, images, and component libraries. Then there are files that support presenting the interface in various languages. And of course, there are the view pages that will be parsed and rendered by the web container, as well as the layout and definition files that will be used by the templating framework (for example, Thymeleaf) to provide a consistent look and feel of the application.

It's always good practice to store files that serve different purposes in a well-structured folder hierarchy to give you a clear picture of the various resources being used by the application and ease ongoing maintenance work.

The project structure was already introduced via Figure 14-6. Now Table 14-2 describes the folder structure of the web application that is developed in this chapter. Note that the structure presented here is not mandatory but is commonly used in the developer community for web application development.

**Table 14-2.** Sample Web Project Folder Structure Description

Folder Name	Purpose
images	Stores images used to style the site: logos, bullets, etc.
styles	Stores the style sheet files in supporting the CSS styles, look and feel for the site.
WEB-INF/classes	Stores property files for theme cookies configuration.
WEB-INF/views	Stores template files for creating views, in this case Thymeleaf templates.
resources/i18n	Stores files for supporting i18n. The file <code>application*.properties</code> stores the layout-related text (for example, page titles, field labels, and menu titles). The <code>message*.properties</code> file stores various messages (for example, success and error messages and validation messages). The sample will support both English (US) and German (DE). The i18n directory contains internationalization resources files. The files could have been placed under WEB-INF/i18n, but for easier migration to Spring Boot at the end of the chapter, it was placed under resources.



Sometimes there might also be a `webapp/scripts` directory containing generic JavaScript files necessary to make the pages dynamic. There might also be other directories specific to JavaScript frameworks used, like jQuery<sup>12</sup> or jqgrid<sup>13</sup>. For the simple example in this chapter no such files are needed.

<sup>12</sup> <https://jquery.com>

<sup>13</sup> <http://www.trirand.com/blog>

Most web files mentioned in Table 14-2 will not be shown here. Given that, we recommend you download a copy of the source code for this chapter and extract it to a temporary folder so that you can copy the files required into the project directly.

## Enabling Internationalization (i18n)

When developing web applications, it's always good practice to enable i18n in the early stages. The main work is to externalize the user interface text and messages into properties files.

Even though you may not have i18n requirements on day one, it's good to externalize the language-related settings so that it will be easier later when you need to support more languages.

With Spring MVC, enabling i18n is simple. First, externalize the language-related user interface settings into various properties files within the `/resources/i18n` folder, as described in Table 14-2. Because we will support both English (US) and German (DE), you will need two files. The `global.properties` file stores the settings for the default locale, which in this case is English (US). The `global_de.properties` file stores the settings in the German (DE) language.

## Configuring i18n in the DispatcherServlet Configuration

Having the language files in place, the next step is to configure the `DispatcherServlet` instance's `WebApplicationContext` for i18n support. For this we need to declare a `MessageSource` bean in the `WebConfig` class introduced in Listing 14-6, inject it in the template resolver, and add request interceptors to replace all message codes in view templates with test representations in the configured language. The configuration modifications to support internationalization are depicted in Listing 14-10.

*Listing 14-10.* Adding Internationalization Configuration Class for Spring's `DispatcherServlet`

```
package com.apress.prospring6.fourteen;

import org.springframework.context.MessageSource;
import org.springframework.context.support.ReloadableResourceBundleMessageSource;
import org.springframework.web.servlet.i18n.LocaleChangeInterceptor;
import org.springframework.web.servlet.mvc.WebContentInterceptor;
import org.springframework.web.servlet.config.annotation.InterceptorRegistry;
import org.springframework.web.servlet.i18n.CookieLocaleResolver;
// other import statements omitted

@Configuration
@EnableWebMvc
@ComponentScan(basePackages = {"com.apress.prospring6.fourteen"})
public class WebConfig implements WebMvcConfigurer {

    @Bean
    @Description("Thymeleaf Template Engine")
    public SpringTemplateEngine templateEngine() {
        var engine = new SpringTemplateEngine();
        engine.addDialect(new Java8TimeDialect());
        engine.setTemplateResolver(templateResolver());
        engine.setTemplateEngineMessageSource(messageSource());
        engine.setEnableSpringELCompiler(true);
        return engine;
    }
}
```



```

@Override
public void addInterceptors(InterceptorRegistry registry) {
    registry.addInterceptor(localeChangeInterceptor()).addPathPatterns("/*");
}

@Bean
MessageSource messageSource() {
    var messageResource = new ReloadableResourceBundleMessageSource();
    messageResource.setBasename("classpath:i18n/global");
    messageResource.setDefaultEncoding(StandardCharsets.UTF_8.name());
    messageResource.setUseCodeAsDefaultMessage(true);
    messageResource.setFallbackToSystemLocale(true);
    return messageResource;
}

@Bean
LocaleChangeInterceptor localeChangeInterceptor() {
    var localeChangeInterceptor = new LocaleChangeInterceptor();
    localeChangeInterceptor.setParamName("lang");
    return localeChangeInterceptor;
}

@Bean
CookieLocaleResolver localeResolver() {
    var cookieLocaleResolver = new CookieLocaleResolver();
    cookieLocaleResolver.setDefaultLocale(Locale.ENGLISH);
    cookieLocaleResolver.setCookieMaxAge(3600);
    cookieLocaleResolver.setCookieName("locale");
    return cookieLocaleResolver;
}

// other configurations omitted
}

```

In this version of the configuration, the `MessageSource` bean is declared as a `ReloadableResourceBundleMessageSource` instance. The `ReloadableResourceBundleMessageSource` class implements the `MessageSource` interface, which loads the messages from the defined files (in this case, it's the `global*.properties` in the `/resources/i18n` folder), to support `i18n`. Note the property `fallbackToSystemLocale`. This property instructs Spring MVC whether to fall back to the locale of the system that the application is running on when a special resource bundle for the client locale isn't found. The instance is configured using the location of the property files, `classpath:i18n/global`, which means they are expected to be on the application classpath, and thus under the `resources` directory at development time. The encoding is also configured, and in case a message code is used in the view files without a value configured for it in the resource files, the code is used as a value. A Spring MVC interceptor with class `LocaleChangeInterceptor` is defined, which intercepts all the requests to `DispatcherServlet`. The interceptor supports locale switching with a configurable request parameter. From the interceptor configuration, the URL parameter with the name `lang` is defined for changing the locale for the application and is customizable, so you can use a different one if you want.

Finally, a bean with the `CookieLocaleResolver` class is defined. This class supports the storage and retrieval of locale settings from the user browser's cookie.

## Modifying Views for i18n Support

Now that internationalization support is configured, the view template files must be modified to support internationalization. The `home.html` view introduced previously does not have any elements needing internationalization, so to show how internationalization is supported in Thymeleaf templates, a snippet from the `views/templates/layout.html` file is shown in Listing 14-11.

**Listing 14-11.** `views/templates/layout.html` Snippet

```
<!DOCTYPE HTML>
<html xmlns:th="http://www.thymeleaf.org"
      th:with="lang=${#locale.language}"
      th:lang="${lang}">

<head th:fragment="pageTitle(title)">
  <link rel="icon" type="image/png" th:href="@{/images/favicon.ico}">
  <link rel="stylesheet" type="text/css" th:href="@{/styles/bootstrap.min.css}">
  <meta http-equiv="Content-Type" content="text/html; charset=UTF-8" />
  <title th:text="${title}"> Layout Page </title>
  <link type="text/css" rel="stylesheet" th:href="@{/styles/general.css}" >
</head>

<body>
  <header th:fragment="pageHeader" class="page-header">
    <div class="row">
      <div class="col-lg-8 col-md-7 col-sm-6">
        <div class="banner"></div>
        <div class="themeLocal">
          <span th:if="${#locale.language eq 'en'}">
            <a th:href="@{/?lang=de}" th:text="#{locale.de}">DE</a>
          </span>
          <span th:unless="${#locale.language eq 'en'}">
            <a th:href="@{/?lang=en}" th:text="#{locale.en}">EN</a>
          </span>
        </div>
      </div>
    </div>
  </header>

  <section th:fragment="pageMenu">
    <!-- code omitted-->
  </section>

  <section th:fragment="pageContent">
    <div class="content">
      <p>Page Content</p>
    </div>
  </section>
```

```

<footer th:fragment="pageFooter">
  <div class="footer">
    <p th:text="#{footer.text}"></p>
  </div>
</footer>
</html>

```

The HTML lang attribute is used to identify the language of text content on the Web. The `th:lang` construct populates this attribute with the value of the `lang` parameter set by the `LocaleChangeInterceptor` on each request. Because we defined `LocaleChangeInterceptor` in `DispatcherServlet`'s `WebApplicationContext`, Spring MVC stores the locale setting in your browser's cookie (with the name `locale`), and by default, the cookie is kept for the user session. If you want to persist the cookie for a longer time, in the `CookieLocaleResolver` bean definition you can override the property `cookieMaxAge`, which is inherited from the class `org.springframework.web.util.CookieGenerator`, by calling `setCookieMaxAge(...)`.

To switch to English (US), you can change the URL in your browser to reflect `?lang=en`, and the page will switch back to English. Since the properties file named `global_en.properties` is not provided, Spring MVC falls back to use the default file `global.properties`, which stores the properties in the default language of the site, of English.

Locale-specific values will be accessed using the keys with the syntax `#{key}`, where `key` is the message key in the internationalization properties files.

## Using Theming and Templating

Besides i18n, a web application requires an appropriate look and feel (for example, a business website needs a professional look and feel, while a social website needs a more vivid style), as well as a consistent layout so that users will not get confused while using the web application.



Currently, the approach is to keep the website separate from the back end and create the website using evolved JavaScript frameworks like [React](https://reactjs.org)<sup>14</sup> and [TypeScript](https://www.typescriptlang.org)<sup>15</sup> that interact with a Spring REST Web application for data management and other high-level operations. This means that the user interface will be mostly static. This is why the `ThemeChangeInterceptor`, `ResourceBundleThemeSource`, and `CookieThemeResolver` types that will be covered in this section are marked as deprecated in Spring 6.x, but no replacement is recommended.

---

## Theming Support

Spring MVC provides comprehensive support for theming, and enabling it in web applications is easy. For this reason, we'll start with the Spring theming configurations that need to be added to the `WebConfig` class, as shown in Listing 14-12.

<sup>14</sup> <https://reactjs.org>

<sup>15</sup> <https://www.typescriptlang.org>

**Listing 14-12.** WebConfig Theming Configuration

```

package com.apress.prospring6.fourteen;

import org.springframework.ui.context.support.ResourceBundleThemeSource;
import org.springframework.web.servlet.theme.CookieThemeResolver;
import org.springframework.web.servlet.theme.ThemeChangeInterceptor;
// other import statements omitted

@Configuration
@EnableWebMvc
@ComponentScan(basePackages = {"com.apress.prospring6.fourteen"})
public class WebConfig implements WebMvcConfigurer {

    @Bean
    ResourceBundleThemeSource themeSource() {
        return new ResourceBundleThemeSource();
    }

    @Bean
    ThemeChangeInterceptor themeChangeInterceptor() {
        var themeChangeInterceptor = new ThemeChangeInterceptor();
        themeChangeInterceptor.setParamName("theme");
        return themeChangeInterceptor;
    }

    @Bean
    CookieThemeResolver themeResolver() {
        var cookieThemeResolver = new CookieThemeResolver();
        cookieThemeResolver.setDefaultThemeName("green");
        cookieThemeResolver.setCookieMaxAge(3600);
        cookieThemeResolver.setCookieName("theme");
        return cookieThemeResolver;
    }

    @Override
    public void addInterceptors(InterceptorRegistry registry) {
        registry.addInterceptor(localeChangeInterceptor()).addPathPatterns("/*");
        registry.addInterceptor(themeChangeInterceptor());
    }

    // other configurations omitted
}

```

The first bean, of type `ResourceBundleThemeSource`, is responsible for loading the `ResourceBundle` bean of the active theme. For example, if the active theme is called `blue`, the bean will look for the file `blue.properties` as the `ResourceBundle` bean of the theme. The property files for the two themes are located under `WEB-INF/classes`. The files are named `blue.properties` and `green.properties` and they match the `blue` and `green` theme. The content of the files is represented by the theme name as a property and other properties pointing to images and paths to CSS files specific to the team. For example, the content of the `green.properties` file is shown in Listing 14-13.

**Listing 14-13.** green.properties File Contents

```
css.style=/styles/decorator-green.css
banner.image=/images/banner-green.png
name=green
```

The new interceptor bean of type `ThemeChangeInterceptor` intercepts every request to add the theme parameter.

The bean of type `CookieThemeResolver` is used to resolve the active theme for users. The property `defaultThemeName` defines the default theme to use, which is the green theme. Note that as its name implies, the `CookieThemeResolver` class uses cookies to store the theme for the user. There is also a type called `SessionThemeResolver`. Beans of this type store the *theme* attribute in a user's session, but in order to use it we would have to add security to our app, and we do not want to do that right now.

Now that theming is configured, there is not much change to be done. In the `views/templates/layout.html` file, we only need to add support for the theme parameter and add a menu option to change the theme, in the same way it was added for locale, as shown in Listing 14-14.

**Listing 14-14.** views/templates/layout.html Snippet

```
<!DOCTYPE HTML>
<html xmlns:th="http://www.thymeleaf.org"
      th:with="lang=${#locale.language}, theme=${#themes.code('name')}"
      th:lang="${lang}"
      th:theme="${theme}">

<head th:fragment="pageTitle(title)">
  <link rel="icon" type="image/png" th:href="@{/images/favicon.ico}">
  <link rel="stylesheet" type="text/css" th:href="@{/styles/bootstrap.min.css}">
  <meta http-equiv="Content-Type" content="text/html; charset=UTF-8" />
  <title th:text="${title}"> Layout Page </title>
  <link type="text/css" rel="stylesheet" th:with="cssStyle=${#themes.code('css.style')}"
        th:href="@({{cssStyle}})" >
  <link type="text/css" rel="stylesheet" th:href="@{/styles/general.css}" >
</head>

<body>
  <header th:fragment="pageHeader" class="page-header">
    <div class="row">
      <div class="col-lg-8 col-md-7 col-sm-6">
        <div class="banner"></div>
        <div class="themelocal">
          <span th:if="${#locale.language eq 'en'}">
            <a th:href="@{/?lang=de}" th:text="#{locale.de}">DE</a>
          </span>
          <span th:unless="${#locale.language eq 'en'}">
            <a th:href="@{/?lang=en}" th:text="#{locale.en}">EN</a>
          </span> |
          <span th:if="${#themes.code('name') eq 'green'}">
            <a th:href="@{/?theme=blue}" th:text="#{theme.Blue}">BLUE</a>
          </span>
          <span th:unless="${#themes.code('name') eq 'green'}">
            <a th:href="@{/?theme=green}" th:text="#{theme.Green}">GREEN</a>
          </span>
        </div>
      </div>
    </div>
  </header>
</body>
```

```

        </span>
    </div>
</div>
</div>
</header>

<section th:fragment="pageMenu">
    <!-- code omitted-->
</section>

<section th:fragment="pageContent">
    <div class="content">
        <p>Page Content</p>
    </div>
</section>

<footer th:fragment="pageFooter">
    <div class="footer">
        <p th:text="#{footer.text}"></p>
    </div>
</footer>
</html>

```

Notice that in the `<head>` section the `th:theme` is added as an attribute. The value of this attribute is set by the `ThemeChangeInterceptor` bean. The `#themes.code('css.style')` construct is a context object used to retrieve the `css.style` property from the theme's `ResourceBundle`, which is the path to the style sheet file `decorator-*.css`. Its value is stored in the `cssStyle` variable using the `th:with` construct and then set as a value for the `href` attribute using `th:href="@{({{cssStyle}})"`.

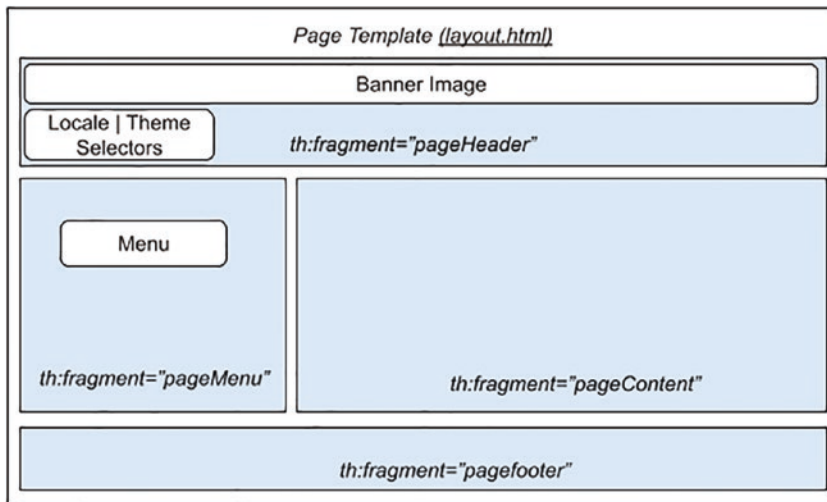
After rebuilding and redeploying the application to the server, open the browser and open `http://localhost:8080/ch14` again, and you will see that the style defined in the `green.css` file was applied, since this is the theme configured to be the default in the `ThemeChangeInterceptor` bean declaration.

If you want, you can right-click on the web page and analyze the HTML code that Thymeleaf produced for the `home.html` template.

## Designing the Template Layout

The consistent structure of the site is already ensured by using the `views/templates/layout.html` file as a template, on which every view is based. To keep colors and element styling consistent and matching, a theme requires a combination of web design and Spring MVC configuration.

The common structure for all web pages has been presented as HTML already in Listing 14-11, but Figure 14-9 provides a more useful visual representation.



**Figure 14-9.** Thymeleaf template with fragments

The banner image and font color are part of the site theme, and thus when switching between blue and green theme, the banner and font color change too. For each view designed based on the `layout.html` the developer can choose to replace some of its sections with fragments from `layout.html` using the `th:replace`, or they can declare its own fragments using `th:fragment`. Obviously, in most views the only things that are customized are the `pageContent` fragment and the page title that is part of the `<head>` element.

## Implementing More Complex Views

Now we can proceed to implement the views that allow users to view the complete list of singers, view the details of a singer, edit existing singers, create new singers, or even delete them.

In the following sections, we discuss the mapping of URLs to the various views, as well as how the views are implemented. We also discuss how to enable JSR-349/Jakarta Bean Validation<sup>16</sup> validation support in Spring MVC for the edit view.

First, we need to design how the various URLs are to be mapped to the corresponding views. In Spring MVC, one of the best practices is to follow the RESTful-style URL for mapping views (wherever possible). Table 14-3 shows the URLs-to-views mapping, as well as the controller method name that will handle the action.

<sup>16</sup> <https://beanvalidation.org/3.0>

**Table 14-3.** Spring Controllers APIs for managing *Singer* instances

URL	HTTP Method	Controller	Method Description
/singers	GET	SingersController	Lists all singers.
/singers	POST	SingersController	Creates new singer.
/singers/create	GET	SingersController	Displays the form to create a singer.
/singers/search	GET	SingersController	Displays the form to search for a singer.
/singers/go	GET	SingersController	Lists singers by criteria provided as request parameters: fieldName, fieldValue, and exactMatch.
/singer/id	GET	OneSingerController	Shows information of singer with the provided id.
/singer/id	PUT	OneSingerController	Updates singer with provided id.
/singer/id	DELETE	OneSingerController	Deletes singer with provided id.
/singer/id/edit	GET	OneSingerController	Displays the form to edit the singer with the provided id.
/singer/id/upload	GET	OneSingerController	Displays the form to upload a photo for the singer with the provided id.
/singer/id/photo	GET	OneSingerController	Retrieves the photo as a byte array for the singer with the provided id.
/singer/id/photo	POST	OneSingerController	Submits user-provided image for singer with provided id.

## Implementing the List Singers View

To implement a view showing a set of data, we need three things:

- A mapping between the URL and the handler method
- A handler method to populate the model
- The view template, which we'll call `list.html`

As mentioned in Table 14-3, the request URL for showing a list of singers is `/singers` and the controller where the handler method is declared is the `SingersController`. There are two controllers in the project. The `SingersController` groups handler methods that do not affect a specific `Singer` instance identified by `id`. All handled requests are grouped under the `/singers` path. The handler methods affecting a single `Singer` instance identified by `id` are grouped under `OneSingerController`. All handled requests are grouped under `/singer/{id}`.

Listing 14-15 shows the `SingersController` class and controller configuration and the handler method populating the model for the view showing the singers.



*Listing 14-15.* SingersController Controller and list(..) Method

```

package com.apress.prospring6.fourteen.controllers;

import com.apress.prospring6.fourteen.services.SingerService;
import org.springframework.context.MessageSource;
import org.springframework.stereotype.Controller;
import org.springframework.ui.Model;
import org.springframework.web.bind.annotation.RequestMapping;
// other import statements omitted

@Controller
@RequestMapping("/singers")
public class SingersController {
    private static Comparator<AbstractEntity> COMPARATOR_BY_ID = Comparator.comparing(Abstract
Entity::getId);

    private final SingerService singerService;
    private final MessageSource messageSource;

    public SingersController(SingerService singerService, MessageSource messageSource) {
        this.singerService = singerService;
        this.messageSource = messageSource;
    }

    @RequestMapping(method = RequestMethod.GET)
    public String list(Model uiModel) {
        List<Singer> singers = singerService.findAll();
        singers.sort(COMPARATOR_BY_ID);
        uiModel.addAttribute("singers", singers);

        return "singers/list";
    }

    // other handler methods omitted
}

```

The `@RequestMapping` annotation placed on the class indicates that all handler methods in this class either apply to the path provided as the argument or to paths relative to that.

On the `list(..)` method, the `@RequestMapping(method = RequestMethod.GET)` applied to it indicates that the method is used to handle a GET request to the URL `/singers`. The `Model` object is populated with an attribute named `singers` and populated with the collection of singers returned by the `singerService.findAll()` invocation.



It was probably mentioned before in this book, but the `findAll()` method should never be used in production environments unless the size of the returned collection is manageable; otherwise, it might lead to serious performance problems.

---

The `@GetMapping` annotation is meta-annotated with `@RequestMapping(method = RequestMethod.GET)` can replace it on handler methods to keep the code more readable.

The value returned by this method is `"singers/list"`, which is the logical name of the view used to render the data in the model. This logical name is used by the `ThymeleafViewResolver` bean to identify the view template to use the HTML page that is returned as a response to the user request.

The `views/singers/list.html` template is shown in Listing 14-16.

**Listing 14-16.** `views/singers/list.html` Template Contents

```
<!DOCTYPE HTML>
<html xmlns:th="http://www.thymeleaf.org">

  <head th:replace=~{templates/layout :: pageTitle('List Singers Page')}></head>

  <body>
    <div class="container">
      <header th:replace=~{templates/layout :: pageHeader}" ></header>

      <header th:replace=~{templates/layout :: pageMenu}" ></header>

      <section th:fragment=~{templates/layout :: pageContent}">
        <div class="card border-success mb-3" style="max-width: 40rem;">
          <div class="card-header" th:text="#{singers.list.title}"/>
          <div class="card-body">
            <table th:if="{not #lists.isEmpty(singers)}" class="table table-hover">
              <thead>
                <tr>
                  <th th:text="#{label.Singer.count}" class="table-success">COUNT</th>
                  <th th:text="#{label.Singer.firstname}" class="table-success">FIRSTNAME</th>
                  <th th:text="#{label.Singer.lastname}" class="table-success">LASTNAME</th>
                </tr>
              </thead>
              <tbody>
                <tr th:each="singer : ${singers}" >
                  <td><a th:href="@{/singer/} + ${singer.id}" th:text="${singer.id}">ID</a></td>
                  <td th:text="${singer.firstName}">...</td>
                  <td th:text="${singer.lastName}">...</td>
                </tr>
              </tbody>
            </table>
          </div>
        </div>
      </section>

      <footer th:replace=~{templates/layout :: pageFooter}" ></footer>
    </div>
  </body>
</html>
```

Thymeleaf is pretty powerful and, in addition to its previously described capabilities, it supports arithmetic operations, comparators, and conditional expressions. For example, the `th:if="{not #lists.isEmpty(singers)}"` construct added as an attribute to the `<table>` element conditions the creation of the table based on the `singer` attribute value being a non-empty list. The `th:each="singer : ${singers}"` construct is used to iterate the values of the `singers` list. When set as an attribute for an HTML element, it will create a copy for each entry in the list. In this template for each value in the `singers` list, a row in the table is created. Using the `${.}` syntax, a cell is created in the table for each property of the objects in the list.

When opening `http://localhost:8080/ch14/singers` in the browser, an HTML table containing singers should be displayed in the page, and if you inspect the page source, you can see the HTML code generated by Thymeleaf. It should look like the code in Listing 14-17.

**Listing 14-17.** HTML Code Generated by Thymeleaf for the `singers/list` View

```
<table class="table table-hover">
  <thead>
    <tr>
      <th class="table-success">Cnt.</th>
      <th class="table-success">First Name</th>
      <th class="table-success">Last Name</th>
    </tr>
  </thead>
  <tbody>
    <tr >
      <td><a href="/ch14/singer/1">1</a></td>
      <td>John</td>
      <td>Mayer</td>
    </tr>
    <tr >
      <td><a href="/ch14/singer/2">2</a></td>
      <td>Ben</td>
      <td>Barnes</td>
    </tr>
    <!-- some rows omitted -->
  </tbody>
</table>
```

## Implementing the Show Singer View

Implementing the `show.html` view to display the information for a singer is quite similar to implementing the `list.html` view. Showing the information requires a GET request for all text information and another GET information to retrieve the photo as an array of bytes. The code for the two handling methods is shown in Listing 14-18.

**Listing 14-18.** `OneSingerController` Controller and `show(..)` and `downloadPhoto(..)` Methods

```
package com.apress.prospring6.fourteen.controllers;

import org.springframework.http.MediaType;
import org.springframework.web.bind.annotation.*;
//other import statements omitted
```

```

@Controller
@RequestMapping("/singer/{id}")
public class OneSingerController {

    private final Logger LOGGER = LoggerFactory.getLogger(OneSingerController.class);
    private final SingerService singerService;
    private final MessageSource messageSource;

    public OneSingerController(SingerService singerService, MessageSource messageSource) {
        this.singerService = singerService;
        this.messageSource = messageSource;
    }

    @GetMapping
    public String showSingerData(@PathVariable("id") Long id, Model uiModel) {
        Singer singer = singerService.findById(id);
        uiModel.addAttribute("singer", singer);

        return "singers/show";
    }

    @GetMapping(value = "/photo")
    @ResponseBody
    public byte[] downloadPhoto(@PathVariable("id") Long id) {
        Singer singer = singerService.findById(id);

        if (singer.getPhoto() != null) {
            LOGGER.info("Downloading photo for id: {} with size: {}", singer.getId(),
                singer.getPhoto().length);
            return singer.getPhoto();
        }
        return null;
    }
}
// other handler methods omitted
}

```

The two methods are part of the `OneSingerController` because both operations apply on a single `Singer` instance. All operations that apply to a `Singer` instance that exists in our system and thus has an `id` are grouped in this controller, and all operations are mapped to requests to URLs starting with `/singer/{id}`.

The code is easily readable, but some extra clarifications are needed regarding the annotations:

- The `@RequestMapping("/singer/{id}")` annotation declares the common URL path for all request URLs handled by methods in this controller. Since it is used at the type level, all method-level mappings inherit it, and additional method-level annotation URL paths are appended to it.
- The `@PathVariable("id")` annotation allows Spring to take the parameter from the URL path and inject it as a value to the `id` parameter that the `showSingerData(..)` method is invoked with. This annotation is itself configured with the name of the URL path variable for demonstration purposes, but when the URL path variable name is the same as the method parameter, this is not necessary. So in this scenario, `@PathVariable("id") Long id` is equivalent to `@PathVariable Long id`

- The `@GetMapping(value = "/photo")` annotation is equivalent to `@RequestMapping(value = "/photo", method = RequestMethod.GET)`. The value attribute in `@GetMapping` is an alias for the same attribute from `@RequestMapping`. In `@RequestMapping`, the value and path attributes are aliases for each other, and both are default attributes, which means all the following annotations are equivalent:
  - `@GetMapping(value = "/photo")`
  - `@GetMapping(path = "/photo")`
  - `@GetMapping("/photo")`
  - `@RequestMapping(value = "/photo", method = RequestMethod.GET)`
  - `@RequestMapping(path = "/photo", method = RequestMethod.GET)`
- The `@ResponseBody` annotation indicates that the returned value should be bound to the response body. This means that Spring is not looking for a view based on the returned value, but returns the value as it is.

The `downloadPhoto(..)` handler method is necessary because photos are saved in the database as an array of bytes, and to render them in HTML, we need to provide this entire array of bytes as a source for an `<img>` element.

The fragment `pageContent` from the `show.html` view template is shown in Listing 14-19. (The rest of the template is inherited unchanged from `layout.html` and is omitted here to save book space.)

*Listing 14-19.* `views/singers/show.html` Template `pageContent` Fragment

```
<section th:fragment=~{templates/layout :: pageContent}>
<div class="card border-info mb-3" style="max-width: 20rem;">
  <div class="card-header" th:text="#{singer.title}"/>
  <div class="card-body">
    <table>
      <tr>
        <th th:text="#{label.Singer.firstname}" >FN</th>
        <td th:text="{singer.firstName}" >FN</td>
      </tr>
      <tr>
        <th th:text="#{label.Singer.lastname}" >LN</th>
        <td th:text="{singer.lastName}" >LN</td>
      </tr>
      <tr>
        <th th:text="#{label.Singer.birthDate}" >BD</th>
        <td th:text="{singer.birthDate}" >BD</td>
      </tr>
      <tr th:if="{singer.photo != null}">
        <td colspan="2">
          
        </td>
      </tr>
    </table>
  </div>
</div>
```

```

<tr>
  <td colspan="2">
    <a th:href="@{/singer/} + ${singer.id} + '/edit'"
      th:text="#{command.edit}"
      class="btn-success">EDIT</a>
  </td>
  <td >
    <a th:href="@{/singer/} + ${singer.id} + '/upload'"
      th:text="#{command.update.photo}"
      class="btn-success">UPLOAD_PHOTO</a>
  </td>
</tr>
</table>
<div class="container col-lg-12">
  <form th:object="${singer}" th:action="@{/singer/} + ${singer.id}"
    th:method="delete" class="col p-3">
    <input type="submit" th:value="#{command.delete}" id="deleteButton" class="btn
      btn-danger"/>
  </form>
</div>
</div>
</div>
</section>

```

To see the details of any singer, you can just click the link on the number in column Cnt. for that singer. Figure 14-10 shows the list of singers, pinpointing the links that cause the show view to be displayed.

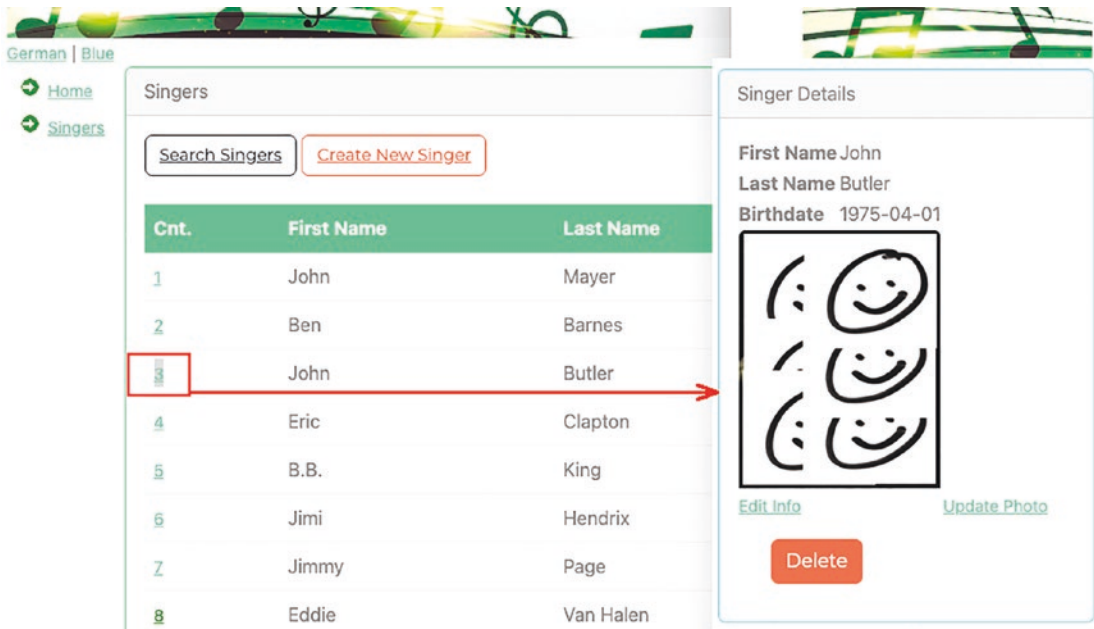


Figure 14-10. List and show views

The highlights of the `show.html` view template are as follows:

- The `th:src="@{/singer/} + ${singer.id} + '/photo'" :the@{...}` Thymeleaf construct is used to build links relative to the current page context. This means the value of the `src` attribute in the generated HTML becomes `/ch14/singer/3/photo` and the full source URL becomes `http://localhost:8080/ch14/singer/3/photo` that is mapped to the `downloadPhoto(..)` handler method.
- The same construct is used to generate the `Edit Info` and `Update Photo` links. The `Edit Info` link opens a new page where the user can edit the singer's info. The `Update Photo` link opens a new page where the user can upload a new photo.

## Handling a Delete Request

There is a form in the `show.html` template that is used to trigger a DELETE request for the singer being shown. The generated HTML is shown in Listing 14-20.

**Listing 14-20.** The Singer Delete Form

```
<form action="/ch14/singer/3" method="post" class="col p-3">
  <input type="hidden" name="_method" value="delete"/>
  <input type="submit" value="Delete" id="deleteButton" class="btn btn-danger"/>
</form>
```

Notice that in fact the form method is POST, but a hidden input was added to the form by Thymeleaf with the name of `_method` and the value of `delete`. If it looks like this form input indicates the actual desired request method, it's because that is exactly what it is used for.

The explanation is simply that when it comes to the HTTP protocol, there are two main things people use it for: to retrieve data (GET) or to send data (POST). This means that methods like PUT and DELETE essentially do the same as POST—they are essentially *subcategories* of POST—and therefore no need exists to directly support more methods in HTML.

However, for practical reasons and readability, Thymeleaf allows declaration of forms with `th:method="delete"` or `th:method="put"` and does the heavy lifting of converting them to POST methods when the responses are generated. How does Spring deal with these requests, though? Or better stated, how should handling methods be mapped to these types of requests?

The answer is: in the same way as GET requests, after all the `@RequestMapping` annotation can be configured for a specific HTTP method, and there are also the meta-annotations: `@DeleteRequest` and `@PutRequest`, equivalent to `@RequestMapping (method = RequestMethod.DELETE)` and `@RequestMapping(method = RequestMethod.PUT)`.

Listing 14-21 shows the handler method for the request to delete a singer.

**Listing 14-21.** The Singer Delete Handler Method

```
package com.apress.prospring6.fourteen.controllers;

import org.springframework.web.bind.annotation.DeleteMapping;
// other import statements omitted

@Controller
@RequestMapping("/singer/{id}")
public class OneSingerController {
```

**@DeleteMapping**

```

public String deleteSinger(@PathVariable("id") Long id) {
    singerService.findById(id);
    singerService.delete(id);
    return "redirect:/singers/list";
}

```

```

// other handler methods omitted
}

```

One other thing is necessary, though: we need to tell Spring that we will have PUT and DELETE requests for the application, so that it knows to convert POST requests with `_method` hidden inputs to appropriate HTTP requests, so that they can be mapped to the suitable type of handlers. This is done by adding an instance of `org.springframework.web.filter.HiddenHttpMethodFilter` to the list of filters that modify requests before they are passed over to `DispatcherServlet`. The modification is made in the `WebInitializer` class introduced in Listing 14-5. Recall that when this configuration was introduced, the `getServletFilters()` was described as returning an array of implementations of `jakarta.servlet.Filter` that will be applied to every request. The method is shown again in Listing 14-22.

**Listing 14-22.** The Configuration to Support PUT and DELETE Methods in a Spring Application

```

package com.apress.prospring6.fourteen;

```

```

public class WebInitializer extends AbstractAnnotationConfigDispatcherServletInitializer {

```

```

    @Override
    protected Filter[] getServletFilters() {
        final CharacterEncodingFilter cef = new CharacterEncodingFilter();
        cef.setEncoding(StandardCharsets.UTF_8.name());
        cef.setForceEncoding(true);
        return new Filter[] { new HiddenHttpMethodFilter(), cef };
    }

```

```

// other methods omitted
}

```



This piece of configuration is something that most developers forget when writing Spring web applications, especially if this is not something that they do often. Who writes Spring web applications from scratch often enough for these configurations to become routine, anyway?

---

## Implementing the Edit Singer View

To edit a singer, we need a different type of view that not only shows data, but does so in components that are editable, and we also need a form to submit the edited data. For requests that submit data used to edit existing records on the server, the REST convention is to use a PUT to differentiate it from a normal POST request, for which the submitted data is used to create a new record.



The Edit Info link, introduced in the section about showing singer data, points to a page showing the singer details in editable fields. A GET request is submitted to the `/singer/{id}/edit` URL. Spring populates a model with the details of the `Singer` instance with the provided `id` and returns the `singers/edit` view logical name. The page contains a form that submits the edited data using a HTTP POST request to `/singer/{id}`.

The Thymeleaf fragment with the form design is shown in Listing 14-23.

**Listing 14-23.** The `singers/edit.html` Fragment Containing the Edit Singer Form

```
<section th:fragment=~{templates/layout :: pageContent}">
<div class="content"> <!-- content -->
  <h4 th:text="#{command.edit} + ' ' + #{singer.title}">EDIT</h4>

  <div class="container col-lg-12">
    <form name="update_info" th:action="@{/singer/} + ${singer.id}" th:object="${singer}"
      th:method="put" class="col p-3">
      <input type="hidden" th:field="*{id}" />

      <div class="row mb-1">
        <label for="firstName" th:text="#{label.Singer.firstName} + ':'" class="col-sm-4
          form-label">FN:</label>
        <div class="col-sm-8">
          <input type="text" th:field="*{firstName}" class="form-control"/>
          <span th:if="${#fields.hasErrors('firstName')}" class="error" th:errors="*{firstNa
            me}">MISSING FN</span>
        </div>
      </div>

      <div class="row mb-1">
        <label for="lastName" th:text="#{label.Singer.lastName} + ':'" class=
          "col-sm-4 form-label">LN:</label>
        <div class="col-sm-8">
          <input type="text" th:field="*{lastName}" class="form-control"/>
          <span th:if="${#fields.hasErrors('lastName')}" class="error"
            th:errors="*{lastName}">MISSING LN</span>
        </div>
      </div>

      <div class="row mb-1">
        <label for="birthDate" th:text="#{label.Singer.birthDate} + ':'" class=
          "col-sm-4 form-label">BD:</label>
        <div class="col-sm-8">
          <input type="date" th:field="*{birthDate}" class="form-control datetimepicker-
            input" data-target="#datetimepicker1"/>
          <span th:if="${#fields.hasErrors('birthDate')}" class="error" th:errors="*{birth
            Date}">MISSING BD</span>
        </div>
      </div>

      <div class="form-group mb-1 align-items-end">
        <input type="submit" th:value="#{command.save}" id="saveButton" class="btn btn-
          primary"/>
      </div>
    </form>
  </div>
</div>
```

```

    </div>
</form>
<p th:if="{message ne null}" th:text="{message}" class="error"></p>
<div class="form-group mb-1 align-items-end">
  <a href="#" th:href="@{/singer/} + {singer.id}" th:text="#{command.cancel}">
    CANCEL</a>
</div>
</div>
</div> <!-- content -->
</section>

```

The highlights in the `edit.html` template are as follows:

- `th:object="{singer}"`: This construct is the model object; its properties are used to populate the fields.
- `th:field="*{propName}"`: This construct is used to mark a form field for user input, but also to populate it with properties of the `singer` object.
- `th:if="{#fields.hasErrors('labelName')}"`: This construct is used to check if the data has any error, if yes the element containing this construct as attribute is displayed. The element is populated with an error message. The error message is displayed after the form was submitted, Spring performed the validation, the errors were added to the model, and the response sent back to the edit view with data and errors.
- `th:if="{message ne null}"`: This construct tests if the message object is not null and displays the element containing it as an attribute. It is used in this case to add an additional message telling the user why the `singer` was not saved.

As mentioned in the previous section, DELETE and PUT methods are supported by Thymeleaf and Spring. Notice that the edit form has the attribute `th:method="put"`, but if you look in the generated HTML, the form method is POST, but a hidden input was added to the form by Thymeleaf with the name of `_method` and the value of `put`. This input configures the actual desired request method and Spring treats these POST requests as PUT requests thanks to the `HiddenHttpMethodFilter` filter already mentioned in the “Handling a Delete Request” section.

Now that we have the view, let’s see what the Spring code to display it and process the submitted data looks like. The code for the two handler methods is shown in Listing 14-24.

**Listing 14-24.** The Handler Methods for Showing the Edit View and Processing a PUT Request

```

package com.apress.prospring6.fourteen.controllers;

import org.springframework.web.bind.annotation.PutMapping;
// other import statements omitted

@Controller
@RequestMapping("/singer/{id}")
public class OneSingerController {

    @RequestMapping(path = "/edit", method = RequestMethod.GET)
    @GetMapping(path = "/edit")
    public String showEditForm(@PathVariable("id") Long id, Model uiModel) {
        Singer singer = singerService.findById(id);
    }
}

```

```

        uiModel.addAttribute("singer", singer);
        return "singers/edit";
    }

    @PutMapping
    public String updateSingerInfo(@Valid Singer singer, BindingResult bindingResult,
        Model uiModel, Locale locale) {
        if (bindingResult.hasErrors()) {
            uiModel.addAttribute("message", messageSource.getMessage("singer.save.fail",
                new Object[] {}, locale));
            uiModel.addAttribute("singer", singer);
            return "singers/edit";
        } else {
            uiModel.asMap().clear();

            var fromDb = singerService.findById(singer.getId());

            fromDb.setFirstName(singer.getFirstName());
            fromDb.setLastName(singer.getLastName());
            fromDb.setBirthDate(singer.getBirthDate());

            singerService.save(fromDb);
            return "redirect:/singer/" + singer.getId();
        }
    }
}
// other handler methods omitted
}

```

Ignore the `@Valid` annotation and all the code related to error handling—that has its own section later in this chapter. One thing to notice in this code section is the introduction of the `redirect:` keyword. Prefixing a logical view name with “`redirect:`” tells Spring to use the logical view name as a redirect URL. In case of a successful edit operation, the redirection is to the page showing the singer details; in case of validation errors, the user is returned to the edit page and the errors are shown.

The edit form should look like the one depicted in Figure 14-11; otherwise something went wrong when deploying the project.

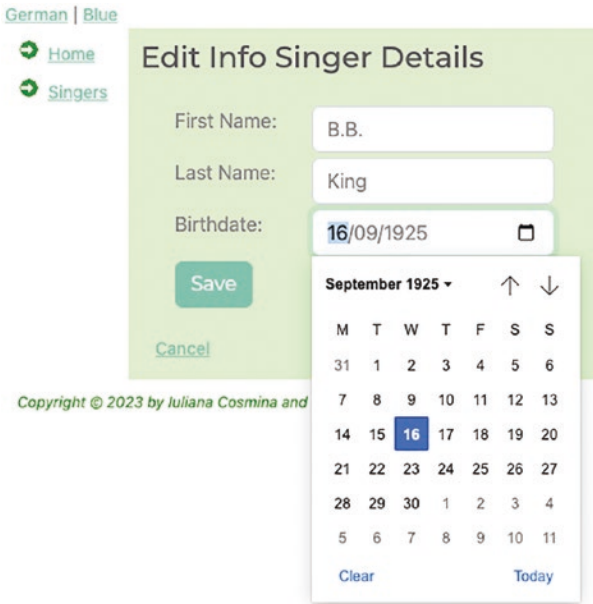


Figure 14-11. The edit view

## Implementing the Create Singer View

Implementing the create singer view is much like implementing the edit view. To make things interesting, the create.html file contains a form that also includes a file chooser to upload a photo of the singer. Aside from that, the form is pretty much identical to the one in edit.html. The pageContent fragment containing the form for creating a singer is shown in Listing 14-25.

Listing 14-25. The singers/create.html Form

```
<section th:fragment=~{templates/layout :: pageContent}">
<div class="content"> <!-- content -->
  <h4 th:text="#{command.create} + ' ' + #{singer.new}">CREATE</h4>
  <div class="container col-lg-12">
    <form name="create_singer" th:action="@{/singers}" th:object="{singerForm}"
      th:method="post" class="col p-3" enctype="multipart/form-data">
      <div class="row mb-1">
        <label for="firstName" th:text="#{label.Singer.firstname} + ':'" class="col-sm-4
          form-label">FN:</label>
        <div class="col-sm-8">
          <input type="text" th:field="{firstName}" class="form-control"/>
          <span th:if="{#fields.hasErrors('firstName')}" class="error" th:errors="{first
            Name}">MISSING FN</span>
        </div>
      </div>
    </div>
  </div>
</div>
```

```

<div class="row mb-1">
  <label for="lastName" th:text="#{label.Singer.lastname} + ':'" class="col-sm-4 form-label">LN:</label>
  <div class="col-sm-8">
    <input type="text" th:field="*{lastName}" class="form-control"/>
    <span th:if="{#fields.hasErrors('lastName')}}" class="error" th:errors="*{lastName}">MISSING LN</span>
  </div>
</div>

<div class="row mb-1">
  <label for="birthDate" th:text="#{label.Singer.birthDate} + ':'" class="col-sm-4 form-label">BD:</label>
  <div class="col-sm-8">
    <input type="date" th:field="*{birthDate}" class="form-control datetimepicker-input" data-target="#datetimepicker1"/>
    <span th:if="{#fields.hasErrors('birthDate')}}" class="error" th:errors="*{birthDate}">MISSING BD</span>
  </div>
</div>
<div class="row mb-1">
  <label for="file" th:text="#{label.Singer.photo} + ':'" class="col-sm-4 form-label">PH:</label>
  <div class="col-sm-8">
    <input type="file" th:field="*{file}" name="file" id="file" class="form-control"/>
  </div>
</div>

<div class="form-group mb-1 align-items-end">
  <input type="submit" th:value="#{command.save}" id="saveButton" class="btn btn-primary"/>
</div>
</form>
<p th:if="{message ne null}" th:text="{message}" class="error"></p>
<div class="form-group mb-1 align-items-end">
  <a href="#" th:href="@{/singers}" th:text="{command.cancel}"> CANCEL</a>
</div>
</div>
</div> <!-- content -->
</section>

```

Having a file chooser in the form means that an input field of type file is part of the form, which in turn means that the type of the form must be declared to be `enctype="multipart/form-data"`. This is a special type used for forms that allows inclusion of entire files in the submitted data. The singer information has a field of `LONGBLOB` type to store a photo, which can be uploaded from the client. This where the data from the creation form should end up. But, user data that includes files needs special handling on the server side.

For a long time, the standard servlet specification didn't support file upload. As a result, Spring MVC worked with other libraries (the most common one being the Apache Commons FileUpload library<sup>17</sup>) to serve this purpose. Spring MVC has built-in support for Commons FileUpload. However, starting from Servlet 3.0, file upload has become a built-in feature of the web container. Apache Tomcat 7 supports Servlet 3.0, and Spring has also supported Servlet 3.0 file upload since version 3.1.

Supporting file upload is thus an easy feat to do in Spring web applications, especially when deploying applications to Apache Tomcat 10.

Let's start with the code for processing the submission data. Since creating a new singer is not an operation on an existing singer, the handler method is in `SingersController`. The code is shown in Listing 14-26.

**Listing 14-26.** The Handler Method for Processing Data Submitted by a Form for Creating a Singer Instance

**package com.apress.prospring6.fourteen.controllers;**

**import org.springframework.web.bind.annotation.PostMapping;**

**import org.springframework.http.MediaType;**

**import com.apress.prospring6.fourteen.util.SingerForm;**

*// other import statements omitted*

@Controller

@RequestMapping("/singers")

**public class** SingersController {

    @GetMapping(value = "/create")

**public** String showCreateForm( Model uiModel) {  
        uiModel.addAttribute("singerForm", **new** SingerForm());  
        **return** "singers/create";  
    }

**@PostMapping(consumes = MediaType.MULTIPART\_FORM\_DATA\_VALUE)**

**public** String create(@Valid SingerForm singerForm, BindingResult bindingResult,  
        Model uiModel,

        HttpServletRequest httpRequest,  
        Locale locale) **throws** IOException {

**if** (bindingResult.hasErrors()) {  
            uiModel.addAttribute("message", messageSource.getMessage("singer.save.fail", **new**  
                Object[] {}, locale));  
            uiModel.addAttribute("singerForm", singerForm);  
            **return** "singers/create";  
        }

        uiModel.asMap().clear();

**var** singer = **new** Singer();  
        singer.setFirstName(singerForm.getFirstName());  
        singer.setLastName(singerForm.getLastName());  
        singer.setBirthDate(singerForm.getBirthDate());

<sup>17</sup><https://commons.apache.org/proper/commons-fileupload/>

```

// Process file upload
if (!singerForm.getFile().isEmpty()) {
    setPhoto(singer, singerForm.getFile());
}

var created = singerService.save(singer);
return "redirect:/singer/" + UrlUtil.encodeUrlPathSegment(created.getId()).
toString(),
    httpRequest);
}

static void setPhoto(Singer singer, MultipartFile file) throws IOException {
    InputStream inputStream = file.getInputStream();
    var fileContent = IOUtils.toByteArray(inputStream);
    singer.setPhoto(fileContent);
}

// other handler methods omitted
}

```

The contents on the form do not map appropriately to a `Singer` instance, because the photo field value is not mapped in the handler method to an `org.springframework.web.multipart.MultipartFile`, and thus the `SingerForm` type is needed.



In complex applications, the entity types declared in the DAO layer are never used in controllers, in the web layer. Usually view types are introduced that wrap around one or more entity types and expose only useful fields, hiding some details such as sensitive data like identifiers and passwords, and fields that are not relevant to the web context, such as the version field.

`SingerForm` is a view type that declares only the fields necessary for creating a `Singer` instance for the web level. The fields of this type are also decorated with validation annotations that match the ones declared on the `Singer` class for the corresponding fields.

The `SingerForm` is shown in Listing 14-27.

**Listing 14-27.** The `SingerForm` View Type

```

package com.apress.prospring6.fourteen.util;

import jakarta.validation.constraints.NotNull;
import jakarta.validation.constraints.Size;
import org.springframework.format.annotation.DateTimeFormat;
import org.springframework.web.multipart.MultipartFile;

import java.time.LocalDate;

public class SingerForm {

```

```

@NotNull
@Size(min = 2, max = 30)
private String firstName;

@NotNull
@Size(min = 2, max = 30)
private String lastName;

@DateTimeFormat(pattern = "yyyy-MM-dd")
private LocalDate birthDate;

MultipartFile file;

// getters and setters omitted
}

```

Spring MVC is smart enough to take the uploaded content, convert it to a `MultipartFile`, and use it as a value for the `file` field in `SingerForm`. From the `SingerForm` populated by Spring MVC, a `Singer` instance is created. The `setPhoto(..)` method is used to read the uploaded content as a byte array that then can be saved into the `LONGBLOG photo` column in the `SINGER` table.

But is this enough? Turns out that this is not enough, because the `Spring DispatcherServlet` needs to be configured to support file uploads. In a Servlet 3.0+–compatible web container with Spring MVC, configuring file upload support is a two-step process.

First, in the Java-based configuration class that defines everything needed to create the `DispatcherServlet` definition, we need to add a bean of type `StandardServletMultipartResolver`. This is a standard implementation of the `MultipartResolver` interface, based on the Servlet 3.0 Jakarta. `Servlet.http.Part` API. Listing 14-28 depicts the declaration of this bean that needs to be added to the `WebConfig` class.

**Listing 14-28.** The Spring Bean Necessary to Support File Uploading

```

package com.apress.prospring6.fourteen;

import org.springframework.web.multipart.support.StandardServletMultipartResolver;
// other import statements omitted

@Configuration
@EnableWebMvc
@ComponentScan(basePackages = {"com.apress.prospring6.fourteen"})
public class WebConfig implements WebMvcConfigurer, ApplicationContextAware {

    @Bean(name = DispatcherServlet.MULTIPART_RESOLVER_BEAN_NAME) // "multipartResolver"
    StandardServletMultipartResolver multipartResolver() {
        StandardServletMultipartResolver multipartResolver = new
            StandardServletMultipartResolver();
        return multipartResolver;
    }
// other configuration code omitted
}

```



The second step is to enable MultiParsing in Servlet 3.0+ environments; this means that the `WebInitializer` implementation needs some changes. There is a method called `customizeRegistration(..)` that is defined in the `AbstractDispatcherServletInitializer` abstract class, which is the class extended by `AbstractAnnotationConfigDispatcherServletInitializer`. This method must be implemented to register an instance of `jakarta.servlet.MultipartConfigElement`. The configuration snippet that needs to be added in the `WebInitializer` class is shown in Listing 14-29.

**Listing 14-29.** The Spring Configuration Necessary to Support File Uploading

```
package com.apress.prospring6.fourteen;

import jakarta.servlet.MultipartConfigElement;
import jakarta.servlet.ServletRegistration;
//other import statements omitted

public class WebInitializer extends AbstractAnnotationConfigDispatcherServletInitializer {

    // other configuration code omitted

    @Override
    protected Filter[] getServletFilters() {
        final CharacterEncodingFilter cef = new CharacterEncodingFilter();
        cef.setEncoding(StandardCharsets.UTF_8.name());
        cef.setForceEncoding(true);
        return new Filter[]{new HiddenHttpMethodFilter(), cef};
    }

    @Override
    public void customizeRegistration(ServletRegistration.Dynamic registration) {
        registration.setInitParameter("throwExceptionIfNoHandlerFound", "true");
        registration.setMultipartConfig(getMultipartConfigElement());
        super.customizeRegistration(registration);
    }

    private MultipartConfigElement getMultipartConfigElement() {
        return new MultipartConfigElement(null, MAX_FILE_SIZE, MAX_REQUEST_SIZE, FILE_SIZE_
            THRESHOLD);
    }

    private static final long MAX_FILE_SIZE = 5000000;
    // Beyond that size spring will throw exception.
    private static final long MAX_REQUEST_SIZE = 5000000;

    // Size threshold after which files will be written to disk
    private static final int FILE_SIZE_THRESHOLD = 0;
}
```

The first parameter of `MultipartConfigElement` is a temporary location where files should be stored. The second parameter is the maximum file size allowed for upload, which is 5MB in this case. The third parameter represents the size of the request, which is also 5MB here. The last parameter represents the threshold after which files will be written to disk.

To test the file upload function, redeploy the application and add a new singer with a photo. Upon completion, you will be able to see the photo in the show view.

## Enabling JSR-349 (Bean Validation)

This topic was reserved until now so that the focus could be on building the web pages and linking functionality to various buttons and links. Just as important as making sure user requests are processed correctly is making sure the data submitted by the user is correct. This is especially important for data being saved into the database, because invalid data can yield invalid results or, in some cases, even allow a hacker to break into your system (e.g., via SQL injection<sup>18</sup>).

**Chapter 11** introduced you to validation, formatting, and type conversion, and mentioned that the true power of Spring beans declared for these purposes is most obvious in web applications when handling user-provided data. **Chapter 11** introduced you to Spring's support of JSR-349 (Bean Validation)<sup>19</sup> (now part of Jakarta libraries). Listing 14-27 introduced class `SingerForm` that declares a few fields that are initialized with user-provided data. The same validation annotations are present in the `Singer` class, which is used to create `Singer` domain objects.

Listing 14-30 shows the `SingerForm` version with validation annotations with customized error message codes.

*Listing 14-30.* The `SingerForm` Type Necessary to Support File Uploading

```
package com.apress.prospring6.fourteen.util;
import jakarta.validation.constraints.*;
import org.springframework.web.multipart.MultipartFile;
// other import statements omitted

public class SingerForm {

    @NotEmpty
    @Size(min = 2, max = 30)
    private String firstName;

    @NotEmpty
    @Size(min = 2, max = 30)
    private String lastName;

    @DateTimeFormat(pattern = "yyyy-MM-dd")
    private LocalDate birthDate;
    private MultipartFile file;

    // getters and setters omitted
}
```

<sup>18</sup> [https://www.w3schools.com/sql/sql\\_injection.asp](https://www.w3schools.com/sql/sql_injection.asp)

<sup>19</sup> <https://beanvalidation.org/3.0>

The constraints are applied to their respective fields. Note that for the validation message, you specify a message key by using the curly braces. This will cause the validation messages to be retrieved from `ResourceBundle` and hence support i18n. The `@Size` annotation is special because it is declared with a minimum value and maximum value; these values are injected from the code into the internationalization messages using the `{*}` syntax.

The error message codes are resolved by an `org.springframework.validation.MessageCodesResolver` bean registered automatically by Spring when validation is configured. The default implementation used by Spring is `org.springframework.validation.DefaultMessageCodesResolver`. This type of bean creates two message codes based on the annotations used on fields to enforce constraints, based on the name of the type where used and based on field names. For example, for the `firstName` field in class `SingerForm`, annotated with `@Size` validation, this bean will create a group of message codes that are resolved in the following order:

- Validation name + object name + field name  $\Rightarrow$  `Size.singerForm.firstName`
- Validation name + field name  $\Rightarrow$  `Size.firstName`
- Validation name + field type  $\Rightarrow$  `Size.java.lang.String`
- Validation name  $\Rightarrow$  `Size`

However, if neither of these message properties is declared, the default message is set to annotation full name + "message"  $\Rightarrow$  `jakarta.validation.constraints.Size.message`. For the `singerForm` object, these messages are not declared in our initial internationalization files, but the ones for the `singer` object are. They are shown in Listing 14-31.

**Listing 14-31.** Message Codes for Validation Errors for Object `singer`, Field `firstName`

```
NotEmpty.singer.firstName=Please insert First Name Value
Size.singer.firstName=Length must be between {2} and {1}
NotEmpty.singer.lastName=Please insert Last Name Value
Size.singer.lastName=Length must be between {2} and {1}
typeMismatch.birthDate=Invalid format, should be \'yyyy-mm-dd\'
```

There are two solutions here: add a copy of messages in Listing 14-28 and replace `singer` with `singerForm` or configure the annotation validations to use the existing set of messages, using the `messages` attribute. The `SingerForm` version with customized error messages is depicted in Listing 14-32.

**Listing 14-32.** `SingerForm` Version with Customized Error Messages

```
package com.apress.prospring6.fourteen.util;
import jakarta.validation.constraints.*;
// other import statements omitted

public class SingerForm {

    @NotEmpty(message="{NotEmpty.singer.firstName}")
    @Size(min=2, max=30, message="{Size.singer.firstName}")
    private String firstName;

    @NotEmpty(message="{NotEmpty.singer.lastName}")
    @Size(min=2, max=30, message="{Size.singer.lastName}")
    private String lastName;
```

```

    @DateFormat(pattern = "yyyy-MM-dd")
    private LocalDate birthDate;
    private MultipartFile file;

    // getters and setters omitted
}

```

To enable JSR-349/Jakarta Bean Validation during the web data binding process, we just need to apply the `@Valid` annotation to the `SingerForm` argument of the `SingersController.create(..)` method and to the `Singer` argument of the `OneSingerController.updateSingerInfo(..)` method. Listing 14-33 shows the signatures for both methods.

**Listing 14-33.** `OneSingerController` handler methods with validated parameters

```

package com.apress.prospring6.fourteen.controllers;

import jakarta.validation.Valid;
// other import statements omitted

@Controller
@RequestMapping("/singer/{id}")
public class OneSingerController {

    @PutMapping
    public String updateSingerInfo(@Valid Singer singer,
                                   BindingResult bindingResult,
                                   Model uiModel, Locale locale) {
        // method body omitted
    }

    // other methods omitted
}

@Controller
@RequestMapping("/singers")
public class SingersController {

    @PostMapping(consumes = MediaType.MULTIPART_FORM_DATA_VALUE)
    public String create(@Valid SingerForm singerForm,
                        BindingResult bindingResult, Model uiModel,
                        HttpServletRequest httpRequest,
                        Locale locale) throws IOException {
        // method body omitted
    }

    // other methods omitted
}

```

We also want the JSR-349 validation message to use the same `ResourceBundle` instance as for the views. To do this, we need to configure the validator in the `DispatcherServlet` configuration, in the `WebConfig` class, as shown in Listing 14-34.

**Listing 14-34.** Spring Validation Configuration

```

package com.apress.prospring6.fourteen;

import org.springframework.validation.Validator;
import org.springframework.validation.beanvalidation.LocalValidatorFactoryBean;
// other import statements omitted

@Configuration
@EnableWebMvc
@ComponentScan(basePackages = {"com.apress.prospring6.fourteen"})
public class WebConfig implements WebMvcConfigurer, ApplicationContextAware {

    @Bean
    public Validator validator() {
        final var validator = new LocalValidatorFactoryBean();
        validator.setValidationMessageSource(messageSource());
        return validator;
    }

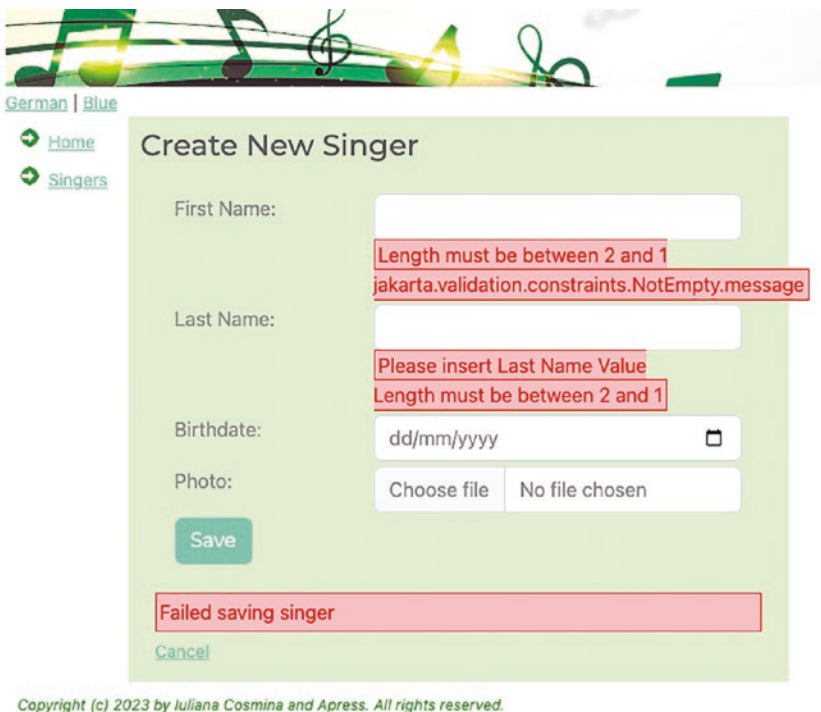
    @Bean
    MessageSource messageSource() {
        var messageResource = new ReloadableResourceBundleMessageSource();
        messageResource.setBasename("classpath:i18n/global");
        messageResource.setDefaultEncoding(StandardCharsets.UTF_8.name());
        messageResource.setUseCodeAsDefaultMessage(true);
        messageResource.setFallbackToSystemLocale(true);
        //messageResource.setCacheSeconds(0);
        return messageResource;
    }

    @Override
    public Validator getValidator() {
        return validator();
    }

    // other configuration code omitted
}

```

First, a validator bean is defined, with the class `LocalValidatorFactoryBean`, for JSR-349 support. Note that we set the `validationMessageSource` property to reference the `MessageSource` bean defined, which instructs the JSR-349 validator to look up the messages by the code from the `MessageSource` bean. Then the `getValidator()` method is implemented to return the validator bean we defined. That's all; we can test the validation now. Bring up the create singer view and click the Save button without inserting any data. The returned page will now show multiple validation errors, as shown in Figure 14-12.



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**Figure 14-12.** View page with validation errors

Switch to the German (DE) language and do the same thing. This time, the messages will be displayed in German. The views are basically complete; all we need now is to handle potential errors.

## Exception Handling

When handler methods are executed, things can go wrong. Some situations, like trying to access a URL that does not exist, might be expected, but others might not. In both scenarios, the activity has to be recorded and the end user has to be notified. Spring MVC catches and handles the exceptions using implementations of `HandlerExceptionResolver`. The typical way to treat an MVC exception is to prepare a model and select an error view. Multiple exception resolvers can be used and ordered in a chain to treat different type of exceptions in different ways. Spring MVC supports the default resolvers shown in Listing 14-35 (resolvers of these types are created automatically for you in a Spring web application), and they are declared in the `DispatcherServlet.properties` file that is packaged in the `spring-webmvc.jar`.

**Listing 14-35.** `DispatcherServlet.properties` Default Exception Resolvers

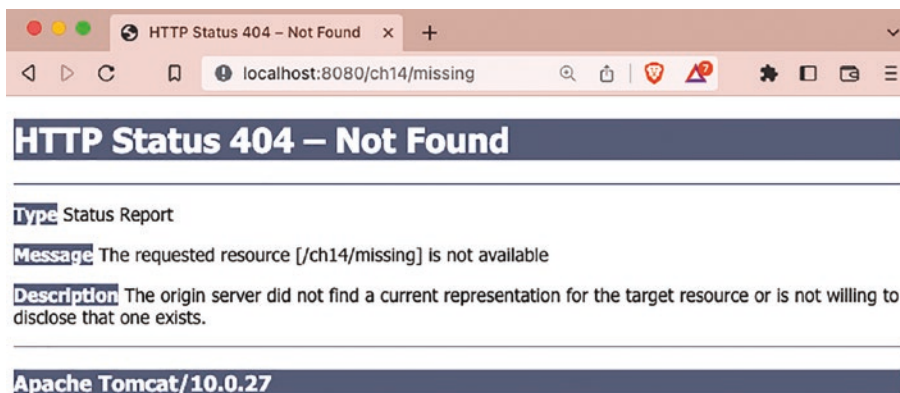
```
org.springframework.web.servlet.HandlerExceptionResolver=
    o.s.web.servlet.mvc.method.annotation.ExceptionHandlerExceptionResolver,\
    o.s.web.servlet.mvc.annotation.ResponseStatusExceptionHandler,\
    o.s.web.servlet.mvc.support.DefaultHandlerExceptionResolver
```

The default exception resolvers perform the following functions:

- `ExceptionHandlerExceptionResolver`: Resolves exceptions by invoking methods annotated with `@ExceptionHandler` found within a controller or a class annotated with `@ControllerAdvice`.
- `ResponseStatusExceptionResolver`: Resolves methods annotated with `@ResponseStatus` and maps them to the status code configured using this annotation.
- `DefaultHandlerExceptionResolver`: Resolves exceptions raised by Spring MVC and maps them to HTTP status codes. The equivalent of this class when REST requests are processed is class `ResponseEntityExceptionHandler`.

The `SimpleMappingExceptionResolver` class is not in the previous list, but beans of this type can be declared and configured to map exception classes to view names, and it is helpful to render error pages in a browser application. An exception resolver provides information related to the context in which the exception was thrown; that is, the handler method that was executing and the arguments that it was called with.

Let's start with the simplest example: people make mistakes when writing URLs all the time. Let's try to access the following URL: `http://localhost:8080/ch14/missing`. Since no exception handling is configured, Spring will try to find a view using the `InternalResourceViewResolver` bean (or whatever other view resolver is found). Since it cannot find one, it assumes it must be a static page and tries to render that. But it fails to provide a proper page, and Apache Tomcat comes to the rescue. It displays its default error page, letting the user know what happened, as shown in Figure 14-13.



**Figure 14-13.** Apache Tomcat default error page for missing view

The default error message does a good job describing the problem, and it returns the proper HTTP status code for missing resources: 404. But still, it's not okay, because this looks like a technical exception or a development problem, and the recommended practice is to not let the end user know that. Also, there is no need to give so many details to the end user, because they should not be bothered with the internal problems an application has. So, what can be done? One rule of developing web applications is to keep the look and feel consistent, so instead of the Apache Tomcat page, we could display a customized error view. Out of the box, Spring MVC offers no default (fallback) error page when a view or a handler method is not found. It doesn't throw an exception either; it just forwards the responsibility of showing the appropriate message to the server. To override this behavior, we need to make the following changes to a Spring web application configuration.

First, customize `DispatcherServlet` to throw `org.springframework.web.servlet.NoHandlerFoundException` when a handler method cannot be found. This is done by overriding the `customizeRegistration(..)` method from the `AbstractDispatcherServletInitializer` class in the `WebInitializer` class, as shown in Listing 14-36.

**Listing 14-36.** Customizing `DispatcherServlet` to Throw `NoHandlerFoundException` When Handlers Are Not Found

```
package com.apress.prospring6.fourteen;

import jakarta.servlet.ServletRegistration;
// other import methods omitted

public class WebInitializer
    extends AbstractAnnotationConfigDispatcherServletInitializer {

    @Override
    public void customizeRegistration(ServletRegistration.Dynamic registration) {
        registration.setInitParameter("throwExceptionIfNoHandlerFound", "true");
        super.customizeRegistration(registration);
    }

    // other config methods omitted
}
```

This configuration declares an initialization parameter named `throwExceptionIfNoHandlerFound` and sets it to “true”, which causes `DispatcherServlet` to throw an `org.springframework.web.servlet.NoHandlerFoundException` when a handler method cannot be found.



Note that adding this configuration does nothing if `DefaultServletHttpRequestHandler` is used, because requests will always be forwarded to it and a `NoHandlerFoundException` will never be thrown in that case. You can verify this by looking into the logs. If you see something similar to the next output snippet, you still have more steps to go.

---

```
DEBUG o.s.w.s.DispatcherServlet - GET "/ch14/missing", parameters={}
DEBUG o.s.w.s.h.SimpleUrlHandlerMapping - Mapped to org.springframework.web.
servlet.resource.DefaultServletHttpRequestHandler@763956dc
DEBUG o.s.w.s.DispatcherServlet - Completed 404 NOT_FOUND
```

So, if in your configuration you have the following:

```
@Override
public void configureDefaultServletHandling(final DefaultServletHandlerConfigurer
configurer) {
    configurer.enable();
}
```



Just remove this method and make do without `DefaultServletHttpRequestHandler` if you want `NoHandlerFoundExceptions` to be thrown.

But this does nothing without a bean of type `HandlerExceptionResolver` customized to do something else than simply tell the application server what to do. And this brings us to the next change. Next, an option is to implement the `HandlerExceptionResolver` interface or extend any of the classes that implement it and provide the desired implementation for the `doResolveException(...)` method that will return the desired view, as shown in Listing 14-37.

*Listing 14-37.* `HandlerExceptionResolver` Implementation

```
package com.apress.cems.web.problem;
import org.springframework.http.HttpStatus;
import org.springframework.web.servlet.ModelAndView;
import org.springframework.web.servlet.NoHandlerFoundException;
import org.springframework.web.servlet.handler.SimpleMappingExceptionResolver;
import javax.servlet.http.HttpServletRequest;
import javax.servlet.http.HttpServletResponse;

public class MissingExceptionResolver extends SimpleMappingExceptionResolver {
    @Override
    protected ModelAndView doResolveException(HttpServletRequest request,
        HttpServletResponse response, Object handler, Exception ex) {
        if (ex instanceof NoHandlerFoundException) {
            ModelAndView model = new ModelAndView("error");
            model.addObject("problem", "URL not supported : "
                + request.getRequestURI());
            response.setStatus(HttpStatus.NOT_FOUND.value());
            return model;
        }
        return null;
    }
}
```



Notice that for error handling the type `ModelAndView` is used. Since the exception handling method is not a normal handler method declared in a controller class, mapping its result to a view template is not possible. An object of this type is a holder for both `Model` and `View` objects in the web MVC framework, needed to return both a model and a view in a single object. This allows Spring MVC to customize the error view before being sent to the user with different error messages based on the exception thrown when a request is handled.

---

Here are a few details about a `HandlerExceptionResolver` implementation:

- It can return a `ModelAndView` that points to an error view, usually the same one for a related class of problems, or for the entire application.
- It can return an empty `ModelAndView` if the exception is handled within the resolver.
- It can return `null` if the exception remains unresolved, thus allowing other exception resolvers to try to handle it. If none of the exception resolvers can handle the exception, it is bubbled up to the `Servlet` container.



In Listing 14-37, note that the method returns an actual ModelAndView instance.

HandlerExceptionResolve implementations are designed to make sure an exception is resolved to a view or allowed to bubble up to the Servlet container.

The next step is to declare a bean of this type with the lowest priority (highest precedence), so that every time something goes wrong within the application, this exception resolver will be used first.

The alternative to having multiple SimpleMappingExceptionHandler mapped to various types of exceptions is to declare different error handler methods and group all of them in a class annotated with @ControllerAdvice. This annotation is meta-annotated with @Component and this means a bean of this type will be created. This bean intercepts any exceptions thrown by handler methods and maps them to methods annotated with @ExceptionHandler that have some logic to process these exceptions and render the corresponding error views. Listing 14-38 shows a class annotated with @ControllerAdvice.

*Listing 14-38.* Class containing multiple exception handler methods

```
package com.apress.prospring6.fourteen.problem;

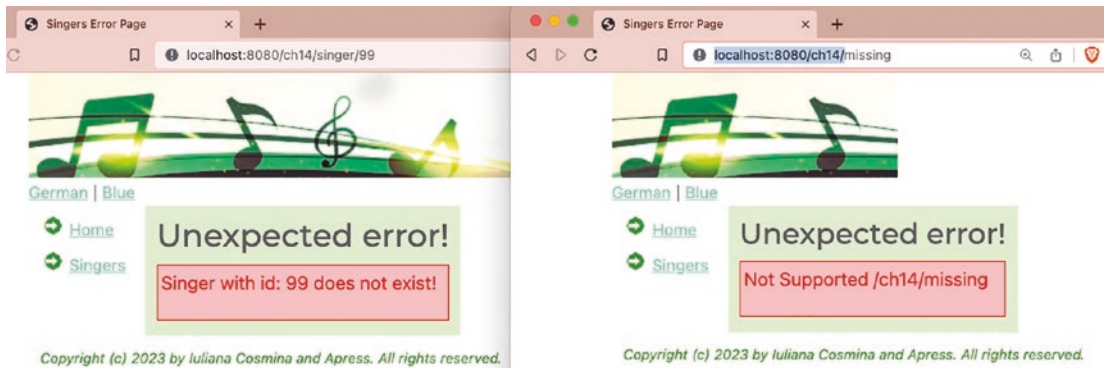
import jakarta.servlet.http.HttpServletRequest;
import org.springframework.http.HttpStatus;
import org.springframework.web.bind.annotation.ControllerAdvice;
import org.springframework.web.bind.annotation.ExceptionHandler;
import org.springframework.web.bind.annotation.ResponseStatus;
import org.springframework.web.servlet.ModelAndView;
import org.springframework.web.servlet.NoHandlerFoundException;

@ControllerAdvice
public class GlobalExceptionHandler {

    @ExceptionHandler(NotFoundException.class)
    @ResponseStatus(HttpStatus.NOT_FOUND)
    public ModelAndView handle(NotFoundException ex) {
        ModelAndView mav = new ModelAndView();
        mav.addObject("problem", ex.getMessage());
        mav.setViewName("error");
        return mav;
    }

    @ExceptionHandler(NoHandlerFoundException.class)
    @ResponseStatus(HttpStatus.NOT_FOUND)
    public ModelAndView notFound(HttpServletRequest req) {
        ModelAndView mav = new ModelAndView();
        mav.addObject("problem", "Not Supported " + req.getRequestURI());
        mav.setViewName("error");
        return mav;
    }
}
```

To test that this exception handler works as expected, you could try accessing `http://localhost:8080/ch14/singer/99` and `http://localhost:8080/ch14/missing`. Notice that there are different types of exceptions being thrown, which causes different error messages to be added to the error view model, as shown in Figure 14-14.



**Figure 14-14.** Different error pages being shown for different errors

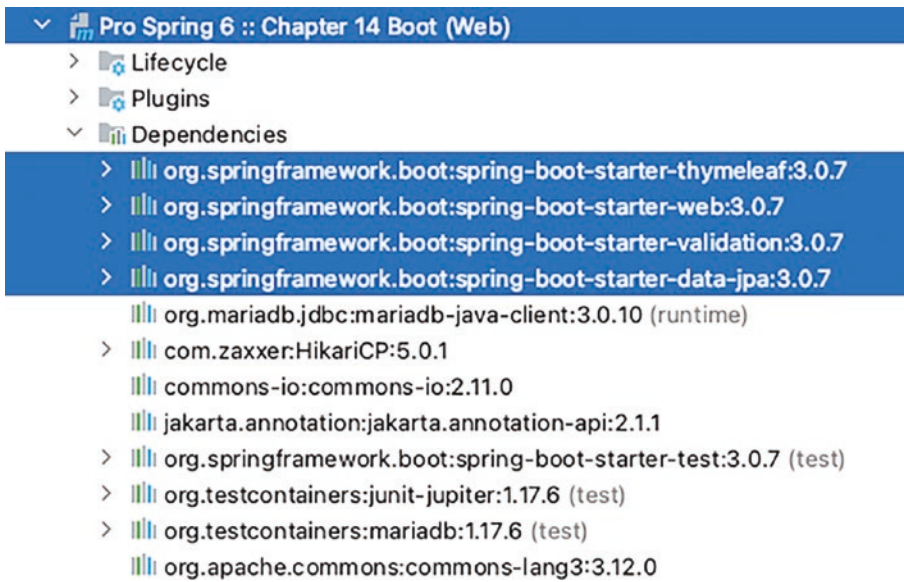
You should view the error page with the proper exception message. Inspect the response contents and you will notice that although an error page is displayed, the HTTP status code is still 200. Since the user is trying to access a resource that does not exist, the HTTP status code should be 404. This can be done easily by annotating the exception handler method with `@ResponseStatus(HttpStatus.NOT_FOUND)`, which was done in Listing 14-38.

And that's pretty much it when it comes to handling exceptions thrown by the handler methods.

## Switching to Spring Boot

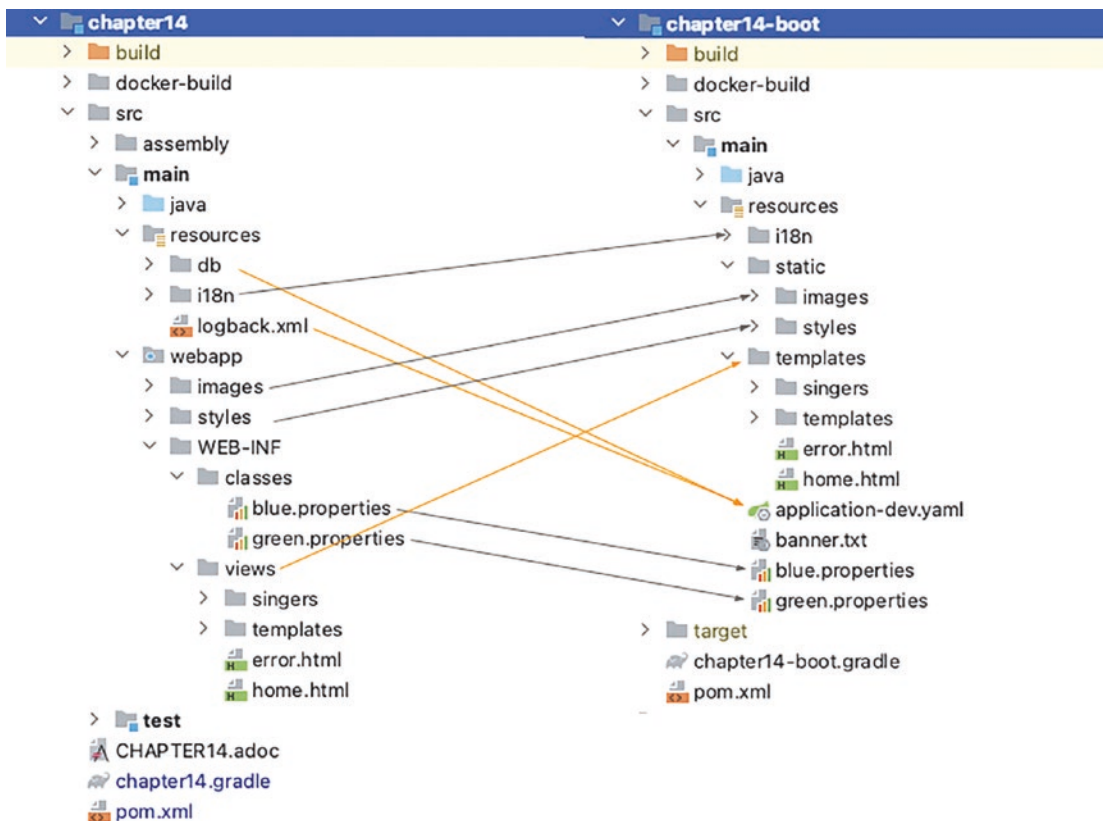
Switching to Spring Boot makes things simpler, because a Spring Boot application does not need an Apache Tomcat server. Also, the structure of the project is simpler and there is no need for special plug-ins to pack the application.

To create a full-blown Spring web application means that, besides the web layer and the view templating layer, you need a DAO layer and a service layer in place. This means you need the specific Boot starter library for persistence and transactions. If you've read this chapter up to now, you know that you also need validation. The complete list of dependencies is shown in Figure 14-15.



**Figure 14-15.** Spring Boot web application dependencies

The structure of the project must change as well, since all interface-related files and resource files can be placed under the resources directory. The internal structure of the project changes as shown in Figure 14-16.



**Figure 14-16.** Spring classic and Spring Boot web application structures comparison

The orange arrows show the files that changed not only name but location as well. For example, the data source configuration files are no longer necessary, since their content is configured by using Spring Boot configuration properties. The `logback.xml` file is also no longer needed, because Logback configuration is done by using Spring Boot properties. And the `views` directory, containing the Thymeleaf templates, is renamed to `templates`, so instead of configuring Thymeleaf support using explicit bean configuration, Spring Boot out-of-the-box configurations can be used.

The `blue.properties` and `green.properties` files for theming configuration were moved from the `classes` directory to the root of the `static` directory to benefit of the default Spring Boot theming beans configuration, because customizing them is a pain.

The next thing to analyze is the Spring Boot `application-dev.yaml` contents, shown in Listing 14-39.

**Listing 14-39.** Spring Boot Web Application Configuration

*# web server configuration*

```
server:
  port: 8081
  servlet:
    context-path: /
  compression:
    enabled: true
  address: 0.0.0.0
```

```

# application configuration
spring:
  mvc:
    hiddenmethod:
      filter: # HTTP Method filter
      enabled: true
# internationalization configuration
messages:
  basename: i18n/global
  encoding: UTF-8
  always-use-message-format: true
# file upload configuration
servlet:
  multipart:
    enabled: true
    max-file-size: 10MB
    max-request-size: 12MB
# view resolver configuration
thymeleaf:
  prefix: classpath:templates/
  suffix: .html
  mode: HTML
  cache: false
  check-template: false
  reactive:
    max-chunk-size: 8192
# data source configuration
datasource:
  driverClassName: org.mariadb.jdbc.Driver
  url: jdbc:mariadb://localhost:3306/musicdb?useSSL=false
  username: prospring6
  password: prospring6
  hikari:
    maximum-pool-size: 25
jpa:
  generate-ddl: false
  properties:
    hibernate:
      jdbc:
        batch_size: 10
        fetch_size: 30
      max_fetch_depth: 3
      show-sql: true
      format-sql: false
      use_sql_comments: false
      hbm2ddl:
        auto: none

# Logging config
logging:
  pattern:

```

```

console: "%-5level: %class{0} - %msg%n"
level:
root: INFO
org.springframework.boot: DEBUG
com.apress.prospring6.fourteen: INFO

```

Each section of the configuration is prefixed by a comment revealing its scope. The following list further explains properties used in each section:

- # web server configuration: This section configures the URL where the application is available. Setting the address to 0.0.0.0 allows the application to be accessible on all network addresses associated with the computer the application runs in; for example, `http://localhost:8081/`, `http://127.0.0.1:8081/`, etc.
- # HTTP Method filter: The `spring.mvc.hiddenmethod.filter.enabled` set to `true` is the Spring Boot equivalent of configuring the filter for supporting PUT and DELETE HTTP methods.
- # internationalization configuration: This section configures the location, name, encoding, and so forth of the internationalization files.
- # file upload configuration: This section configures all components necessary to support file upload.
- # view resolver configuration: This section configures location, encoding, max size, and so forth for the Thymeleaf view templates. Spring Boot uses this configuration to configure a Thymeleaf Engine and Thymeleaf resolver bean.
- # data source configuration: This section groups all data source configurations, including persistence.
- # Logging config: This section configures logging.

The parts of the configuration that cannot be put in `application-dev.yaml` are placed into typical configuration classes, annotated with `@Configuration`.



The `HibernateCfg` class is a workaround for a bug Spring Data JPA with MariaDB related to database objects naming. Without this class the repositories cannot be mapped to tables because Spring Boot looks for a table named `musicdb.singer` but doesn't find it, since the MariaDB Docker container was configured by declaring objects using uppercase letters (e.g.: `MUSICDB.SINGER`). Since lowercasing the Docker SQL queries was a bit too much work, there was an opportunity to introduce an advanced configuration example. The `HibernateCfg` class is shown in Listing 14-40.

---

*Listing 14-40.* `HibernateCfg` Class

```

package com.apress.prospring6.fourteen.boot;

import org.hibernate.boot.model.naming.Identifier;
import org.hibernate.boot.model.naming.PhysicalNamingStrategyStandardImpl;
import org.hibernate.engine.jdbc.env.spi.JdbcEnvironment;

```

```

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;

@Configuration(proxyBeanMethods = false)
public class HibernateCfg {

    @Bean
    PhysicalNamingStrategyStandardImpl caseSensitivePhysicalNamingStrategy() {
        return new PhysicalNamingStrategyStandardImpl() {
            @Override
            public Identifier toPhysicalTableName(Identifier logicalName, JdbcEnvironment
            context) {
                return apply(logicalName, context);
            }

            @Override
            public Identifier toPhysicalColumnName(Identifier logicalName, JdbcEnvironment
            context) {
                return apply(logicalName, context);
            }

            private Identifier apply(final Identifier name, final JdbcEnvironment context) {
                if ( name == null ) {
                    return null;
                }
                StringBuilder builder = new StringBuilder( name.getText().replace( '.',
                '_' ) );
                for ( int i = 1; i < builder.length() - 1; i++ ) {
                    if ( isUnderscoreRequired( builder.charAt( i - 1 ), builder.charAt( i ),
                    builder.charAt( i + 1 ) ) ) {
                        builder.insert( i++, '_' );
                    }
                }
                return Identifier.toIdentifier(builder.toString().toUpperCase());
            }

            private boolean isUnderscoreRequired(final char before, final char current,
            final char after) {
                return Character.isLowerCase( before ) && Character.isUpperCase( current )
                && Character.isLowerCase( after );
            }
        };
    }
}

```

The `PhysicalNamingStrategyStandardImpl` class, extended here by an anonymous class, is itself implementing `PhysicalNamingStrategy`, which is a pluggable strategy contract for applying physical naming rules for database object names. The `@Configuration(proxyBeanMethods = false)` configuration is used to exclude beans declared in this class from getting proxied to enforce bean life-cycle behavior. This means that any bean that is created by calling the `caseSensitivePhysicalNamingStrategy()` method will get a new copy of the `PhysicalNamingStrategyStandardImpl` bean.



The `WebConfig` class is a Spring web configuration class extending `WebMvcConfigurer` and is necessary to configure the locale and theme interceptors and resolvers. They are not automatically configured by Spring Boot, so this job is left to the developer. The `WebConfig` class is shown in Listing 14-41.

**Listing 14-41.** `WebConfig` Class

```

package com.apress.prospring6.fourteen.boot;
// import statements omitted

import java.util.Locale;

@Configuration
@ComponentScan(basePackages = {"com.apress.prospring6.fourteen.boot"})
public class WebConfig implements WebMvcConfigurer {
    @Bean
    LocaleChangeInterceptor localeChangeInterceptor() {
        var localeChangeInterceptor = new LocaleChangeInterceptor();
        localeChangeInterceptor.setParamName("lang");
        return localeChangeInterceptor;
    }

    @Bean
    ThemeChangeInterceptor themeChangeInterceptor() {
        var themeChangeInterceptor = new ThemeChangeInterceptor();
        themeChangeInterceptor.setParamName("theme");
        return themeChangeInterceptor;
    }

    @Bean
    CookieLocaleResolver localeResolver() {
        var cookieLocaleResolver = new CookieLocaleResolver();
        cookieLocaleResolver.setDefaultLocale(Locale.ENGLISH);
        cookieLocaleResolver.setCookieMaxAge(3600);
        cookieLocaleResolver.setCookieName("locale");
        return cookieLocaleResolver;
    }

    @Bean
    CookieThemeResolver themeResolver() {
        var cookieThemeResolver = new CookieThemeResolver();
        cookieThemeResolver.setDefaultThemeName("green");
        cookieThemeResolver.setCookieMaxAge(3600);
        cookieThemeResolver.setCookieName("theme");
        return cookieThemeResolver;
    }

    @Bean
    WebContentInterceptor webChangeInterceptor() {
        var webContentInterceptor = new WebContentInterceptor();
        webContentInterceptor.setCacheSeconds(0);
    }
}

```

```

        webContentInterceptor.setSupportedMethods("GET", "POST", "PUT", "DELETE");
        return webContentInterceptor;
    }

    @Override
    public void addInterceptors(InterceptorRegistry registry) {
        registry.addInterceptor(localeChangeInterceptor()).addPathPatterns("/*");
        registry.addInterceptor(themeChangeInterceptor());
        registry.addInterceptor(webChangeInterceptor());
    }
}

```



Notice that this class is not annotated with `@EnableWebMvc`. It is not needed because Spring Boot configures the web application context. Using this annotation in a Spring Boot application will cause unpredictable behavior, if the application starts at all.

---

What is left is to tell Spring Boot where our entities and repository interfaces are, and enable transactional support. These configurations are easily done via annotations placed on the Spring Boot main class, depicted in Listing 14-42.

*Listing 14-42.* Chapter14Application Class

```

package com.apress.prospring6.fourteen.boot;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.boot.autoconfigure.domain.EntityScan;
import org.springframework.core.env.AbstractEnvironment;
import org.springframework.data.jpa.repository.config.EnableJpaRepositories;
import org.springframework.transaction.annotation.EnableTransactionManagement;

import java.util.Arrays;
import java.util.stream.Collectors;

@EntityScan(basePackages = {"com.apress.prospring6.fourteen.boot.entities"})
@EnableJpaRepositories("com.apress.prospring6.fourteen.boot.repos")
@EnableTransactionManagement
@SpringBootApplication
public class Chapter14Application {

    public static void main(String... args) {
        System.setProperty(AbstractEnvironment.ACTIVE_PROFILES_PROPERTY_NAME, "dev");
        SpringApplication.run(Chapter14Application.class, args);
    }
}

```

The reason for declaring a profile named `dev` for running the application is so that the context can be slightly modified for running tests.

With the configuration described so far, running the `Chapter14Application` will start the same applications deployed on an Apache Tomcat server in previous sections.

## Testing a Spring Boot Web Application

As expected, testing with Spring Boot is easier too. As an example, we'll add two very simple tests for the `HomeController` with Spring Boot. Spring Boot tests are annotated with `@SpringBootTest`, which can be used to start a web application on a random port that can be then accessed to send requests using an instance of `TestRestTemplate`. The test class is shown in Listing 14-43.

*Listing 14-43.* `HomeController1Test` Class Using `TestRestTemplate`

```
package com.apress.prospring6.fourteen.boot;

import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.boot.test.web.client.TestRestTemplate;
import static org.assertj.core.api.Assertions.assertThat;
// other import statements

@ActiveProfiles("test")
@SpringBootTest(webEnvironment = SpringBootTest.WebEnvironment.RANDOM_PORT)
public class HomeController1Test {

    @Value(value="${local.server.port}")
    private int port;

    @Autowired
    private TestRestTemplate restTemplate;

    @Test
    public void testHomeController(){
        assertThat(this.restTemplate.getForObject("http://localhost:" + port + "/",
            String.class))
            .contains("Spring Boot Thymeleaf Example");
    }
}
```

`TestRestTemplate` is the non-reactive equivalent of the `WebTestClient` that is covered in **Chapter 20**, and it is convenient alternative of `RestTemplate` that is suitable for integration tests. It is designed specifically for testing, because failed requests with 4xx and 5xx do not throw an exception, this being very useful for writing negative test cases. Testing using `TestRestTemplate` consists of checking assumptions about the response returned by the application so the testing is data-oriented, since correct mapping of requests to handlers is not checked.

Another alternative to `TestRestTemplate` is `Rest Assured`<sup>20</sup>.

The same test can be written by using `MockMvc`, introduced earlier in this chapter, but previously the test was configured using `@SpringJUnitWebConfig`. When Spring Boot is in the mix, a different annotation is used: `@AutoConfigureMockMvc`. The test is shown in Listing 14-44.

<sup>20</sup> <https://rest-assured.io>

**Listing 14-44.** HomeController2Test Class Using MockMvc

```

package com.apress.prospring6.fourteen.boot;
import org.springframework.boot.test.autoconfigure.web.servlet.AutoConfigureMockMvc;
// other import statements

@ActiveProfiles("test")
@AutoConfigureMockMvc
@SpringBootTest
public class HomeController2Test {

    @Autowired
    MockMvc mockMvc;

    @Test
    void testHome() throws Exception {
        mockMvc.perform(MockMvcRequestBuilders.get("/home"))
            .andDo(print())
            .andExpect(status().isOk())
            .andExpect(view().name("home"))
            .andExpect(content().string(containsString("Spring Boot Thymeleaf
            Example!!")));
    }
}

```

Testing using MockMvc is a little more powerful because it allows checking of assumptions on the actual controller handler method configuration. In Listing 14-44, you can see that an assumption over the view name is tested too, which makes this approach more config-oriented.

## Summary

In this chapter, we covered many topics related to web development using Spring MVC. First, we discussed the high-level concepts of the MVC pattern. Then we covered Spring MVC's architecture, including its `WebApplicationContext` hierarchy, request-handling life cycle, and configuration.

Next you learned how to develop a sample singer management application using Spring MVC, with Thymeleaf as the view technology. During the course of developing the samples, we elaborated on different areas. Main topics included i18n, theming, and template support with Thymeleaf.

To integrate a Spring web application with a view technology, there needs to be at least a custom bean that implements Spring's `org.springframework.web.servlet.ViewResolver`. Thymeleaf is also a templating view technology, and thus its `ViewResolver` implementation relies on a `SpringTemplateEngine` and `SpringResourceTemplateResolver`.

And because Spring Boot is the prodigy feature of the Spring team, how to build a full-blown web application using it had to be covered. In the next chapter, we cover more features that Spring brings in terms of web application development by covering REST requests.



# Spring REST Support

**Chapter 13** introduced communication over the HTTP protocol between two Spring web applications that exposed REST API. This chapter expands the subject by introducing you to RESTful web services, also referred to as RESTful-WS.

Nowadays, RESTful-WS is perhaps the most widely used technology for remote access. From remote service invocation via HTTP to supporting an Ajax-style interactive web front end, RESTful-WS is being adopted intensively, especially because of the rise of microservices. RESTful web services are popular for several reasons:

- *Easy to understand:* RESTful web services are designed around HTTP. The URL, together with the HTTP method, specifies the intention of the request. For example, the URL <http://somedomain.com/restful/customer/1> with an HTTP method of GET means that the client wants to retrieve the customer information, where the customer ID equals 1.
- *Lightweight:* RESTful is much more lightweight when compared to SOAP-based web services, which include a large amount of metadata to describe which service the client wants to invoke. For a RESTful request and response, it's simply an HTTP request and response, as with any other web application.
- *Firewall friendly:* Because RESTful web services are designed to be accessible via HTTP (or HTTPS), the application becomes much more firewall friendly and easily accessed by remote clients.

In this chapter, we present the basic concepts of RESTful-WS and Spring's support of RESTful-WS through its Spring MVC module.

## Introducing RESTful Web Services

The REST in RESTful-WS is short for **RE**presentational **S**tate **T**ransfer, which is an architectural style. REST defines a set of architectural constraints that together describe a uniform interface for accessing resources. The main concepts of this uniform interface include the identification of resources and the manipulation of resources through representations. For the identification of resources, a piece of information should be accessible via a uniform resource identifier (URI). For example, the URL <http://somedomain.com/api/singer/1> is a URI that represents a resource, which is a piece of singer information with an identifier of 1. If the singer with an identifier of 1 does not exist, the client will get a 404 HTTP status code, just like a “page not

found” error on a web site. Another example, <http://somedomain.com/api/singers>, is a URI that represents a resource that is a list of singer information. Those identifiable resources can be managed through various representations, as shown in Table 15-1.

**Table 15-1.** *Representations for Manipulating Resources*

HTTP Method	Description
GET	GET retrieves a representation of a resource.
HEAD	Identical to GET, without the response body. Typically used for getting a header.
POST	POST creates a new resource.
PUT	PUT updates a resource.
DELETE	DELETE deletes a resource.
OPTIONS	OPTIONS retrieves allowed HTTP methods.

For a detailed description of RESTful web services, we recommend *Ajax and REST Recipes: A Problem-Solution Approach* by Christian Gross (Apress, 2006).

## Using Spring MVC to Expose RESTful Web Services

In this section, we show you how to use Spring MVC to expose the singer services as RESTful web services, as designed in the previous section. This sample builds upon the already introduced `Singer` class and the `SingerRepo` repository interface.



In the previous edition of the book, Castor<sup>1</sup> XML was used for serialization. The Castor library hasn't been maintained for a while, so in this edition it was dropped in favor of Jackson<sup>2</sup>.

The Jackson library is very capable and provides components for serializing objects to JSON and XML. Mapping Java properties to XML elements or JSON properties is easily done via annotations. Although Jackson annotations are named `@Json*`, they work as configurations for XML serialization too. Listing 15-1 shows the `Singer` class decorated with Jackson annotations.

**Listing 15-1.** The Updated `Singer` Class Decorated with Jackson Annotations

```
package com.apress.prospring6.fifteen.entities;

import com.fasterxml.jackson.annotation.JsonFormat;
import com.fasterxml.jackson.annotation.JsonIgnore;
// other import statements omitted

@Data
@Entity
```

<sup>1</sup><https://castor.exolab.org/xml-framework.html>

<sup>2</sup><https://github.com/FasterXML/jackson>

```

@Table(name = "SINGER")
public class Singer {
    @Serial
    private static final long serialVersionUID = 2L;

    @Id
    @GeneratedValue(strategy = IDENTITY)
    @Column(name = "ID")
    protected Long id;

    @JsonIgnore
    @Version
    @Column(name = "VERSION")
    protected int version;

    @NotEmpty
    @Size(min = 2, max = 30)
    @Column(name = "FIRST_NAME")
    private String firstName;

    @NotEmpty
    @Size(min = 2, max = 30)
    @Column(name = "LAST_NAME")
    private String lastName;

    @JsonFormat(pattern = "yyyy-MM-dd")
    @DateTimeFormat(pattern = "yyyy-MM-dd")
    @Column(name = "BIRTH_DATE")
    private LocalDate birthDate;
}

```

By default, all `Singer` fields that Jackson knows how to serialize to text values are serialized. All fields that should not be serialized, such as the `version` field, must be annotated with the `@JsonIgnore` annotation.

For complex types such as calendar dates, there are two options: use the `@JsonFormat` annotation configured with the pattern we want our date value converted to or extend `com.fasterxml.jackson.databind.ser.std.StdSerializer`.

## Implementing SingerController

To keep things simple, we'll skip declaring a `SingerService` and write a `SingerController` that uses `SingerRepo`. The `SingerController` is displayed in Listing 15-2.

*Listing 15-2.* The `SingerController` Implementation

```

package com.apress.prospring6.fifteen.controllers;

import org.springframework.stereotype.Controller;
import org.springframework.web.bind.annotation.*;
// other import statements omitted

```

```

@Controller
@RequestMapping(path = "singer")
public class SingerController {
    final Logger logger = LoggerFactory.getLogger(SingerController.class);

    private final SingerRepo singerRepo;

    public SingerController(SingerRepo singerRepo) {
        this.singerRepo = singerRepo;
    }

    @ResponseStatus(HttpStatus.OK)
    @ResponseBody
    @RequestMapping(path="{"/, ""}, method = RequestMethod.GET)
    public List<Singer> all() {
        return singerRepo.findAll();
    }

    @ResponseStatus(HttpStatus.OK)
    @ResponseBody
    @RequestMapping(path =("/{id}", method = RequestMethod.GET)
    public Singer findSingerById(@PathVariable Long id) {
        return singerRepo.findById(id).orElse(null);
    }

    @ResponseStatus(HttpStatus.CREATED)
    @ResponseBody
    @RequestMapping(path = "/", method = RequestMethod.POST)
    public Singer create(@RequestBody Singer singer) {
        logger.info("Creating singer: " + singer);
        var saved = singerRepo.save(singer);
        logger.info("Singer created successfully with info: " + saved);
        return singer;
    }

    @ResponseStatus(HttpStatus.OK)
    @ResponseBody
    @RequestMapping(path =("/{id}", method = RequestMethod.PUT)
    public void update(@RequestBody Singer singer, @PathVariable Long id) {
        LOGGER.info("Updating singer: {}", singer);
        var fromDb = singerRepo.findById(id).orElseThrow(() -> new IllegalArgumentException(
            "Singer does not exist!" ));
        fromDb.setFirstName(singer.getFirstName());
        fromDb.setLastName(singer.getLastName());
        fromDb.setBirthDate(singer.getBirthDate());
        singerRepo.save(fromDb);
        LOGGER.info("Singer updated successfully with info: " + fromDb);
    }

    @ResponseStatus(HttpStatus.NO_CONTENT)
    @ResponseBody

```



```

@RequestMapping(path =("/{id}", method = RequestMethod.DELETE)
public void delete(@PathVariable Long id) {
    logger.info("Deleting singer with id: " + id);
    singerRepo.deleteById(id);
    logger.info("Singer deleted successfully");
}
}

```

The main points about the previous class are as follows:

- The class is annotated with `@Controller`, indicating that it's a Spring MVC controller.
- The class-level annotation `@RequestMapping(value="/singer")` indicates that this controller will be mapped to all URLs under the main web context. In this sample, all URLs under `http://localhost:8080/singer` will be handled by this controller.
- The `SingerRepo` is required for this controller to work.
- The `@RequestMapping` annotation for each method indicates the URL pattern and the corresponding HTTP method that it will be mapped to. For example, the `all()` method will be mapped to the `http://localhost:8080/singer` URL, with an HTTP GET method. For the `update(..)` method, it will be mapped to the URL `http://localhost:8080/singer/1` with an HTTP PUT method.
- What is the difference between this controller and the ones introduced in **Chapter 14**? What makes a controller suitable for REST requests? Two things: the `@ResponseBody` annotation being placed on each handler method and the fact that the handler methods do not return a logical view name, because there is no view, the methods return the actual data. The `@ResponseBody` annotation indicates a method return value should be bound to the web response body, which is the fancy technical way to say that the value returned by the method is the actual web response. If annotating each method with `@ResponseBody` seems verbose, you can easily skip that by just using the annotation once the class level, but this means no method in the controller is expected to return a view or a view name.
- For methods that accept path variables (for example, the `findSingerById(..)` method), the path variable is annotated with `@PathVariable`. This instructs Spring MVC to bind the path variable within the URL (for example, `http://localhost:8080/singer/1`) into the `id` argument of the `findSingerById(..)` method. Note that for the `id` argument, the type is `Long`, and Spring's type conversion system will automatically handle the conversion from `String` to `Long` for us.
- For the `create(..)` and `update(..)` methods, the `Singer` argument is annotated with `@RequestBody`. This instructs Spring to automatically bind the content within the HTTP request body into the `Singer` domain object. The conversion will be done by the declared instances of the `HttpMessageConverter<Object>` interface (under the package `org.springframework.http.converter`) for supporting formats, which will be discussed later in this chapter.

Spring version 4.3 introduced some customization of the `@RequestMapping` annotations that match basic HTTP methods. Table 15-2 lists the equivalence between the new annotations and old-style `@RequestMapping`.

**Table 15-2.** Annotations for Mapping HTTP Method Requests onto Specific Handler Methods Introduced in Spring 4.3

Annotation	Old-Style Equivalent
@GetMapping	@RequestMapping(method = RequestMethod.GET)
@PostMapping	@RequestMapping(method = RequestMethod.POST)
@PutMapping	@RequestMapping(method = RequestMethod.PUT)
@DeleteMapping	@RequestMapping(method = RequestMethod.DELETE)

There is also another stereotype annotation that was introduced in Spring 4.0 for REST controller classes, called `@RestController`. This annotation is declared in the `org.springframework.web.bind` annotation as well and is meta-annotated with `@Controller` and `@ResponseBody`, which basically give it the power of both. Using this annotation, and the ones in Table 15-2, the `SingerController` class becomes less verbose, as shown in Listing 15-3.

**Listing 15-3.** The `SingerController` Implementation Using `@RestController`

```
package com.apress.prospring6.fifteen.controllers;

import org.springframework.web.bind.annotation.RestController;
// other import statements omitted

@RestController
@RequestMapping(path = "singer")
public class SingerController {
    final Logger logger = LoggerFactory.getLogger(SingerController.class);

    private final SingerRepo singerRepo;

    public SingerController(SingerRepo singerRepo) {
        this.singerRepo = singerRepo;
    }

    @ResponseStatus(HttpStatus.OK)
    @GetMapping(path="/")
    public List<Singer> all() {
        return singerRepo.findAll();
    }

    @ResponseStatus(HttpStatus.OK)
    @GetMapping(path =("/{id}")
    public Singer findSingerById(@PathVariable Long id) {
        return singerRepo.findById(id).orElse(null);
    }

    @ResponseStatus(HttpStatus.CREATED)
    @PostMapping(path="/")
    public Singer create(@RequestBody Singer singer) {
        LOGGER.info("Creating singer: {}", singer);
    }
}
```

```

        var saved = singerRepo.save(singer);
        LOGGER.info("Singer created successfully with info: " + saved);
        return singer;
    }
    // other methods omitted
}

```

For a Spring Web REST application, one that doesn't require specialized web views, there is no need for specialized view resolver beans. So, the configuration is a little simpler. The `WebInitializer` class, the one configuring the `DispatcherServlet` is pretty standard for Spring web applications and when no specialized views are used, the `HiddenHttpMethodFilter` is not needed. This class is depicted in Listing 15-4.

*Listing 15-4.* The `WebInitializer` Class

```

package com.apress.prospring6.fifteen;

import jakarta.servlet.Filter;
import org.springframework.web.filter.CharacterEncodingFilter;
import org.springframework.web.filter.HiddenHttpMethodFilter;
import org.springframework.web.servlet.support.
AbstractAnnotationConfigDispatcherServletInitializer;

import java.nio.charset.StandardCharsets;

import java.nio.charset.StandardCharsets;

public class WebInitializer
    extends AbstractAnnotationConfigDispatcherServletInitializer {

    @Override
    protected Class<?>[] getRootConfigClasses() {
        return new Class[]{BasicDataSourceCfg.class, TransactionCfg.class};
    }

    @Override
    protected Class<?>[] getServletConfigClasses() {
        return new Class[]{WebConfig.class};
    }

    @Override
    protected String[] getServletMappings() {
        return new String[]{"/*"};
    }

    @Override
    protected Filter[] getServletFilters() {
        final CharacterEncodingFilter cef = new CharacterEncodingFilter();
        cef.setEncoding(StandardCharsets.UTF_8.name());
        cef.setForceEncoding(true);
        return new Filter[]{new HiddenHttpMethodFilter(), cef};
    }
}

```

The Spring MVC configuration class (`WebConfig`, shown in Listing 15-5) is simple as well, since usually a REST application does not require theming or internationalization.

*Listing 15-5.* The `WebConfig` Class

```
package com.apress.prospring6.fifteen;

import org.springframework.web.servlet.config.annotation.EnableWebMvc;
import org.springframework.web.servlet.config.annotation.WebMvcConfigurer;
// other import statements omitted

@Configuration
@EnableWebMvc
@ComponentScan(basePackages = {"com.apress.prospring6.fifteen"})
public class WebConfig implements WebMvcConfigurer {

    @Override
    public void addViewControllers(ViewControllerRegistry registry) {
        registry.addRedirectViewController("/", "/home");
    }

    @Bean
    public Validator validator() {
        final var validator = new LocalValidatorFactoryBean();
        return validator;
    }

    @Override
    public Validator getValidator() {
        return validator();
    }
}
```

This configuration is minimal, and even in classic configuration, Spring MVC determines the requested media types from the request based on the `Accept` header.

You can configure the requested media type based on path extension, query parameters, or other methods by overriding the `configureContentNegotiation(..)` method in your `WebConfig` class<sup>3</sup>, or by declaring different handler methods and using the `produces` attribute.

The other way to configure the requested media type is to override the default message converters created by Spring MVC by overriding the `configureMessageConverters()` method, or adding custom message converters to the set of default ones by overriding method `extendMessageConverters()`.<sup>4</sup>

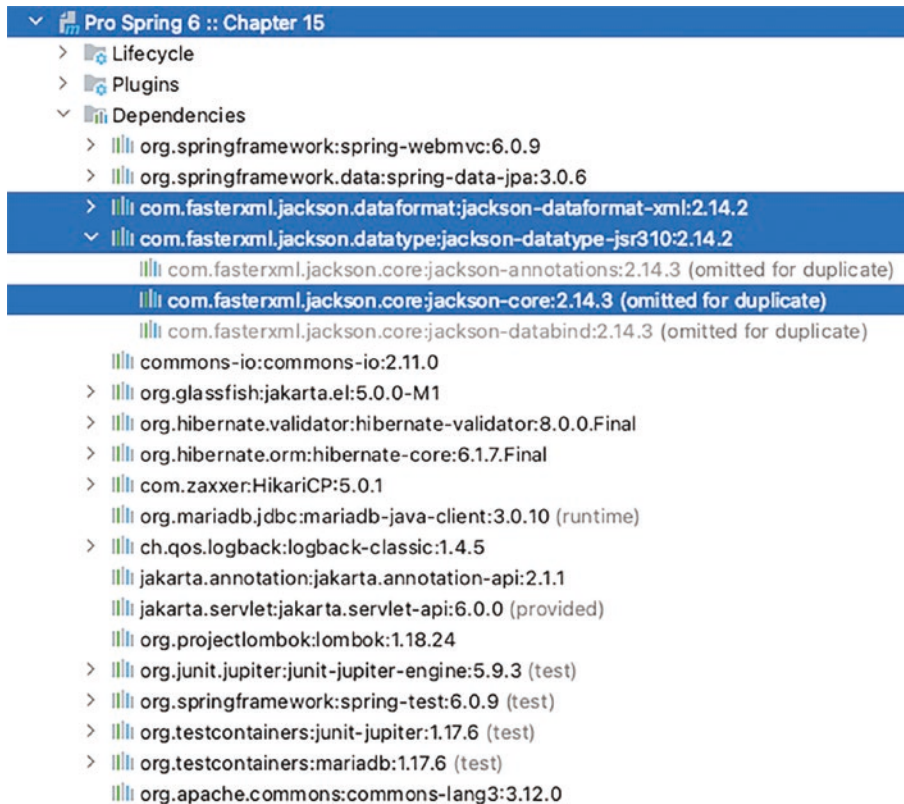
For this chapter, we don't need to do any of that, because the default message converters configured by Spring MVC are all that we need.

<sup>3</sup><https://docs.spring.io/spring-framework/docs/current/reference/html/web.html#mvc-config-content-negotiation>

<sup>4</sup><https://docs.spring.io/spring-framework/docs/current/reference/html/web.html#mvc-config-message-converters>

So, now that we've decided the Accept header is the one that a client must provide in the request to specify the format they want for the data, do we need to configure anything else to make this work? The answer is no, no other Spring configuration is needed. We do, however, need to add the suitable Jackson libraries to the classpath, so Spring MVC can use them.

The dependencies for the chapter15 project are shown in Figure 15-1.



*Figure 15-1. Project chapter15 dependencies*

In Figure 15-1 you can see the following three Jackson libraries highlighted:

- `jackson-dataformat-xml` is needed for serialization to XML.
- `jackson-core` is the core Jackson library used for serialization to JSON; it contains all the `@Json*` annotations.
- `jackson-datatype-jsr310` is needed for serialization and formatting of Java 8 Date and Time types.

Now, the server-side service is complete. At this point, can build the WAR file containing the web application and deploy it to an Apache Tomcat 10 instance or, if you are using IntelliJ IDEA, create an Apache Tomcat Launcher as shown in **Chapter 14**.

## Testing the RESTful-WS Application

There are many ways to test a REST application. We can build a Java client, we can use HTTPie requests, or we can use `curl`<sup>5</sup>, Postman<sup>6</sup>, or any other application or CLI for making HTTP requests. Let's start with the simplest HTTPie, the IntelliJ IDEA HTTP client. The request to retrieve all singers as XML and a snippet of the returned response is shown in Listing 15-6

**Listing 15-6.** HTTPie Request to Get All Singers As XML and Response

```
### Request
GET http://localhost:8080/ch15/singer/
Accept: application/xml

### Response
HTTP/1.1 200
Content-Type: application/xml;charset=UTF-8
Transfer-Encoding: chunked
Date: Tue, 17 Jan 2023 22:13:57 GMT
Keep-Alive: timeout=20
Connection: keep-alive

<List>
  <item>
    <firstName>John</firstName>
    <lastName>Mayer</lastName>
    <birthDate>1977-10-16</birthDate>
  </item>
  <item>
    <firstName>Ben</firstName>
    <lastName>Barnes</lastName>
    <birthDate>1981-08-20</birthDate>
  </item>
<!-- other elements omitted -->
</list>
```

<sup>5</sup><https://curl.se>

<sup>6</sup><https://www.postman.com>

This command sends an HTTP request to the server's RESTful web service; in this case, it invokes the `all()` method in `SingerController` to retrieve and return all singer information. Also, the `Accept` HTTP header value is set to `application/xml`, meaning that the client wants to receive data in XML format.

To get the data in JSON format, all we have to do is replace the `Accept` header value with `application/json`. And because `curl` was mentioned, Listing 15-7 shows the verbose (`-v` option) `curl` request for retrieving the data as JSON and a snippet of the response.

**Listing 15-7.** `curl` Request to Get All Singers As JSON and Response

```
### Request
curl -v -H "Accept: application/json" http://localhost:8080/ch15/singer/

### Response
* Trying 127.0.0.1:8080...
* Connected to localhost (127.0.0.1) port 8080 (#0)
> GET /ch15/singer/ HTTP/1.1
> Host: localhost:8080
> User-Agent: curl/7.84.0
> Accept: application/json
>
* Mark bundle as not supporting multiuse
< HTTP/1.1 200
< Content-Type: application/json;charset=UTF-8
< Transfer-Encoding: chunked
< Date: Tue, 17 Jan 2023 22:22:54 GMT
<
* Connection #0 to host localhost left intact
[
  {
    "firstName":"John",
    "lastName":"Mayer",
    "birthDate":"1977-10-16"
  },
  {
    "firstName":"Ben",
    "lastName":"Barnes",
    "birthDate":"1981-08-20"
  }
]
# other JSON elements omitted
]
```

This command sends an HTTP request to the server's RESTful web service, and the same `all()` method in `SingerController` to retrieve and return all singer information. In this case, the `-H` option declares an HTTP header attribute, meaning that the client wants to receive data in JSON format.

Both `HTTPie` and `curl` make the same request; the only thing different is the value of the `Accept` header. Changing the data format works because Spring MVC registers `org.springframework.http.converter.HttpMessageConverter<T>` implementations found on the classpath and uses them for content type resolution.

For modelling communication between non-reactive Spring REST applications a `RestTemplate` instance is used. **Chapter 13** introduced `RestTemplate` to test a Spring Boot application, and the tests were designed to run in a Spring Boot test context. For this section, the application is configured in a classic way, without Spring Boot and packed as a `*.war` that is deployed on an Apache Tomcat server. This means

that the tests written for this application are separate from the application context. The application runs in Tomcat, and the test class shares only the classpath with the application, not the context, thus the test is equivalent to a client for the application.

Listing 15-8 shows the `RestClientTest` class that uses a `RestTemplate` instance to submit all type of HTTP requests to the application deployed on Tomcat.

**Listing 15-8.** `RestClientTest` Class Making Requests to ch15 Web Application Using `RestTemplate`

```
package com.apress.prospring6.fifteen;
```

```
import org.springframework.web.client.RestTemplate;
// other import statements omitted
```

```
public class RestClientTest {
```

```
    final Logger LOGGER = LoggerFactory.getLogger(RestClientTest.class);
    private static final String URI_SINGER_ROOT = "http://localhost:8080/ch15/singer/";
    private static final String URI_SINGER_WITH_ID = "http://localhost:8080/ch15/
    singer/{id}";
```

```
    RestTemplate restTemplate = new RestTemplate();
```

```
    @Test
```

```
    public void testFindAll() {
        LOGGER.info("--> Testing retrieve all singers");
        var singers = restTemplate.getForObject(URI_SINGER_ROOT, Singer[].class);
        assertEquals(15, singers.length);
        Arrays.stream(singers).forEach(s -> LOGGER.info(s.toString()));
    }
```

```
    @Test
```

```
    public void testFindById() {
        LOGGER.info("--> Testing retrieve a singer by id : 1");
        var singer = restTemplate.getForObject(URI_SINGER_WITH_ID, Singer.class, 1);
        assertNotNull(singer);
        LOGGER.info(singer.toString());
    }
```

```
    @Test
```

```
    public void testCreate() {
        LOGGER.info("--> Testing create singer");
        Singer singerNew = new Singer();
        singerNew.setFirstName("TEST");
        singerNew.setLastName("Singer");
        singerNew.setBirthDate(LocalDate.now());
        singerNew = restTemplate.postForObject(URI_SINGER_ROOT, singerNew, Singer.class);

        LOGGER.info("Singer created successfully: " + singerNew);
    }
```



```

@Test
public void testDelete() {
    LOGGER.info("--> Testing delete singer by id : 33");
    var initialCount = restTemplate.getForObject(URI_SINGER_ROOT, Singer[].
class).length;
    restTemplate.delete(URI_SINGER_WITH_ID, 33);
    var afterDeleteCount = restTemplate.getForObject(URI_SINGER_ROOT, Singer[].
class).length;
    assertEquals((initialCount - afterDeleteCount), 1);
}

@Test
public void testUpdate() {
    LOGGER.info("--> Testing update singer by id : 1");
    var singer = restTemplate.getForObject(URI_SINGER_ROOT, Singer.class, 1);
    singer.setFirstName("John Marvelous");
    restTemplate.put(URI_SINGER_ROOT, singer, 1);
    LOGGER.info("Singer update successfully: " + singer);
}
}

```

The `RestClientTest` class contains methods for testing all the URLs supported by the web application. Each method can be run individually in a smart editor such as IntelliJ IDEA. The URLs for accessing various operations are declared, which will be used in later samples. The `RestTemplate` instance is created and used in all test methods.

In the `testFindAll()` method, the `RestTemplate#getForObject(..)` method is called (which corresponds to the HTTP GET method), passing in the URL and the expected return type, which is the `Singers[]` class that contains the full list of singers.

Make sure the application server is running and the web application is exposed under context `ch15`. Running the `testFindAll()` test method, the test should pass and produce the output shown in Listing 15-9.

**Listing 15-9.** Console Log for Execution of `RestClientTest#testFindAll()`

```

11:33:06.970 [Test worker] INFO c.a.p.f.RestClientTest - --> Testing retrieve all singers
11:33:07.002 [Test worker] DEBUG o.s.w.c.RestTemplate - HTTP GET http://localhost:8080/
ch15/singer/
11:33:07.018 [Test worker] DEBUG o.s.w.c.RestTemplate - Accept=[application/xml, text/xml,
application/json, application/*+xml, application/*+json]
11:33:07.090 [Test worker] DEBUG o.s.w.c.RestTemplate - Response 200 OK
11:33:07.096 [Test worker] DEBUG o.s.w.c.RestTemplate - Reading to [com.apress.prospring6.
fifteen.entities.Singer[]]
11:33:07.179 [Test worker] INFO c.a.p.f.RestClientTest - Singer(id=null, version=0,
firstName=John, lastName=Mayer, birthDate=1977-10-16)
11:33:07.179 [Test worker] INFO c.a.p.f.RestClientTest - Singer(id=null, version=0,
firstName=Ben, lastName=Barnes, birthDate=1981-08-20)
...
# the rest of the singers omitted

```

As you can see, the `RestTemplate` instance submits the request with `Accept` header values matching all converters found on the classpath, in this case `application/xml`, `text/xml`, `application/json`, `application/xml`, `application/json`, which guarantees a correct interpretation of the response and a

successful conversion to the Java type provided as an argument, in this case an array of `Singer`. We cannot use `List<Singer>` as a type for the response to be converted to, because this type is generic and cannot be used as an argument.

The method `getForObject(..)`, as its name makes obvious, is useful for submitting GET requests. If you analyze the rest of the test methods, you can see that there are matching methods in `RestTemplate` for the rest of the HTTP methods: `postForObject(..)` for POST, `put(..)` for PUT, and `delete(..)` for DELETE. Aside from these, there are also the specialized `execute(..)` and `exchange()` sets of methods. The `execute(..)` method is suitable when a callback method (provided as an implementation for `RequestCallback`) must be executed right after the request is submitted, and since the type to convert the response body is not provided as an argument, a `ResponseExtractor<T>` can be provided to explicitly convert the body into the required type. There is more than one version of this method, including additional request parameters. Listing 15-10 shows how a test method equivalent to `testFindAll(..)` can be written using the `execute(..)` method.

**Listing 15-10.** The method testing `testFindAll(..)` using `restTemplate.execute(..)`

```
package com.apress.prospring6.fifteen;

import org.springframework.web.client.RequestCallback;
import org.springframework.web.client.ResponseExtractor;
// other import statements omitted

public class RestClientTest {

    @Test
    public void testFindAllWithExecute() {
        LOGGER.info("--> Testing retrieve all singers");
        var singers = restTemplate.execute(URI_SINGER_ROOT, HttpMethod.GET,
            request -> LOGGER.debug("Request submitted ..."),
            response -> {
                assertEquals(HttpStatus.OK, response.getStatusCode());
                return new String(response.getBody().readAllBytes());
            }
        );
        LOGGER.info("Response: {}" , singers);
    }

    // other test methods omitted
}
```

Both `RequestCallback`<sup>7</sup> and `ResponseExtractor<T>`<sup>8</sup> are functional interfaces, which allows for their implementations to be declared inline using lambda expressions. The two functional interfaces are shown in Listing 15-11.

<sup>7</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-web/src/main/java/org/springframework/web/client/RequestCallback.java>

<sup>8</sup><https://github.com/spring-projects/spring-framework/blob/main/spring-web/src/main/java/org/springframework/web/client/ResponseExtractor.java>

**Listing 15-11.** The RequestCallback and ResponseExtractor<T> Functional Interfaces

```
// comments omitted
package org.springframework.web.client;

import java.io.IOException;
import java.lang.reflect.Type;

import org.springframework.http.client.ClientHttpRequest;

@FunctionalInterface
public interface RequestCallback {

    void doWithRequest(ClientHttpRequest request) throws IOException;
}

//-----

package org.springframework.web.client;

import java.io.IOException;
import java.lang.reflect.Type;

import org.springframework.http.client.ClientHttpResponse;
import org.springframework.lang.Nullable;

@FunctionalInterface
public interface ResponseExtractor<T> {

    @Nullable
    T extractData(ClientHttpResponse response) throws IOException;
}

```

The set of exchange(..) methods are the most general/capable methods provided by RestTemplate suitable when none of the other methods provides a complete enough parameter set to meet your needs. As its name reveals, the exchange(..) method is designed to do an exchange of information between the client and the application running on a server, and thus is most suitable for complex POST and PUT requests. Listing 15-12 shows the testCreate(..) version using exchange(..).

**Listing 15-12.** Testing the RequestCallback Interfaces

```
package com.apress.prospring6.fifteen;

import org.springframework.http.HttpEntity;
import org.springframework.http.HttpMethod;
// other import statements omitted

public class RestClientTest {

    @Test
    public void testCreateWithExchange() {

```

```

    LOGGER.info("--> Testing create singer");
    Singer singerNew = new Singer();
    singerNew.setFirstName("TEST");
    singerNew.setLastName("Singer");
    singerNew.setBirthDate(LocalDate.now());
    HttpEntity<Singer> request = new HttpEntity<>(singerNew);
    ResponseEntity<Singer> created =
        restTemplate.exchange(URI_SINGER_ROOT, HttpMethod.POST, request, Singer.class);
    assertEquals(HttpStatus.CREATED, created.getStatusCode());

    var singerCreated = created.getBody();
    assertNotNull(singerCreated);

    LOGGER.info("Singer created successfully: " + singerCreated);
}

// other test methods omitted
}

```

The `HttpEntity<T>` is powerful, as it can wrap together body and headers, making it possible for `RestTemplate#exchange(..)` to submit secured rest requests.

Testing with `RestTemplate` is simple, but the controller might need some work to make it more capable REST wise. What happens if the `Singer` instance we are trying to edit does not exist? What happens if we try to create a `Singer` instance with some name? What would the response be? No way to know, because all the handler methods are annotated with `@ResponseStatus` to configure the response status code to return when all goes well, but no error status code was configured anywhere. For example, running the `testCreateWithExchange(..)` method now returns `500(INTERNAL_SERVER_ERROR)` because the repository throws a `org.springframework.dao.DataIntegrityViolationException` that is not handled anywhere. And so, handling exceptions is necessary.

## REST Exception Handling Using `ResponseEntity<t>`

The first thing we could do is treat an exception where it happens, and return the desired `HttpStatus` value explicitly via the `ResponseEntity<T>` type. This type is an extension of `org.springframework.http.HttpEntity<T>` that includes a `HttpStatus` status code. It can be used to wrap the result of a `RestTemplate` method invocation, but it can also be used as a return type in REST handler methods.

This being said, let's modify the `findSingerById(..)` handler method to return a `ResponseEntity<Singer>` that includes the `HttpStatus.OK` code when a singer with the provided `id` exists and return a `ResponseEntity<HttpStatus>` that includes the `HttpStatus.NOT_FOUND` code when a singer with the provided `id` cannot be found. Listing 15-13 shows this version of the method, which is part of a new REST controller class named `Singer2Controller`.

**Listing 15-13.** The `Singer2Controller#findSingerById(..)` Method That Returns a `ResponseEntity<T>`

```
package com.apress.prospring6.fifteen.controllers;
```

```
import org.springframework.http.HttpStatus;
import org.springframework.http.ResponseEntity;
//other import statements omitted
```

```
@RestController
```

```

@RequestMapping(path = "singer2")
public class Singer2Controller {
    final Logger LOGGER = LoggerFactory.getLogger(Singer2Controller.class);

    private final SingerRepo singerRepo;

    public Singer2Controller(SingerRepo singerRepo) {
        this.singerRepo = singerRepo;
    }

    @GetMapping(path = "{id}")
    public ResponseEntity<Singer> findSingerById(@PathVariable Long id) {
        Optional<Singer> fromDb = singerRepo.findById(id);
        return fromDb
            .map(s -> new ResponseEntity<>(s, HttpStatus.OK))
            .orElseGet(() -> new ResponseEntity<>(HttpStatus.NOT_FOUND));
    }
    // other methods omitted
}

```

Notice that now the `@ResponseStatus(HttpStatus.OK)` is no longer necessary, but also in case the `id` does not match an existing singer, an empty response is sent together in the `HttpStatus.NOT_FOUND`. The response is represented as a `ResponseEntity<T>` that contains a body and a successful `200(OK)` HTTP status code for a successful request, and only a `404(Not Found)` HTTP status code for a failed request. The objects are created explicitly by invoking constructors, but `ResponseEntity<T>` provides builders for constructing requests specific to the most common HTTP status codes. Listing 15-14 shows the `findSingerById(..)` handler method written using `ResponseEntity<T>` builders.

**Listing 15-14.** The `Singer2Controller#findSingerById(..)` Method That Returns a `ResponseEntity<T>` Created Using Builders

```

package com.apress.prospring6.fifteen.controllers;

import org.springframework.http.HttpStatus;
import org.springframework.http.ResponseEntity;
//other import statements omitted

@RestController
@RequestMapping(path = "singer2")
public class Singer2Controller {
    final Logger LOGGER = LoggerFactory.getLogger(Singer2Controller.class);

    private final SingerRepo singerRepo;

    public Singer2Controller(SingerRepo singerRepo) {
        this.singerRepo = singerRepo;
    }

    @GetMapping(path = "{id}")
    public ResponseEntity<Singer> findSingerById(@PathVariable Long id) {
        Optional<Singer> fromDb = singerRepo.findById(id);
        return fromDb

```

```

        .map(s -> ResponseEntity.ok().body(s))
        .orElseGet(() -> ResponseEntity.notFound().build());
    }
    // other methods omitted
}

```

Since the response now is a `ResponseEntity<Singer>`, to test this method two tests can be written using the `RestTemplate#exchange(..)` method, one positive, one negative. Listing 15-15 shows the two test methods.

**Listing 15-15.** Testing the `Singer2Controller#findSingerById(..)` Methods

```

package com.apress.prospring6.fifteen;

import org.springframework.web.client.HttpClientErrorException;
import org.springframework.web.client.RestTemplate;
import org.springframework.http.ResponseEntity;
// other import statements omitted

public class RestClient2Test {
    final Logger LOGGER = LoggerFactory.getLogger(RestClientTest.class);
    private static final String URI_SINGER2_ROOT = "http://localhost:8080/ch15/singer2/";

    RestTemplate restTemplate = new RestTemplate();

    @Test
    public void testPositiveFindById() throws URISyntaxException {
        HttpHeaders headers = new HttpHeaders();
        headers.setAccept(List.of(MediaType.APPLICATION_JSON));
        ResponseEntity<HttpHeaders> req = new ResponseEntity<>(headers, HttpMethod.GET, new
        URI(URI_SINGER2_ROOT + 1));
        LOGGER.info("--> Testing retrieve a singer by id : 1");
        ResponseEntity<Singer> response = restTemplate.exchange(req, Singer.class);
        assertEquals(HttpStatus.OK, response.getStatusCode());
        assertTrue(Objects.requireNonNull(response.getHeaders()).get(HttpHeaders.CONTENT_
        TYPE)).contains(MediaType.APPLICATION_JSON_UTF8_VALUE));
        assertNotNull(response.getBody());
    }

    @Test
    public void testNegativeFindById() throws URISyntaxException {
        LOGGER.info("--> Testing retrieve a singer by id : 99");
        ResponseEntity<HttpHeaders> req = new ResponseEntity<>(HttpMethod.GET, new
        URI(URI_SINGER2_ROOT + 99));

        assertThrowsExactly(HttpClientErrorException.NotFound.class, () -> restTemplate.
        exchange(req, HttpStatus.class));
    }
}

```

As mentioned previously, the `RestTemplate#exchange(..)` exchange methods are very powerful. In the `testPositiveFindById()` test method, the version of the method that requires a `RequestEntity<T>` and the returned object type as arguments is invoked. The `RequestEntity<T>` type is an extension of `HttpEntity<T>` that exposes the HTTP method and the target URL. Just for fun, the requested resource representation is JSON, but `RestTemplate` is smart enough to convert it back to `Singer` so assertions can be run on the returned object.

In the `testNegativeFindById()` test method, notice that instead of inspecting a `RequestEntity<T>`, an assumption that an `org.springframework.web.client.HttpClientErrorException.NotFound` exception is thrown is checked. This is because the under the hood an error handler handles the response with the 404 (Not Found) by throwing this type of exception. This kind of handling happens for other HTTP status codes corresponding to responses other than the successful one, and the exception types all extend `org.springframework.web.client.HttpClientErrorException`.

The rest of the methods in `Singer2Controller` are shown in Listing 15-16.

**Listing 15-16.** The Complete `Singer2Controller`

```
package com.apress.prospring6.fifteen.controllers;
// other import statements are omitted

@RestController
@RequestMapping(path = "singer2")
public class Singer2Controller {

    final Logger LOGGER = LoggerFactory.getLogger(Singer2Controller.class);

    private final SingerRepo singerRepo;

    public Singer2Controller(SingerRepo singerRepo) {
        this.singerRepo = singerRepo;
    }

    @GetMapping(path={"/", ""})
    public ResponseEntity<List<Singer>> all() {
        var singers = singerRepo.findAll();
        if(singers.isEmpty()) {
            return ResponseEntity.notFound().build();
        }
        return ResponseEntity.ok().body(singerRepo.findAll());
    }

    @GetMapping(path =("/{id}")
    public ResponseEntity<Singer> findSingerById(@PathVariable Long id) {
        Optional<Singer> fromDb = singerRepo.findById(id);
        return fromDb
            .map(s -> ResponseEntity.ok().body(s))
            .orElseGet(() -> ResponseEntity.notFound().build());
    }

    @PostMapping(path="/")
    public ResponseEntity<Singer> create(@RequestBody @Valid Singer singer) {
        LOGGER.info("Creating singer: {}", singer);
    }
}
```

```

    try {
        var saved = singerRepo.save(singer);
        LOGGER.info("Singer created successfully with info: {}", saved);
        return new ResponseEntity<>(saved, HttpStatus.CREATED);
    } catch (DataIntegrityViolationException dive) {
        LOGGER.debug("Could not create singer." , dive);
        return ResponseEntity.badRequest().build();
    }
}

@PutMapping(value="/{id}")
public ResponseEntity<Object> update(@RequestBody Singer singer, @PathVariable
Long id) {
    LOGGER.info("Updating singer: " + singer);
    Optional<Singer> fromDb = singerRepo.findById(id);

    return fromDb
        .map(s -> {
            s.setFirstName(singer.getFirstName());
            s.setLastName(singer.getLastName());
            s.setBirthDate(singer.getBirthDate());
            try {
                singerRepo.save(s);
                return ResponseEntity.ok().build();
            } catch (DataIntegrityViolationException dive) {
                LOGGER.debug("Could not update singer." , dive);
                return ResponseEntity.badRequest().build();
            }
        })
        .orElseGet(() -> ResponseEntity.notFound().build());
}

@DeleteMapping(value="/{id}")
public ResponseEntity<Object> delete(@PathVariable Long id) {
    LOGGER.info("Deleting singer with id: " + id);

    Optional<Singer> fromDb = singerRepo.findById(id);
    return fromDb
        .map(s -> {
            singerRepo.deleteById(id);
            return ResponseEntity.noContent().build();
        })
        .orElseGet(() -> ResponseEntity.notFound().build());
}
}
}

```

Looking at the full `Singer2Controller`, you might notice that there is a repetitive situation when a singer is not found in the database: a `ResponseEntity.notFound().build()` is built and returned. This leads to the same code being written quite a few times. Just to make the situation more dire, we've also returned this type of response when no singer is found in the database. So, can all this repetitive code be avoided? Of course, and you will learn how by reading the following section.



## REST Exception Handling Using `@RestControllerAdvice`

To reduce the code that needs to be written, we can write a `SingerService` that wraps around the `SingerRepo` and throws an exception named `NotFoundException`, declared to extend `RuntimeException` because checked exceptions are annoying. We inject a bean of this type in the controller and annotate this class with `@ResponseStatus(value= HttpStatus.NOT_FOUND)`, and *voilà*, automatic mapping of this exception to the response status that is returned to the client. Listing 15-17 shows the `NotFoundException` class.

*Listing 15-17.* The `NotFoundException` REST-Specific Exception Class

```
package com.apress.prospring6.fifteen.problem;

import org.springframework.http.HttpStatus;
import org.springframework.web.bind.annotation.ResponseStatus;

import java.io.Serializable;

@ResponseStatus(value= HttpStatus.NOT_FOUND, reason="Requested item(s) not found")
public class NotFoundException extends RuntimeException {

    @Serial
    private static final long serialVersionUID = 2L;

    private Long objIdentifier;

    public <T> NotFoundException(Class<T> cls) {
        super("table for " + cls.getSimpleName() + " is empty");
    }

    public <T> NotFoundException(Class<T> cls, Long id) {
        super(cls.getSimpleName() + " with id: " + id + " does not exist!");
    }

    public Long getObjIdentifier() {
        return objIdentifier;
    }
}
```

Notice that an error message can be attached via the `reason` attribute, and it will be part of the response.

Listing 15-18 shows the `SingerService` implementation that throws this type of exception whenever some data cannot be found.

*Listing 15-18.* The `SingerService` Class

```
package com.apress.prospring6.fifteen.services;

import com.apress.prospring6.fifteen.problem.NotFoundException;
// other import statements omitted

@Transactional
@Service("singerService")
```

```

public class SingerServiceImpl implements SingerService {

    private final SingerRepo singerRepo;

    public SingerServiceImpl(SingerRepo singerRepo) {
        this.singerRepo = singerRepo;
    }

    @Override
    public List<Singer> findAll() {
        var singers = singerRepo.findAll();
        if(singers.isEmpty()) {
            throw new NotFoundException(Singer.class);
        }
        return singerRepo.findAll();
    }

    @Override
    public Singer findById(Long id) {
        return singerRepo.findById(id).orElseThrow(() -> new NotFoundException
            (Singer.class, id));
    }

    @Override
    public Singer save(Singer singer) {
        return singerRepo.save(singer);
    }

    @Override
    public Singer update(Long id, Singer singer) {
        return singerRepo.findById(id)
            .map(s -> {
                s.setFirstName(singer.getFirstName());
                s.setLastName(singer.getLastName());
                s.setBirthDate(singer.getBirthDate());
                return singerRepo.save(s);
            })
            .orElseThrow(() -> new NotFoundException(Singer.class, id));
    }

    @Override
    public void delete(Long id) {
        Optional<Singer> fromDb = singerRepo.findById(id);
        if (fromDb.isEmpty()) {
            throw new NotFoundException(Singer.class, id);
        }
        singerRepo.deleteById(id);
    }
}

```

Notice that most of the logic we previously had in the controller handler methods now has moved to this class. This means that we can write a new controller named `Singer3Controller` to use a bean of this type, and this controller is way more elegant and compact, as shown in Listing 15-19.

**Listing 15-19.** The `Singer3Controller` Class

```

package com.apress.prospring6.fifteen.controllers;

import com.apress.prospring6.fifteen.services.SingerService;
// other import statements omitted

@RestController
@RequestMapping(path = "singer3")
public class Singer3Controller {

    final Logger LOGGER = LoggerFactory.getLogger(Singer3Controller.class);

    private final SingerService singerService;

    public Singer3Controller(SingerService singerService) {
        this.singerService = singerService;
    }

    @GetMapping(path={"/", ""})
    public List<Singer> all() {
        return singerService.findAll();
    }

    @GetMapping(path =("/{id}")
    public Singer findSingerById(@PathVariable Long id) {
        return singerService.findById(id);
    }

    @PostMapping(path="/")
    @ResponseStatus(HttpStatus.CREATED)
    public Singer create(@RequestBody @Valid Singer singer) {
        LOGGER.info("Creating singer: " + singer);
        return singerService.save(singer);
    }

    @PutMapping(value="/{id}")
    public void update(@RequestBody @Valid Singer singer, @PathVariable Long id) {
        LOGGER.info("Updating singer: " + singer);

        singerService.update(id, singer);
    }

    @ResponseStatus(HttpStatus.NO_CONTENT)
    @DeleteMapping(value="/{id}")
    public void delete(@PathVariable Long id) {

```

```

        LOGGER.info("Deleting singer with id: {}", id);
        singerService.delete(id);
    }
}

```

To test that this exception causes a response with the 404 (Not Found) HTTP status code, the job is done by the `testNegativeFindById(..)` introduced in Listing 15-15, but by sending the request `"http://localhost:8080/ch15/singer3/99"`.

Having an exception annotated like this gets the job done, but our controller also throws a `DataIntegrityViolationException` that is not mapped to any HTTP status code. This type of exception is not part of our application, and thus cannot be annotated with `@ResponseStatus`.

For this type of exception, the solution is to write an exception handler class, annotate it with `@RestControllerAdvice` (the REST equivalent of `@ControllerAdvice`), and declare a method handler for the `DataIntegrityViolationException`, similar to what was done in **Chapter 14** for Spring web applications.

The `RestErrorHandler` class that is a global exception handler for REST requests is shown in Listing 15-20.

*Listing 15-20.* The `RestErrorHandler` Class

```

package com.apress.prospring6.fifteen.controllers;

import org.springframework.dao.DataIntegrityViolationException;
import org.springframework.http.HttpStatus;
import org.springframework.http.ResponseEntity;
import org.springframework.web.bind.annotation.ControllerAdvice;
import org.springframework.web.bind.annotation.ExceptionHandler;

@RestControllerAdvice
public class RestErrorHandler {

    @ExceptionHandler(DataIntegrityViolationException.class)
    public ResponseEntity<HttpStatus> handleBadRequest(DataIntegrityViolationException ex) {
        return ResponseEntity.badRequest().build();
    }

}

```

How do we test that when a `DataIntegrityViolationException` happens we no longer have a 500 (Internal Server Error)? Simple: we try to create a new `Singer` instance with an existing `firstName` and `lastName`, and since a combination of these two is declared to be the `SINGER` table unique key, the exception is thrown. The test is depicted in Listing 15-21.

*Listing 15-21.* The `RestClient3Test#testNegativeCreate()` Test Method

```

package com.apress.prospring6.fifteen;

import org.springframework.web.client.HttpClientErrorException;
import org.springframework.web.client.RestTemplate;
// other import statements omitted

```

```

public class RestClient3Test {
    final Logger LOGGER = LoggerFactory.getLogger(RestClientTest.class);
    private static final String URL_GET_ALL_SINGERS = "http://localhost:8080/ch15/singer3/";
    private static final String URL_CREATE_SINGER = "http://localhost:8080/ch15/singer3/";

    RestTemplate restTemplate = new RestTemplate();

    @Test
    public void testNegativeCreate() throws URISyntaxException {
        LOGGER.info("--> Testing create singer");
        Singer singerNew = new Singer();
        singerNew.setFirstName("Ben");
        singerNew.setLastName("Barnes");
        singerNew.setBirthDate(LocalDate.now());

        RequestEntity<Singer> req = new RequestEntity<>(singerNew, HttpMethod.POST, new
        URI(URL_CREATE_SINGER));

        assertThrowsExactly(HttpClientErrorException.BadRequest.class, () -> restTemplate.
        exchange(req, HttpStatus.class));
    }

    // other test methods omitted
}

```

Notice that the type of exception being thrown by `RestTemplate` is `HttpClientErrorException.BadRequest`, which is the type of exception matching the 400(Bad Request) HTTP status code.

This is where this section about writing a Spring REST Web application must end, because when it comes to REST APIs with Spring, the subject is quite vast. Check out the next section to see how easy it is to build Spring REST Web application using Spring Boot.

## RESTful-WS with Spring Boot

This section is included because Spring Boot makes everything easier to develop. The `Singer` entity, repository, service, exception, and exception handler classes are the same as before; there's no need to change anything. The same rule as for a classic Spring REST application applies: if we want XML and JSON serialization, we need to add the required Jackson libraries to the classpath. Figure 15-2 shows the `chapter15-boot` project dependencies.



Figure 15-2. Project chapter15-boot dependencies

Being a web application, the Spring Boot configuration is almost identical to the one introduced in Chapter 14, except the Thymeleaf section. Listing 15-22 shows the Spring Boot configuration contained by the application-dev.yaml.

Listing 15-22. The Spring Boot Configuration for the chapter15-boot Project

```
# web server config
server:
  port: 8081
  servlet:
    context-path: /
  compression:
    enabled: true # improves website performance by compressing response body
  address: 0.0.0.0
```

```
# datasource config
spring:
  datasource:
    driverClassName: org.mariadb.jdbc.Driver
    url: jdbc:mariadb://localhost:3306/musicdb?useSSL=false
    username: prospring6
    password: prospring6
    hikari:
      maximum-pool-size: 25
  jpa:
    generate-ddl: false
    properties:
      hibernate:
        jdbc:
          batch_size: 10
          show-sql: true
          format-sql: false
          use_sql_comments: false
        hbm2ddl:
          auto: none
```

```
# Logging config
logging:
  pattern:
    console: "%-5level: %class{0} - %msg%n"
  level:
    root: INFO
    org.springframework.boot: DEBUG
    com.apress.prospring6.fifteen: INFO
```

As usual, the dev profile is used to connect the application to an existing container. This allows for a test profile to spin up a container using Testcontainers. Testing this application is way easier because Spring Boot makes it so. The application-test.yaml file is simple because the data source configuration is the only one being customized. Listing 15-23 shows the data source configuration for the Spring Boot test context.

**Listing 15-23.** The Spring Boot Test Configuration for the chapter15-boot Project

```
spring:
  datasource:
    url: "jdbc:tc:mariadb:latest:///testdb?TC_INITSCRIPT=testcontainers/create-schema.sql"
  jpa:
    properties:
      hibernate:
        jdbc:
          batch_size: 10
          fetch_size: 30
          max_fetch_depth: 3
          show-sql: true
          format-sql: true
          use_sql_comments: true
        hbm2ddl:
          auto: none
```

The Chapter15ApplicationTest class is shown in Listing 15-24.

*Listing 15-24.* The Spring Boot Chapter15ApplicationTest Class

```

package com.apress.prospring6.fifteen.boot;

import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.boot.test.web.client.TestRestTemplate;
import org.springframework.test.context.ActiveProfiles;
import static org.junit.jupiter.api.Assertions.*;
// other import statements omitted

@ActiveProfiles("test")
@SpringBootTest(webEnvironment = SpringBootTest.WebEnvironment.RANDOM_PORT)
public class Chapter15ApplicationTest {
    final Logger LOGGER = LoggerFactory.getLogger(Chapter15ApplicationTest.class);

    @Value(value="${local.server.port}")
    private int port;

    @Autowired
    private TestRestTemplate restTemplate;

    @Test
    public void testFindAll() {
        LOGGER.info("--> Testing retrieve all singers");
        var singers = restTemplate.getForObject("http://localhost:"+port+"/singer/",
            Singer[].class);
        assertTrue( singers.length >= 15);
        Arrays.stream(singers).forEach(s -> LOGGER.info(s.toString()));
    }

    @Test
    public void testPositiveFindById() throws URISyntaxException {
        HttpHeaders headers = new HttpHeaders();
        headers.setAccept(List.of(MediaType.APPLICATION_JSON));
        RequestEntity<HttpHeaders> req = new RequestEntity<>(headers, HttpMethod.GET, new
            URI("http://localhost:"+port+"/singer/1"));
        LOGGER.info("--> Testing retrieve a singer by id : 1");
        ResponseEntity<Singer> response = restTemplate.exchange(req, Singer.class);
        assertAll("testPositiveFindById",
            () -> assertEquals(HttpStatus.OK, response.getStatusCode()),
            () -> assertTrue(Objects.requireNonNull(response.getHeaders().
                get(HttpHeaders.CONTENT_TYPE)).contains(MediaType.APPLICATION_JSON_
                VALUE)),
            () -> assertNotNull(response.getBody()),
            () -> assertEquals(Singer.class, response.getBody().getClass())
        );
    }

    @Test
    public void testNegativeFindById() throws URISyntaxException {

```



```

LOGGER.info("--> Testing retrieve a singer by id : 99");
RequestEntity<Singer> req = new RequestEntity<>(HttpMethod.GET, new URI("http://
localhost:"+port+"/singer/99"));

ResponseEntity<Singer> response = restTemplate.exchange(req, Singer.class);
assertAll("testNegativeFindById",
    () -> assertEquals(HttpStatus.NOT_FOUND, response.getStatusCode()),
    () -> assertNull(response.getBody().getFirstName()),
    () -> assertNull(response.getBody().getLastName()));
);
}

@Test
public void testNegativeCreate() throws URISyntaxException {
    LOGGER.info("--> Testing create singer");
    Singer singerNew = new Singer();
    singerNew.setFirstName("Ben");
    singerNew.setLastName("Barnes");
    singerNew.setBirthDate(LocalDate.now());

    RequestEntity<Singer> req = new RequestEntity<>(singerNew, HttpMethod.POST, new
    URI("http://localhost:"+port+"/singer/"));

    ResponseEntity<String> response = restTemplate.exchange(req, String.class);
    assertAll("testNegativeCreate",
        () -> assertEquals(HttpStatus.BAD_REQUEST, response.getStatusCode()),
        ()-> assertTrue(response.getBody().contains("could not execute statement;
        SQL [n/a]; constraint [FIRST_NAME]"));
    }
}

```

This test class uses a `TestRestTemplate` instance to submit requests. `TestRestTemplate` is the non-reactive equivalent of the `WebClient` that is covered in **Chapter 20**, and it is a convenient alternative to `RestTemplate` that is suitable for integration tests. It is designed specifically for testing because failed requests with 4xx and 5xx do not throw an exception (like you've noticed in the tests for the classic application), this being very useful for writing negative test cases.

Notice the `testNegativeFindById()` method. Normally a `HttpClientErrorException.BadRequest` would be thrown, but when using `TestRestTemplate`, an actual `ResponseEntity<Singer>` is returned, with an actual body, that is a `Singer` instance with all fields set to null.

This raises the following question: is it possible to handle handler method exceptions better and return a body with proper details? Of course it is. The exception-handling methods in the `RestExceptionHandler` class, annotated with `@RestControllerAdvice`, return a `ResponseEntity<T>`. A custom type could be declared to contain exception details that are clearer and more relevant, like in the example provided here: <https://www.toptal.com/java/spring-boot-rest-api-error-handling>.

## Summary

In this chapter, we covered a few topics about creating Spring Restful web services and exposing them via Spring configuration. The types of configurations covered were the classic configuration, where the application is packed as a \*.war and deployed to an Apache Tomcat 10 server, and configuration using Spring Boot. The REST APIs were consumed using RestTemplate and TestRestTemplate.

This chapter also covered various ways of writing handler methods for REST requests and exception handling. The next chapter is not related to Spring REST in any way, but does cover some newer Spring features, so if you are not sleepy yet, you can start that one.



# Spring Native and Other Goodies

In previous chapters, you saw how the Spring Framework can help Java developers create JEE applications. By using the Spring Framework's dependency injection (DI) mechanism and its integration with each layer (via libraries within the Spring Framework's own modules or via integration with third-party libraries), you can simplify implementing and maintaining business logic.

The Spring Framework has evolved a lot over the years, splitting into separate projects integrating with the latest technologies. Version 6 is truly rich in features and new projects. This chapter introduces you to three important new developments:

- *Spring Native Images*: Spring Boot 2.3.0 introduced the ability to package your app into a Docker image with Cloud Native Buildpacks (CNB). At the same time, Oracle was working on GraalVM,<sup>1</sup> a high-performance JDK distribution written for Java and other JVM languages that promised incredible performance optimizations for individual languages and interoperability for polyglot applications. The goal was eventually to have compact, fast-starting applications that can be run, for example, in an AWS Lambda function. AWS Lambda functions are applications that are triggered on request, without the need for a server running all time. A Spring Boot application running on an AWS EC2 is an infrastructure as a service (IaaS), whereas a Spring Boot application running in a AWS Lambda is a platform as a service (PaaS) that helps you to run and execute your back-end code, only when needed. The Spring Native project provided support for compiling Spring applications to native executables using the GraalVM native-image compiler. This project is now retired, since it was experimental, and its result is the Spring Boot 3 official native support.<sup>2</sup>

---

<sup>1</sup><https://www.graalvm.org>

<sup>2</sup><https://docs.spring.io/spring-boot/docs/current/reference/html/native-image.html>

- *Spring for GraphQL*: GraphQL<sup>3</sup> is a query language for APIs and a runtime for fulfilling those queries with your existing data. For a long time, components in the service layer (services) have been communicating over HTTP using REST requests, handling information in various formats such as JSON, XML, and others. What GraphQL adds in is the possibility to easily declare which data you want retrieved and nothing more without writing complicated code to provide it. Spring for GraphQL<sup>4</sup> provides support for Spring applications built on GraphQL Java. It is a joint collaboration between the GraphQL Java team and Spring engineering. In this chapter you will learn how to build a Spring Boot application capable of retrieving data efficiently in response to GraphQL queries.
- *Spring Kotlin applications*: Kotlin<sup>5</sup> is a cross-platform, statically typed, general-purpose, high-level programming language with type inference. Kotlin is designed to interoperate fully with Java, and the JVM version of Kotlin's standard library provides a more concise syntax, various types, and programming constructs. Some developers have described it as a cross between Scala and Java. The language has a great community supporting it, and is developed by the team that produced the best Java editor, so it is no surprise its adoption was quick; its hype is well deserved. In this chapter you will learn how to use Kotlin to build a small Spring Boot web application.

## Spring Native Images

A Spring Native image is a stand-alone executable that is created by processing a compiled Spring application ahead of time using the GraalVM native-image compiler. Native images are usually a smaller memory footprint and start faster than their JVM counterparts. Also, you don't need a JVM to run them. In previous chapters, the result of building a Spring project was an executable JAR containing all bytecode, a result of compiling all the Java and Spring Code making up that project. To execute the JAR you need a JVM, provided by a JDK (or JRE, in the distant past before Java 9). Spring Native will produce an executable for the targeted system. A native executable is made of the following:

- *Substrate VM*: A virtual machine compiled and configured for the code that needs to be run on it. It is a replacement for a JVM. The process to create it is very similar to how `jlink`<sup>6</sup> is used to strip away from the JDK all modules that are not necessary for running an application, to assemble and optimize a set of modules and their dependencies into a custom runtime image.
- *DWARF info*: Information useful during the debugging processes. DWARF is a debugging information file format used by many compilers. You can read more about it here: <https://dwarfstd.org>.
- *Initial heap*: Memory for the application to run.
- *Native machine code*: Low level code designed to run on a particular operating system.
- *Application compiled to native code*: In this case, a Spring Boot application and all its dependencies.

---

<sup>3</sup><https://graphql.org>

<sup>4</sup><https://docs.spring.io/spring-graphql/docs/current/reference/html>

<sup>5</sup><https://kotlinlang.org>

<sup>6</sup><https://docs.oracle.com/javase/9/tools/jlink.htm>

To keep things simple, the Spring Boot ability to create Docker images is leveraged in this section to create a Docker image that contains the Spring native executable and run the application by starting up a container. This is easier since it doesn't require you to install GraalVM on your machine. Also, you obviously need Docker locally, because the Docker image that you will create needs to be added to an image catalog and then needs a runtime to run a container based on it.

So, what is *ahead-of-time (AOT) compilation* and how is it different from normal Java compilation? There are a few things that are worth mentioning:

- AOT compilation is a process that involves statically analyzing your application code from its main entry point.
- Code that cannot be reached when the native image is created is excluded from the executable. This obviously means that using Spring dynamic elements is out of the window, along with the “automagic” that naive developers are so enthralled by. GraalVM must be told about reflection, resources, serialization, and dynamic proxies.
- The application classpath is known at build time and does not change at runtime. This means there is no lazy class loading, and all the classes in the executables are loaded in memory on startup.
- There might be other limitations for Java applications and the platform that can only be discovered after more companies start using GraalVM. (For example, IJulia have had some problems when building native images for macOS running Apple M1 architecture.)

So, the flexibility and dynamism of Spring Boot applications must be given up in exchange for a small memory footprint and a faster startup. This means profiles are not supported, and beans cannot be modified once created. Is this worth it? Time will tell.

When a Spring application is processed ahead of time, the following must happen for it to be transformed into a native executable:

- Java code is generated
- Bytecode is generated for dynamic proxies
- The following GraalVM JSON hint files are generated that describe how GraalVM should deal with things that it can't understand by directly inspecting the code:
  - Resource hints (`resource-config.json`)
  - Reflection hints (`reflect-config.json`)
  - Serialization hints (`serialization-config.json`)
  - Java proxy hints (`proxy-config.json`)
  - JNI hints (`jni-config.json`)

In a typical Spring application, a lot of reflection is required to inject beans into other beans. The Spring IoC container identifies `@Configuration` classes and bean definitions and creates a dependency tree to decide the order in which the beans are created, so that they can be injected. All this work is done when the application starts, at runtime. This obviously takes some time, as you've probably noticed if you've read the previous chapters and ran the code yourself.

In a Spring Native executable, Spring behaves differently. Configuration classes are no longer identified and parsed and bean definitions are not created at runtime; all this work is done at build time. The bean definitions are processed and converted into source code that is analyzed by the GraalVM compiler, so that

the ones that are not reached (used) can be dropped. The generated code is seriously verbose, because without the power of Spring IoC, all that is left is very explicit code, injecting the right beans in the right places through classic Java code—direct assignment and explicit instantiation of the bean type. This obviously increases the build time, but that is not really a problem.



Development can be done on a normal JVM for the developer's comfort and speed, and the production

build can be isolated on a pipeline and run only when a release is necessary.

---

There are two main ways to build a Spring Boot native image application:

- Using Spring Boot support for Cloud Native Buildpacks (CNB)<sup>7</sup> to generate a lightweight container containing a native executable
- Using GraalVM Native Build Tools to generate a native executable

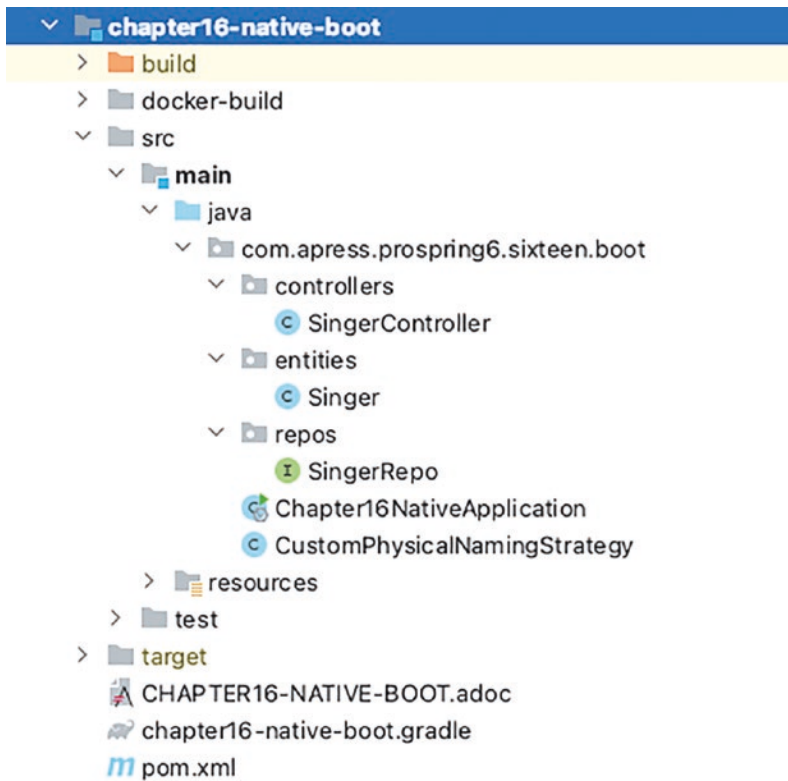
Spring Boot native support is a breeze, especially if you happen to use Gradle, which makes the configuration very concise because of the Gradle Native Build Tools plug-in. For Maven, things are simple too if you declare `spring-boot-starter-parent` as the parent of your project. This is because your project inherits the `native` profile that is configured with all the components necessary to build a Spring Native executable. If having `spring-boot-starter-parent` as a parent is not an option (some companies prefer to have their own custom parent), the configuration is a bit more complicated. The focus of this section is not the code and techniques for writing a Spring application, but the configurations necessary to compile a Spring application into a native executable and run it using a Docker runtime.

## The Application

The Spring application that is compiled into a native executable in this section is a simple Spring Boot REST web application. It uses Spring Data JPA to retrieve data from a database running in a container on your local Docker (could be also remote somewhere if you have the resources). Figure 16-1 shows the structure of the simple project used in this section.

---

<sup>7</sup><https://buildpacks.io>



*Figure 16-1. Project chapter16-native-boot structure*

All the classes should be familiar to you from previous chapters. The `Singer` class is a very simple entity class, declared using Lombok to keep it simple and write it fast, and is shown in Listing 16-1.

*Listing 16-1.* The `Singer` Entity Class

```
package com.apress.prospring6.sixteen.boot.entities;

import jakarta.persistence.*;
import lombok.*;
import org.springframework.format.annotation.DateTimeFormat;
import static jakarta.persistence.GenerationType.IDENTITY;

@Entity // JPA
@Data // Lombok
@AllArgsConstructor // Lombok
@NoArgsConstructor // Lombok
@EqualsAndHashCode(onlyExplicitlyIncluded = true) // Lombok
@Table(name = "SINGER") // JPA
public class Singer {
    @Serial
    private static final long serialVersionUID = 1L;
```

```

@Id // JPA
@GeneratedValue(strategy = IDENTITY) // JPA
@EqualsAndHashCode.Include // Lombok
@Column(name = "ID") // JPA
protected Long id;

@Version
@Column(name = "VERSION")
protected int version;

@Column(name = "FIRST_NAME")
private String firstName;

@Column(name = "LAST_NAME")
private String lastName;

@DateTimeFormat(pattern = "yyyy-MM-dd")
@Column(name = "BIRTH_DATE")
private LocalDate birthDate;
}

```

To handle `Singer` instances, the `SingerRepo` interface is declared as extending `JpaRepository<Singer, Long>` as shown in Listing 16-2.

**Listing 16-2.** The `SingerRepo` Spring Data Interface Class

```

package com.apress.prospring6.sixteen.boot.repos;

import com.apress.prospring6.sixteen.boot.entities.Singer;
import org.springframework.data.jpa.repository.JpaRepository;

public interface SingerRepo extends JpaRepository<Singer, Long> {
}

```

To keep things simple, the `SingerController` class requires an instance of `SingerRepo` to pass data back and forth via its handler methods (for simplicity, we are skipping the service layer). This class and bean declaration are shown in Listing 16-3.

**Listing 16-3.** The `SingerController` Class

```

package com.apress.prospring6.sixteen.boot.controllers;

// other import statements omitted
import org.springframework.web.bind.annotation.*;

@RestController
@RequestMapping(value="/singer")
public class SingerController {

    final Logger LOGGER = LoggerFactory.getLogger(SingerController.class);

    private final SingerRepo singerRepo;
}

```



```

public SingerController(SingerRepo singerRepo) {
    this.singerRepo = singerRepo;
}

@GetMapping(path="/", "")
public List<Singer> all() {
    return singerRepo.findAll();
}

@GetMapping(path =("/{id}")
public Singer findSingerById(@PathVariable Long id) {
    return singerRepo.findById(id).orElse(null);
}

// other methods omitted
}

```

The CustomPhysicalNamingStrategy bean is used to configure Spring Data to recognize database objects with names consisting of only uppercase letters, and is out of scope for this section. The Chapter16NativeApplication class shown in Listing 16-4 is a basic Spring Boot configuration and main class, the entry point of this application.

**Listing 16-4.** The Chapter16NativeApplication Class

```

package com.apress.prospring6.sixteen.boot;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.boot.autoconfigure.domain.EntityScan;
import org.springframework.data.jpa.repository.config.EnableJpaRepositories;
import org.springframework.transaction.annotation.EnableTransactionManagement;

@EntityScan(basePackages = {"com.apress.prospring6.sixteen.boot.entities"})
@EnableJpaRepositories("com.apress.prospring6.sixteen.boot.repos")
@EnableTransactionManagement
@SpringBootApplication
public class Chapter16NativeApplication {

    public static void main(String... args) {
        SpringApplication.run(Chapter16NativeApplication.class, args);
    }
}

```

As you can see, there is nothing in the code that needs to be modified for this application to be eligible to be compiled as a Spring Native executable.

## The Configuration

It is all in the configuration. So, let's look at the Gradle configuration first, because this is the smaller one. Listing 16-5 shows the Gradle configuration for the chapter16-native-boot project.

**Listing 16-5.** The Contents of the chapter16-native-boot.gradle File

```

apply plugin: 'java'
apply plugin: 'org.graalvm.buildtools.native'

dependencies {
    implementation 'org.springframework.boot:spring-boot-starter-web'
    implementation 'org.springframework.boot:spring-boot-starter-data-jpa'

    implementation "commons-io:commons-io:2.11.0"

    compileOnly "org.projectlombok:lombok:$lombokVersion"
    annotationProcessor "org.projectlombok:lombok:$lombokVersion"

    implementation "com.zaxxer:HikariCP:$hikariVersion"
    implementation "org.mariadb.jdbc:mariadb-java-client:$mariadbClientVersion"
}

tasks.named("bootBuildImage") {
    docker {
        buildpacks = [
            "gcr.io/paketo-buildpacks/graalvm",
            "gcr.io/paketo-buildpacks/java-native-image",
        ]
    }
    imageName = "prospring6-gradle-native:1.0"
}

bootJar {
    manifest {
        attributes 'Start-Class': 'com.apress.prospring6.sixteen.boot.
        Chapter16NativeApplication'
    }
}

```

The most important part of this configuration is the GraalVM Native Image plug-in: `org.graalvm.buildtools.native`. The current version of this project is 0.9.22 and it is added to the classpath of the parent project `pro-spring-6`. The parent project also configures the Spring Boot project for all subprojects with names ending in `boot`. The configuration snippets are shown in Listing 16-6.

**Listing 16-6.** `pro-spring-6` Project Configuration Snippets

```

buildscript {
    repositories {
        mavenLocal()
        mavenCentral()
    }

    dependencies {
        classpath 'io.spring.gradle:dependency-management-plugin:1.1.0'
        classpath 'org.springframework.boot:spring-boot-gradle-plugin:3.0.7'
    }
}

```

```

        classpath 'org.graalvm.buildtools.native:org.graalvm.buildtools.native.gradle.
        plugin:0.9.22'
    }
}

ext {
    bootProjects = subprojects.findAll { ( it.name.endsWith('-boot')) }
    // various version variables omitted
}
// other configuration somitted

configure(bootProjects) { project ->
    apply plugin: 'org.springframework.boot'
}

```

Notice the `buildscript.dependencies` declaring plug-ins to be added to the project classpath. The plug-in declarations follow the template of `groupId:artifactId:version`. This is the equivalent of a `<pluginManagement><plugins>` declaration in Maven.

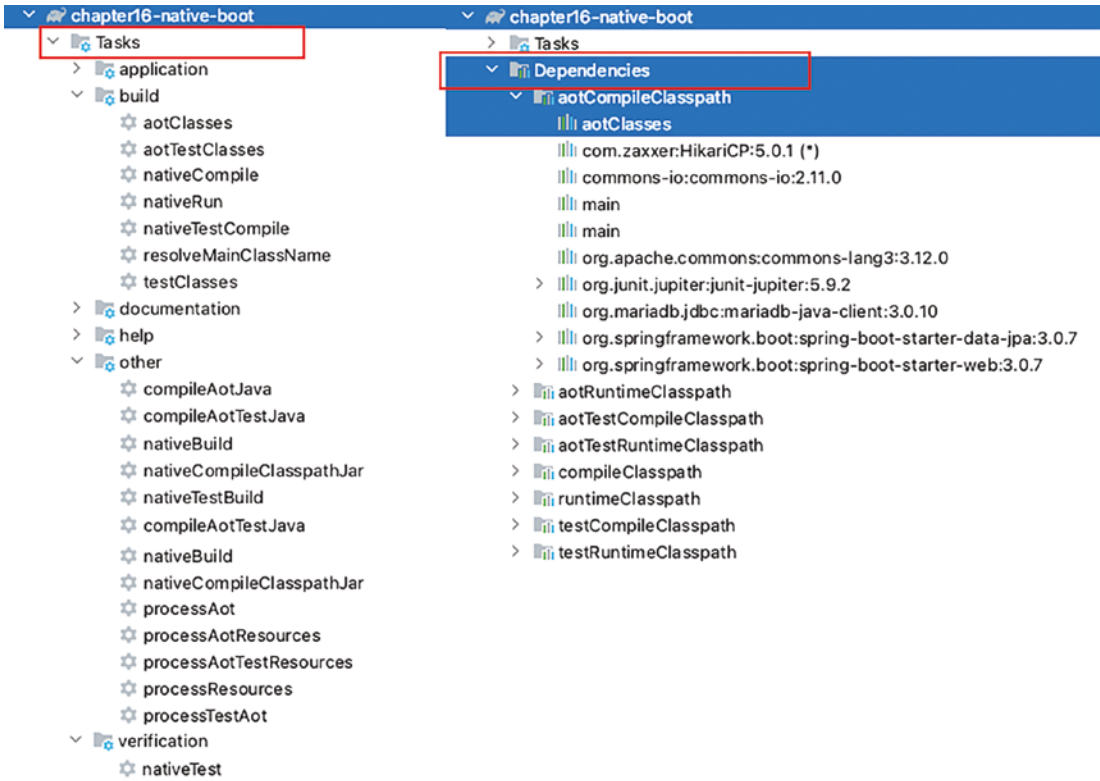
The `bootProjects` variable is an array containing all the Spring Boot subprojects (or modules) of the `pro-spring-6` parent. The `configure(bootProjects)` statement configures the Spring Boot plug-in for all Spring Boot subprojects. Independently, each subproject Gradle configuration contains additional plug-in configurations for the plug-ins in the classpath.



This configuration approach is specific to the `pro-spring-6` project. This is a multi-modular project containing Spring Boot and Spring classic projects, all making use of the awesome Spring Dependency management, and reusing a lot of configurations. When using Spring Initializr to create a Spring Boot project, whether using Maven or Gradle, all that configuration is already declared in the Spring Boot project you are inheriting it from.

---

The `chapter16-native-boot.gradle` file contains the `org.graalvm.buildtools.native` plug-in declaration. Because of its presence in the configuration, the Spring Boot Gradle plug-in adds AOT tasks to the project. Since IntelliJ IDEA is smart, it shows in the Gradle View all the tasks under their scope and the dependencies for AOT purposes. Figure 16-2 depicts the Gradle View, showing the AOT and Native tasks and dependency groups.



**Figure 16-2.** AOT and Native task and dependency groups for project `chapter16-native-boot`

Notice that in `aotCompileClasspath` there is an item named `aotClasses`, which represents the static code generated for Spring configuration classes and bean definitions. The `main` probably represents the main entry point of the application, which is the `main(..)` method in the `Chapter16NativeApplication` class.

Since Java 19 is configured for this project, we need to customize the Cloud Native Buildpacks used to create the executable. We do so by specifying an array with the two values shown in the configuration for the buildpacks property: `gcr.io/paketo-buildpacks/graalvm` and `gcr.io/paketo-buildpacks/java-native-image`.

To easily recognize the resulting native image in the Docker dashboard, the `imageName` property is set to `prospring6-gradle-native:1.0`.

With this configuration, all that remains to do is to create the image by running `gradle bootBuildImage` in the terminal, in the `chapter16-native-boot` directory. The execution will take a long time, at least the first time. For this small project it took about 5 minutes, but this is because the Docker images the executable is based on need to be downloaded too. Listing 16-7 shows some snippets of this execution.

**Listing 16-7.** `gradle bootBuildImage` Execution Log Snippets

```
> Task :chapter16-native-boot:compileJava
...
> Task :chapter16-native-boot:processAot
...
>Task :chapter16-native-boot:compileAotJava
...
> Task :chapter16-native-boot:bootBuildImage
```

```

Building image 'docker.io/library/prospring6-gradle-native:1.0'

> Pulling builder image 'docker.io/paketobuildpacks/builder:tiny' ...
> Pulling run image 'docker.io/paketobuildpacks/run:tiny-cnb' ...
> Pulling buildpack image 'gcr.io/paketo-buildpacks/graalvm:latest' ...
> Pulling buildpack image 'gcr.io/paketo-buildpacks/java-native-image:latest' ...
> Executing lifecycle version v0.16.0

> Running creator
[creator]      ==> ANALYZING
[creator]      Previous image with name "docker.io/library/prospring6-gradle-native:1.0"
not found
[creator]      ==> DETECTING
[creator]      7 of 15 buildpacks participating
[creator]      paketo-buildpacks/graalvm          7.10.0
...
[creator]      ==> BUILDING
[creator]      Paketo Buildpack for GraalVM 7.10.0
...
[creator]      Build Configuration:
[creator]      $BP_NATIVE_IMAGE                true  enable native image build
# other build specific variables
[creator]      Native Image: Contributing to layer
[creator]      Executing native-image ... # classpath omitted
[creator]      =====
[creator]      GraalVM Native Image: Generating '/layers/paketo-buildpacks_native-image/
native-image/com.apress.prospring6.sixteen.boot.Chapter16NativeApplication' (static
executable)...
[creator]      =====
[creator]      [1/7] Initializing...
[creator]      [2/7] Performing analysis... [*****]                (138.0s @ 3.28GB)
[creator]      [3/7] Building universe...                (16.0s @ 3.34GB)
[creator]      [4/7] Parsing methods... [***]                (10.8s @ 3.47GB)
[creator]      [6/7] Compiling methods... [*****]                (75.3s @ 3.19GB)
[creator]      [7/7] Creating image...                (13.0s @ 2.88GB)
# listing packages, object types and sizes omitted
...
[creator]      20.4s (6.9% of total time) in 129 GCs | Peak RSS: 5.36GB | CPU
load: 5.51
[creator]      -----
[creator]      Produced artifacts:
[creator]      /layers/paketo-buildpacks_native-image/native-image/com.apress.
prospring6.sixteen.boot.Chapter16NativeApplication (executable)
[creator]      /layers/paketo-buildpacks_native-image/native-image/com.apress.prospring6.
sixteen.boot.Chapter16NativeApplication.build_artifacts.txt (txt)
[creator]      =====
[creator]      Finished generating '/layers/paketo-buildpacks_native-image/native-image/
com.apress.prospring6.sixteen.boot.Chapter16NativeApplication' in 4m 53s.
[creator]      ==> EXPORTING
[creator]      Adding layer 'paketo-buildpacks/ca-certificates:helper'
[creator]      Adding layer 'buildpacksio/lifecycle:launch.sbom'

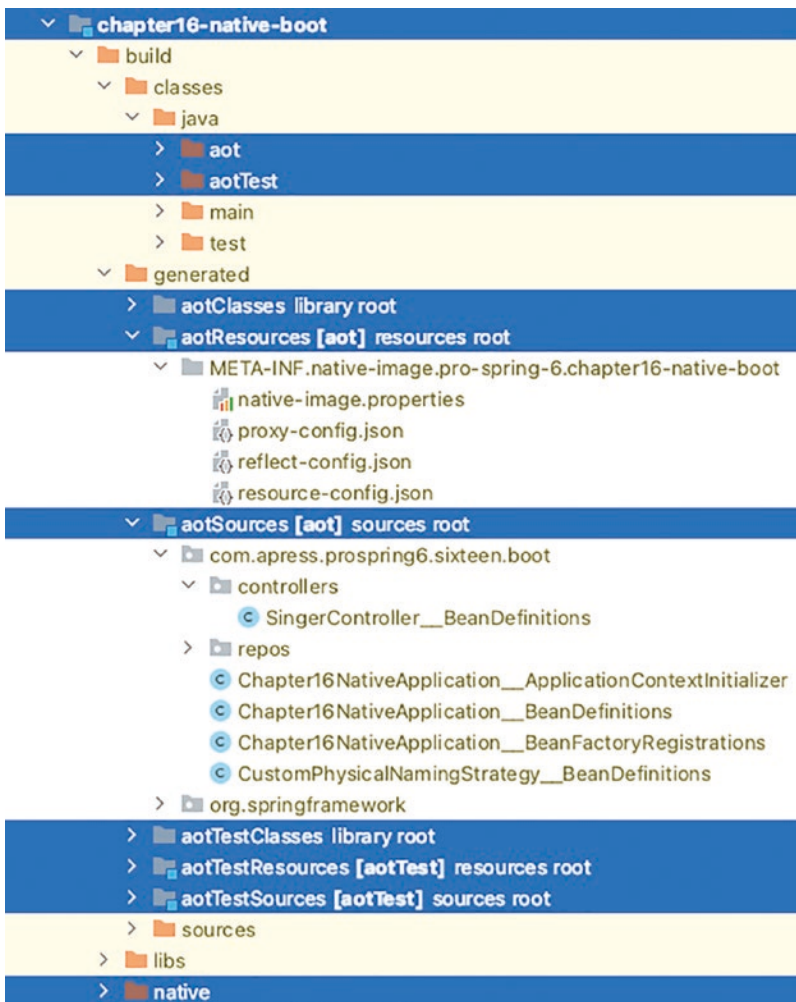
```

```
# layers to build the image
Successfully built image 'docker.io/library/prospring6-gradle-native:1.0'
```

BUILD SUCCESSFUL in 5m 36s  
 9 actionable tasks: 8 executed, 1 up-to-date

First, the compileJava task compiles the project, making sure all dependencies are provided and the project is functional. Then the processAot task generates the AOT Java code. Then the processAot starts the application to check that it still works. Then the compileAotJava produces the **native bytecode**.

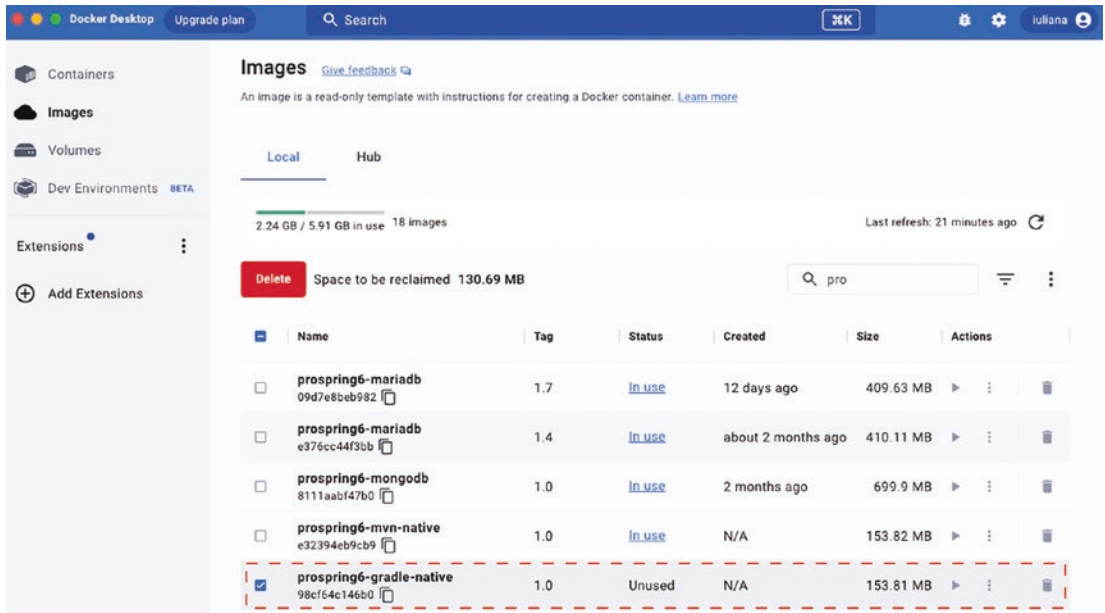
The results of all these tasks can be seen in the build/generated directory. This is where the AOT-generated Java code and the GraalVM JSON hint files are saved. The bytecode and native code are stored under build/classes/java/ directories grouped by their scope. Figure 16-3 shows these new directories and some contents.



**Figure 16-3.** Intermediary files created by the build process that produces a native image

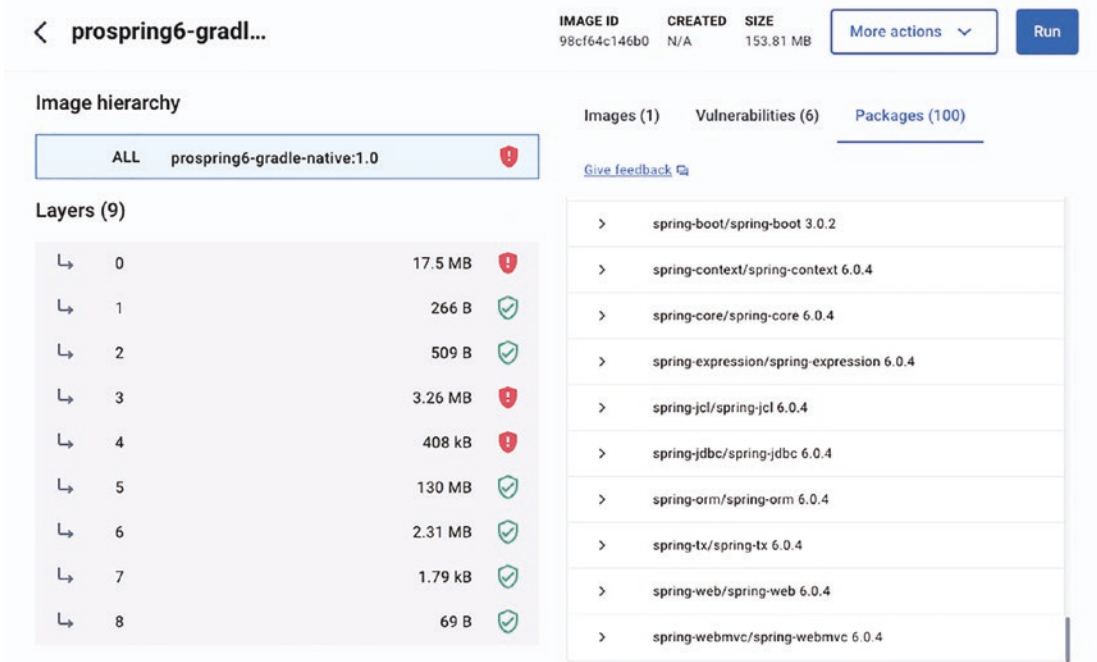
Finally, the `bootBuildImage` starts building the image for the native executable. First it downloads the base CNB images, and then it builds the executable based on the GraalVM JDK 19.0.2, adding only bits and pieces necessary for the executable to run. In the end a static executable is produced, and then processed to compute the memory footprint and its storage requirements, which will determine these parameters for the Docker image.

If all these steps are successful, the Images tab of the Docker dashboard should list the recently produced `prospring6-gradle-native:1.0` image, as shown in Figure 16-4.



**Figure 16-4.** Docker dashboard showing the `prospring6-gradle-native:1.0` image

Notice the size of the image. Clicking its name reveals details of the image, as shown in Figure 16-5, such as the layers, its contents, and its vulnerabilities (nothing to worry about necessarily, because any software has vulnerabilities; it only depends on how critical they are).



**Figure 16-5.** Docker dashboard showing the details of the `prospring6-gradle-native:1.0` image

To check if this image works, we should start a container based on it, but since we know our application needs a database, we need a way to tell it where to find it and how to connect to it. All these details are provided via program arguments that become environment variables for the container. Spring Boot applications can reference these variables in the configuration files. The `application.yaml` file data source configuration needs to be modified to pick up the values necessary for connecting to the database from environment variables. The configuration sample is depicted in Listing 16-8.

**Listing 16-8.** Spring Boot Configuration File That References Environment Variables

```
spring:
  datasource:
    driverClassName: org.mariadb.jdbc.Driver
    url: jdbc:mariadb://${DB_HOST:localhost}:${DB_PORT:3306}/${DB_SCHEMA:musicdb}?useSSL=false
    username: ${DB_USER:prospring6}
    password: ${DB_PASS:prospring6}
```

The `${VAR_NAME:default_value}` construct are used to provide a default value for a variable in the case when starting the application, the environment variable is neither set nor provided via the command line. All the variables in the configuration have default values. When running an application within a container that needs to connect to a database running in another container, the only one variable we need a value for is `DB_HOST`, because in a container `localhost` points to itself. To obtain the IP address of the container where the database is accessible, assuming the container is named `local-mariadb`, the command in Listing 16-9 gets the job done.



**Listing 16-9.** Command to Retrieve a Running Docker Container’s IP Address

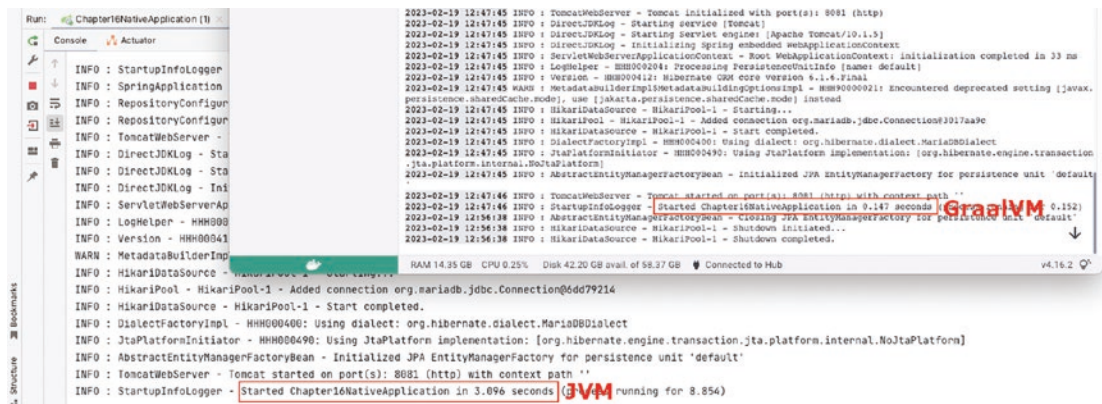
```
docker inspect local-mariadb | grep IPAddress # assuming 172.17.0.2
```

Now that we have the database IP address, we can start our native container using the command in Listing 16-10.

**Listing 16-10.** Command to Start the Container Using the Native Image we’ve built with Gradle

```
docker run --name prospring6-native -e DB_HOST=172.17.0.2 -d -p 8081:8081 prospring6-gradle-native:1.0
```

To make sure the application started correctly, you can try accessing `http://localhost:8081/singers`, and all `Singer` instances’ JSON representations should be returned. The other way to ensure the application started correctly is to inspect the container log in the Docker dashboard, which shows not only the Spring Boot application startup log, but also the time it took the application to start, which is where one of the superpowers of native images shines. Figure 16-6 shows a comparison between the `Chapter16NativeApplication` being started on a local system on JVM and the same application starting from a native executable within a container.



**Figure 16-6.** Startup times for a container based on the `prospring6-gradle-native:1.0` image

The time dropped from 3 seconds to 0.147 second when the application was built into a native executable, so the startup time diminished by half, and this is just for a small, very simple application. For applications doing more complex operations, the improvement might be even better.

Declaring `spring-boot-starter-parent` ensures that the project inherits default configurations for the Spring Boot and GraalVM Maven plug-ins grouped under the native profile. When using `spring-boot-starter-parent` as a parent, the only explicit configuration needed is for Spring Boot, as shown in Listing 16-11.

**Listing 16-11.** Native Configuration for a Spring Boot Project That Declares `spring-boot-starter-parent` As a Parent

```
<!-- other configurations omitted -->
<build>
  <plugins>
    <plugin>
```

```

    <groupId>org.graalvm.buildtools</groupId>
    <artifactId>native-maven-plugin</artifactId>
    <version>0.9.22</version>
  </plugin>
  <plugin>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-maven-plugin</artifactId>
    <configuration>
      <mainClass>com.example.demo.DemoApplication</mainClass>
      <image>
        <buildpacks>
          <buildpack>gcr.io/paketo-buildpacks/graalvm</buildpack>
          <buildpack>gcr.io/paketo-buildpacks/java-native-image</buildpack>
        </buildpacks>
      </image>
      <imageName>demo-native-mvn:${project.version}</imageName>
    </configuration>
  </plugin>
</plugins>
</build>

```

The configuration is pretty similar to what was done in Gradle. Custom buildpacks are declared to support Java 19 and a custom image name is added to the configuration so that the result of the build is easy to spot in the Docker image collection.

When `spring-boot-starter-parent` is not used as a parent, the Maven configuration must include more-verbose configurations for the `native-maven-plugin` and `spring-boot-maven-plugin`. It's pretty easy to do since they can be copied from the `spring-boot-starter-parent` pom file. The configuration is shown in Listing 16-12.

**Listing 16-12.** Native Configuration for a Spring Boot Project That Does Not Declare `spring-boot-starter-parent` As a Parent

```

<!-- other configurations omitted -->
<build>
  <plugins>
    <plugin>
      <groupId>org.graalvm.buildtools</groupId>
      <artifactId>native-maven-plugin</artifactId>
      <version>${spring-native.version}</version>
      <configuration>
        <classesDirectory>${project.build.outputDirectory}</classesDirectory>
        <metadataRepository>
          <enabled>true</enabled>
        </metadataRepository>
        <requiredVersion>22.3</requiredVersion>
      </configuration>
    <executions>
      <execution>
        <id>add-reachability-metadata</id>
        <goals>
          <goal>add-reachability-metadata</goal>
        </goals>
      </execution>
    </executions>
  </plugins>
</build>

```

```

        </execution>
    </executions>
</plugin>
<plugin>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-maven-plugin</artifactId>
    <version>${spring-boot.version}</version>
    <configuration>
        <mainClass>com.apress.prospring6.sixteen.boot.Chapter16NativeApplication</
        mainClass>
        <image>
            <builder>paketobuildpacks/builder:tiny</builder>
            <env>
                <BP_NATIVE_IMAGE>true</BP_NATIVE_IMAGE>
            </env>
            <buildpacks>
                <buildpack>gcr.io/paketo-buildpacks/graalvm</buildpack>
                <buildpack>gcr.io/paketo-buildpacks/java-native-image</buildpack>
            </buildpacks>
        </image>
        <imageName>prospring6-mvn-native:1.0</imageName>
        <excludes>
            <exclude>
                <groupId>org.projectlombok</groupId>
                <artifactId>lombok</artifactId>
            </exclude>
        </excludes>
    </configuration>
</plugin>
</plugins>
</build>

```

With this configuration, you can generate the native image by executing `mvn spring-boot:build-image`. Notice that the image name was set to `prospring6-mvn-native:1.0` to differentiate it easily from the one generated with Gradle.

All the intermediary generated sources, bytecode, and native code are located under the `target` directory, but compared to Gradle, they are just scattered everywhere under `target/classes`, because Maven does not create separate directories for different goals.

The Maven build execution for generating a native image for the `Chapter16NativeApplication` takes about 5 minutes as well, and at the end the image is listed in the Docker dashboard, as shown in Figure 16-7.

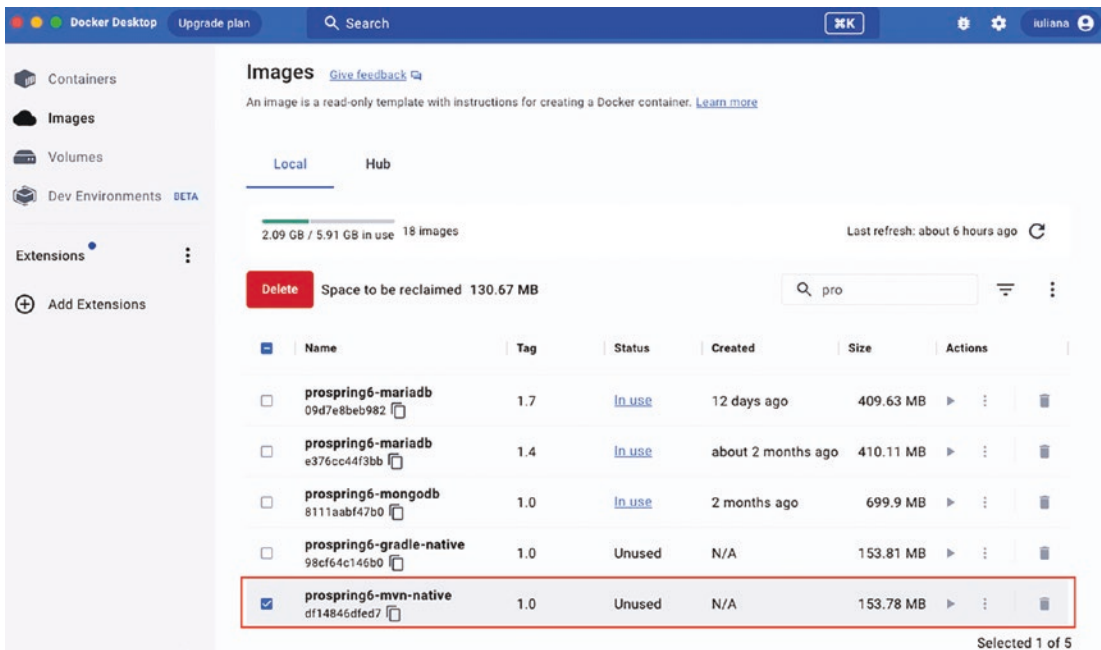


Figure 16-7. Docker dashboard showing the `prospring6-mvn-native:1.0` image

Starting a container based on this image is done with the same command as the one shown in Listing 16-10; just make sure to name the container differently.

To read more about native images and recommendations on how to better develop Spring applications such that they are easily built into native executables, read the official documentation, and keep an eye out for any talks on this subject at conferences. The technology, although out of the experimental phase, is still in an early phase and has a long way to go to become the industry default for Java applications, if that even happens at all.

## Spring for GraphQL

GraphQL is a query language for APIs and a runtime for providing data according to those queries. GraphQL provides a complete and understandable description of the data in your API and allows the client to ask for some data and receive only what they asked for without writing complicated code to do so.

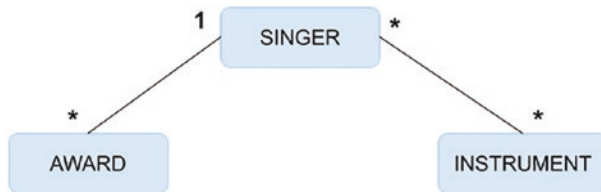
Consider the REST APIs that were built so far in this book. REST requests are mapped to URL paths such as `http://localhost:8081/singer/1`. A client sends an HTTP GET request and receives all the information about a singer that is retrieved from a database table named `SINGER` for the record identified with a primary key equal to 1. If the client needs information about this singer that is held in other tables, different queries must be written, and they will be mapped to different URL paths. So, the client must do multiple requests. With GraphQL, the client doesn't have to change the URL for the request, just the schema used to specify the required data. In the end, GraphQL is just another alternative to established remote communications between applications such as REST, SOAP, or gRPC.

Facebook invented GraphQL because REST was not a solution to retrieve a graph of related information for a single request. Using REST, multiple back and forth communication would make the page load slowly and generate unacceptable flicker. We could describe GraphQL in a lot more depth, but for purposes of this discussion, we'll simply list its most important characteristics:

- GraphQL is schema based.
- GraphQL queries look a lot like JSON, but they are not JSON.
- GraphQL is heavily typed. The GraphQL schema language supports the scalar types of `String`, `Int`, `Float`, `Boolean`, and `ID`, so you can use these directly in the schema you pass to `buildSchema`.
- GraphQL is designed for developers.
- GraphQL is transport agnostic; it is mostly used over HTTP, but is not limited to it. For example, you can use it over TCP and over WebSockets.
- GraphQL queries are sent over using POST requests, so they can be as big and as complex as necessary to specify data to be retrieved from different levels in a database by nesting the desired properties.

REST APIs are a collection of endpoints, whereas GraphQL APIs are focused on the data. This section is focused on writing a Spring Boot application with support for GraphQL. Core concepts of GraphQL are explained gradually as the need arises.

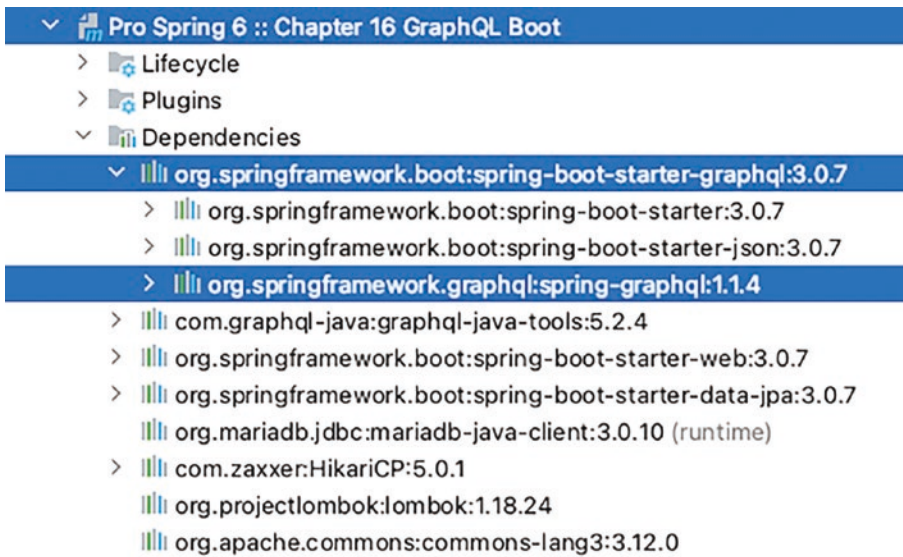
For this section we'll use a modified version of the database used so far in the book. The data managed by this application is stored in three tables, `SINGER`, `AWARD`, and `INSTRUMENT`, that are related as shown in Figure 16-8.



**Figure 16-8.** Table relationships for project `chapter16-graphql-boot`

For the code samples in this chapter, the tables are part of a schema that is named `MUSICDB`, and the user to access it is named `prospring6`. The SQL code to create the schema can be found in the `chapter16-graphql-boot/docker-build/scripts/CreateTable.sql` file in the directory of the `chapter16-graphql-boot` project. The SQL code to execute to populate the tables can be found in the `chapter16-graphql-boot/docker-build/scripts/InsertData.sql` file in the directory of the `chapter16-graphql-boot` project. These scripts are part of a Docker configuration used to build an image with the database needed for the examples.

Except the `spring-boot-starter-graphql` dependency, all the dependencies are the same as for a Spring Boot web application backed up by a MariaDB database accessed through Spring Data repositories. Figure 16-9 shows the dependencies of the `chapter16-graphql-boot` project.



**Figure 16-9.** Dependencies for project *chapter16-graphql-boot*

The Singer entity class is shown in Listing 16-13 and is no different than the entity classes introduced in the data access chapters.

**Listing 16-13.** The Singer Entity Class

```
package com.apress.prospring6.sixteen.boot.entities;
```

```
import jakarta.persistence.*;  
import lombok.*;  
// other import statements omitted
```

```
@Entity  
@Data  
@AllArgsConstructor  
@NoArgsConstructor  
@EqualsAndHashCode(onlyExplicitlyIncluded = true)  
@Table(name = "SINGER")  
public class Singer implements Serializable {  
    @Serial  
    private static final long serialVersionUID = 1L;  
  
    @Id  
    @GeneratedValue(strategy = IDENTITY)  
    @EqualsAndHashCode.Include  
    @Column(name = "ID")  
    protected Long id;
```

```

@Version
@Column(name = "VERSION")
protected int version;

@Column(name = "FIRST_NAME")
private String firstName;

@Column(name = "LAST_NAME")
private String lastName;

@Column(name = "PSEUDONYM")
private String pseudonym;

@Column(name = "GENRE")
private String genre;

@DateTimeFormat(pattern = "yyyy-MM-dd")
@Column(name = "BIRTH_DATE")
private LocalDate birthDate;

@OneToMany(mappedBy = "singer")
private Set<Award> awards;

@ManyToMany
@JoinTable(name = "SINGER_INSTRUMENT",
    joinColumns = @JoinColumn(name = "SINGER_ID"),
    inverseJoinColumns = @JoinColumn(name = "INSTRUMENT_ID"))
private Set<Instrument> instruments;
}

```

To keep things simple and avoid the need for a lot of boilerplate code, Lombok is used to annotate this class and its fields, so that the proper setters, getters, constructors, and so on are generated. Notice the `@OneToMany` relationship between the `Singer` and `Award` classes and the `@ManyToMany` relationship between `Singer` and `Instrument`. Both relationships are by default lazily initialized by the persistence provider runtime when first accessed. This is an important detail, as you will see later.

The `Award` entity class is shown in Listing 16-14.

**Listing 16-14.** The `Award` Entity Class

```

package com.apress.prospring6.sixteen.boot.entities;

import jakarta.persistence.*;
import lombok.*;
// other import statements omitted

@Entity
@Data
@NoArgsConstructor
@AllArgsConstructor
@EqualsAndHashCode(onlyExplicitlyIncluded = true)
@Table(name = "AWARD")

```

```

public class Award implements Serializable {
    @Serial
    private static final long serialVersionUID = 3L;

    @Id
    @EqualsAndHashCode.Include
    @GeneratedValue(strategy = IDENTITY)
    @Column(name = "ID")
    protected Long id;

    @Version
    @Column(name = "VERSION")
    protected int version;

    @ManyToOne
    @JoinColumn(name = "SINGER_ID")
    private Singer singer;

    @Column(name = "YEAR")
    private Integer year;

    @Column(name = "TYPE")
    private String category;

    @Column(name = "ITEM_NAME")
    private String itemName;

    @Column(name = "AWARD_NAME")
    private String awardName;
}

```

Notice the `@ManyToOne` relationship between `Award` and `Singer`. By default, the `singer` field is eagerly initialized by the persistence provider runtime when first accessed. The `SINGER_ID` column is actually a foreign key, making the `singer` record a parent of this award, so it makes sense that when an award record is accessed, its parent should be accessible too.

The `Instrument` entity class is a very simple one, mapping to a table with a single column that is its primary key as well. It was introduced more as a plot device (sic!) to show a `@ManyToMany` relationship.

The Spring Data repository interfaces are those used in the data access chapters—simple extensions of `JpaRepository`. The repository interfaces are shown in Listing 16-15.

**Listing 16-15.** The Repository Interfaces

```

package com.apress.prospring6.sixteen.boot.entities;
// import statements omitted

public interface SingerRepo extends JpaRepository<Singer, Long> { }

public interface AwardRepo extends JpaRepository<Award, Long>{ }

public interface InstrumentRepo extends JpaRepository<Instrument, String> {
}

```



For simplicity, we will not be using service beans, and we'll jump directly to implementing GraphQL controllers. Spring for GraphQL provides an annotation-based programming model where `@Controller` components use specific GraphQL annotations to decorate handler methods with flexible signatures, to fetch data for specific GraphQL fields. Let's consider the simplest example, querying for all the singers. Listing 16-16 shows a controller with a handler method for responding to a GraphQL query for retrieving all singers.

**Listing 16-16.** GraphQL Handler Method for Returning All Singers in the Singer Table

```
package com.apress.prospring6.sixteen.boot.controllers;

import org.springframework.graphql.data.method.annotation.QueryMapping;
import org.springframework.stereotype.Controller;

// other import statements omitted

@Controller
public class SingerController {

    private final SingerRepo singerRepo;

    public SingerController(SingerRepo singerRepo) {
        this.singerRepo = singerRepo;
    }

    @QueryMapping
    public Iterable<Singer> singers(){
        return singerRepo.findAll();
    }

    // other handler methods omitted
}
```

The `@Controller` annotation is the same stereotype annotation introduced earlier in this book. It is automatically picked up by Spring Boot, which adds all `org.springframework.graphql.execution.RuntimeWiringConfigurer` beans to `org.springframework.graphql.execution.GraphQLSource.Builder` and enables support for annotated `graphql.schema.DataFetcher` instances.

The `@QueryMapping` annotation binds the method to a query, a GraphQL field under a Query type. `@QueryMapping` is a composed annotation that acts as a shortcut for `@SchemaMapping` with `typeName="Query"`. It is a practical way to map controller methods to GraphQL queries. You can think of the `@SchemaMapping` as the `@RequestMapping` for GraphQL.

Now that we have a handler method, we need to configure the GraphQL schemas with objects, queries, and mutations definitions. These three terms are the core terms of GraphQL. As previously mentioned, GraphQL is statically typed, which means the server knows exactly the shape of every object you can query and any client can actually “introspect” the server and ask for the “schema.” These types are declared in schema files located under `resources/graphql` and they map to all objects involved in GraphQL actions of any kind.

Listing 16-17 shows the schema for the `Singer` object and the `singers` query definition that are declared in `resources/graphql/singer.graphqls`.

**Listing 16-17.** GraphQL Schema for the Singer Type and singers Query

```

type Singer {
  id: ID!
  firstName: String!
  lastName: String!
  pseudonym: String
  genre: String
  birthDate: String
  awards: [Award]
  instruments: [Instrument]
}

type Query {
  singers: [Singer]
}

```

The schema describes what queries are possible and what fields you can get back for a certain type. If fields are supposed to be not null, in the declaration the type must be suffixed with ! (exclamation mark).

So, now that we have a schema, are we ready to submit GraphQL requests? Not yet, because we still need to configure the Spring Boot application to support GraphQL, as shown in Listing 16-18.

**Listing 16-18.** Spring Boot Application Configuration for GraphQL

```

server:
  port: 8081
  servlet:
    context-path: /
  compression:
    enabled: true
  address: 0.0.0.0

spring:
  graphql:
    graphiql:
      enabled: true
      path: graphiql

datasource:
  driverClassName: org.mariadb.jdbc.Driver
  url: jdbc:mariadb://localhost:3307/musicdb?useSSL=false
  username: prospring6
  password: prospring6
  hikari:
    maximum-pool-size: 25

jpa:
  generate-ddl: false
  properties:
    hibernate:
      naming:
        physical-strategy: com.apress.prospring6.sixteen.boot.CustomPhysicalNamingStrategy
  jdbc:

```

```

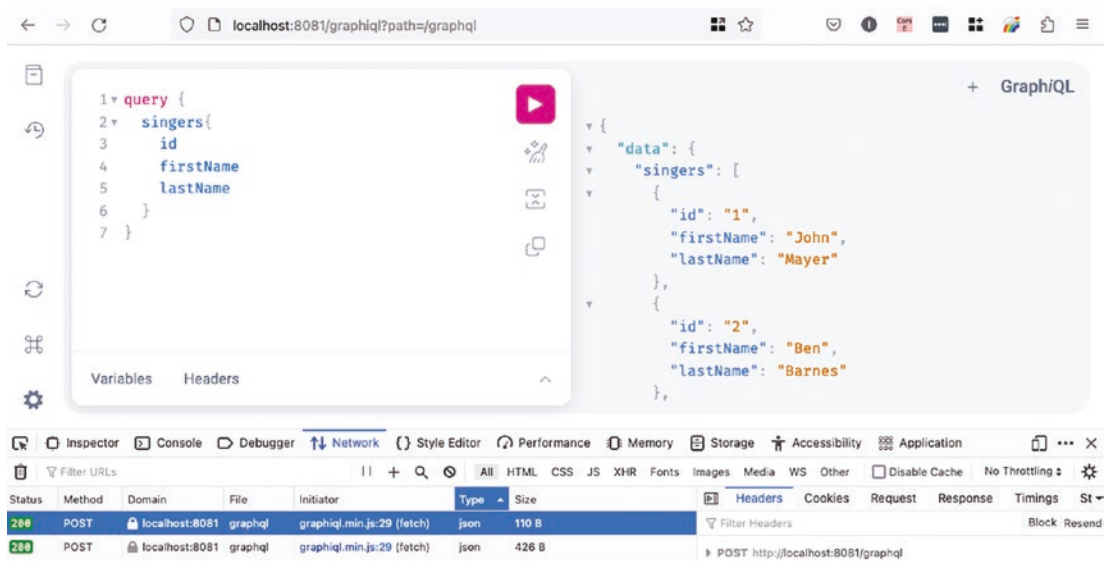
    batch_size: 10
    fetch_size: 30
    max_fetch_depth: 3
    hbm2ddl:
      auto: none
# logging configuration omitted

```

GraphQL queries can be sent to an application using a web interface named GraphiQL. This is a web console that can communicate with any GraphQL server and helps to consume and develop against a GraphQL API. It is included in the Spring Boot starter for GraphQL and is exposed by default at the `/graphql` endpoint. In the configuration sample in Listing 16-8 the same value is configured just to show that the property `spring.graphql.graphiql.path` can be used to customize the URL path where the web console is accessible. The endpoint is disabled by default, but it can be turned on by setting the `spring.graphql.graphiql.enabled` property to `true`. GraphiQL is a very practical tool to write and test queries, particularly during development and testing.

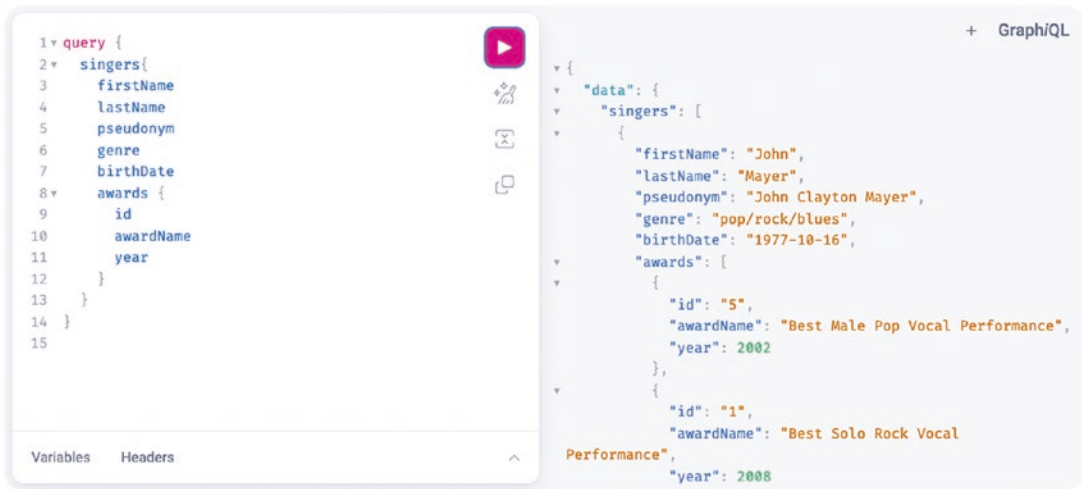
Now we are ready to start the application and write some queries. To access GraphiQL, open the `http://localhost:8081/graphql` URL in the browser. This opens a page with a nice editor that on the left has an entry text area where the queries can be written and, on the right, the retrieved data is shown.

Figure 16-10 shows the GraphiQL web console.



**Figure 16-10.** GraphiQL web console with a simple query

The query in this image is simple; we can add more fields and even relationships. Figure 16-11 shows a GraphQL query that retrieves all the details for all the singers (not something you would ever need to do, but just know it is possible).



**Figure 16-11.** GraphQL web console with a nested query

So this works, even though, as previously mentioned, the awards collection is lazily initialized. So, how is GraphQL doing it? It would be interesting to see how many queries are executed on the table for retrieving that data—in short, how efficient it really is. To figure this out, let’s enable SQL logging in the Spring Boot configuration by adding the property `logging.level.sql=debug` to the configuration.

If we send the same query and look in the console log, we can see the log in Listing 16-19.

**Listing 16-19.** Database Queries logged in the console for a lazily initialized collection

```

DEBUG: SqlStatementLogger - select s1_0.ID,s1_0.BIRTH_DATE,s1_0.FIRST_NAME,s1_0.GENRE,s1_0.LAST_NAME,s1_0.PSEUDONYM,s1_0.VERSION from SINGER s1_0
DEBUG: SqlStatementLogger - select a1_0.SINGER_ID,a1_0.ID,a1_0.AWARD_NAME,a1_0.TYPE,a1_0.ITEM_NAME,a1_0.VERSION,a1_0.YEAR from AWARD a1_0 where a1_0.SINGER_ID=?
DEBUG: SqlStatementLogger - select a1_0.SINGER_ID,a1_0.ID,a1_0.AWARD_NAME,a1_0.TYPE,a1_0.ITEM_NAME,a1_0.VERSION,a1_0.YEAR from AWARD a1_0 where a1_0.SINGER_ID=?
DEBUG: SqlStatementLogger - select a1_0.SINGER_ID,a1_0.ID,a1_0.AWARD_NAME,a1_0.TYPE,a1_0.ITEM_NAME,a1_0.VERSION,a1_0.YEAR from AWARD a1_0 where a1_0.SINGER_ID=?
DEBUG: SqlStatementLogger - select a1_0.SINGER_ID,a1_0.ID,a1_0.AWARD_NAME,a1_0.TYPE,a1_0.ITEM_NAME,a1_0.VERSION,a1_0.YEAR from AWARD a1_0 where a1_0.SINGER_ID=?
...

```

Two things are going on here:

- For every singer, an extra query is executed to extract the awards (N+1 complexity problem).
- This is possible because, by default, Spring Boot configures a Hibernate session to be open when a request for data is coming. This allows for lazy associations to be loaded, which improves developer productivity because it keeps things simple. There is no need for special queries with join statements. The bean providing this behavior is the `OpenSessionInViewInterceptor`.<sup>8</sup>

<sup>8</sup><https://docs.spring.io/spring-framework/docs/current/javadoc-api/org/springframework/orm/hibernate5/support/OpenSessionInViewInterceptor.html>

The problem with the *session per request* transactional pattern is that it can become inefficient in production environments. This behavior can be disabled by adding the following property to the Spring Boot configuration: `spring.jpa.open-in-view=false`. This, however, does not go well with GraphQL nested queries when it tries to fetch lazy relationships.

What is the fix for this? We need to modify the GraphQL handler method and use Spring JPA Specification API methods to extract relationship data only when required. This obviously means we need to analyze the query sent by the client. There is more than one way to do this, but the easiest is to use the `graphql.schema.DataFetchingEnvironment` parameter inside the `QueryResolver` implementation. In methods annotated with `@QueryMapping`, Spring Boot automatically injects the value for this parameter and depending on the requested relations we build different queries. If you remember, we did have two relations, “awards” and “instruments”. Listing 16-20 shows the improved `singers(..)` handler method.

**Listing 16-20.** GraphQL handler methods for nested queries

```
package com.apress.prospring6.sixteen.boot.controllers;

import org.springframework.graphql.data.method.annotation.QueryMapping;
import org.springframework.stereotype.Controller;
import graphql.schema.DataFetchingEnvironment;
import graphql.schema.DataFetchingFieldSelectionSet;
import jakarta.persistence.criteria.Fetch;
import jakarta.persistence.criteria.Join;
import jakarta.persistence.criteria.JoinType;
import org.springframework.data.jpa.domain.Specification;
// other import statements omitted

@Controller
public class SingerController {

    @QueryMapping
    public Iterable<Singer> singers(DataFetchingEnvironment environment) {
        DataFetchingFieldSelectionSet s = environment.getSelectionSet();
        if (s.contains("awards") && !s.contains("instruments"))
            return singerRepo.findAll(fetchAwards());
        else if (s.contains("awards") && s.contains("instruments"))
            return singerRepo.findAll(fetchAwards().and(fetchInstruments()));
        else if (!s.contains("awards") && s.contains("instruments"))
            return singerRepo.findAll(fetchInstruments());
        else
            return singerRepo.findAll();
    }

    private Specification<Singer> fetchAwards() {
        return (root, query, builder) -> {
            Fetch<Singer, Award> f = root.fetch("awards", JoinType.LEFT);
            Join<Singer, Award> join = (Join<Singer, Award>) f;
            return join.getOn();
        };
    }

    private Specification<Singer> fetchInstruments() {
        return (root, query, builder) -> {
```

```

        Fetch<Singer, Instrument> f = root.fetch("instruments", JoinType.LEFT);
        Join<Singer, Instrument> join = (Join<Singer, Instrument>) f;
        return join.getOn();
    };
}
// other methods omitted
}

```

The `findAll(Specification<T> spec)` method used to retrieve a list of `Singer` instances with some relationships loaded is provided by `org.springframework.data.jpa.repository.JpaSpecificationExecutor<T>`, so the `SingerRepo` must be modified to extend this interface too.

If we restart the application and send the query in Listing 16-21, we get the expected reply, and if we look in the console, we notice that a single query is executed.

**Listing 16-21.** GraphQL Query Requesting a One-to-Many Relationship

```

query {
  singers {
    firstName
    lastName
    pseudonym
    genre
    birthDate
    awards {
      awardName
      year
    }
  }
}

```

The query in the console log is shown in Listing 16-22.

**Listing 16-22.** SQL Query Generated for a Nested GraphQL Query

```

select s1_0.ID,
       a1_0.SINGER_ID,
       a1_0.ID,a1_0.AWARD_NAME,
       a1_0.TYPE,
       a1_0.ITEM_NAME,
       a1_0.VERSION,a1_0.YEAR,
       s1_0.BIRTH_DATE,
       s1_0.FIRST_NAME,
       s1_0.GENRE,
       s1_0.LAST_NAME,
       s1_0.PSEUDONYM,
       s1_0.VERSION
from SINGER s1_0
left join AWARD a1_0 on s1_0.ID=a1_0.SINGER_ID

```

What happens if we add the `instruments` relationship to the query as well? This is a many-to-many relationship that is modelled under the hood using two one-to-many relationships: one between `SINGER` and `SINGER_INSTRUMENT` and one between `INSTRUMENT` and `SINGER_INSTRUMENT`. Listing 16-23 shows the GraphQL query and the queries generated to extract the requested data.

**Listing 16-23.** GraphQL Query with a Many-to-Many Relationship

```

query {
  singers{
    firstName
    lastName
    pseudonym
    genre
    birthDate
    awards {
      awardName
      year
    }
    instruments {
      name
    }
  }
}

```

# Resulted queries

```

select s1_0.ID,
        a1_0.SINGER_ID,a1_0.ID,
        a1_0.AWARD_NAME,
        a1_0.TYPE,a1_0.ITEM_NAME,
        a1_0.VERSION,a1_0.YEAR,
        s1_0.BIRTH_DATE,
        s1_0.FIRST_NAME,
        s1_0.GENRE,
        i1_0.SINGER_ID,
        i1_1.INSTRUMENT_ID,
        s1_0.LAST_NAME,
        s1_0.PSEUDONYM,
        s1_0.VERSION
from SINGER s1_0
      left join AWARD a1_0 on s1_0.ID=a1_0.SINGER_ID
      left join (SINGER_INSTRUMENT i1_0 join INSTRUMENT i1_1 on i1_1.INSTRUMENT_ID=i1_0.
INSTRUMENT_ID) on s1_0.ID=i1_0.SINGER_ID;

select s1_0.INSTRUMENT_ID,s1_1.ID,s1_1.BIRTH_DATE,s1_1.FIRST_NAME,s1_1.GENRE,s1_1.LAST_
NAME,s1_1.PSEUDONYM,s1_1.VERSION
from SINGER_INSTRUMENT s1_0
      join SINGER s1_1 on s1_1.ID=s1_0.SINGER_ID
      where s1_0.INSTRUMENT_ID=?;

select s1_0.INSTRUMENT_ID,s1_1.ID,s1_1.BIRTH_DATE,s1_1.FIRST_NAME,s1_1.GENRE,s1_1.LAST_
NAME,s1_1.PSEUDONYM,s1_1.VERSION
from SINGER_INSTRUMENT s1_0
      join SINGER s1_1 on s1_1.ID=s1_0.SINGER_ID
      where s1_0.INSTRUMENT_ID=?;

select s1_0.INSTRUMENT_ID,s1_1.ID,s1_1.BIRTH_DATE,s1_1.FIRST_NAME,s1_1.GENRE,s1_1.LAST_
NAME,s1_1.PSEUDONYM,s1_1.VERSION
from SINGER_INSTRUMENT s1_0
      join SINGER s1_1 on s1_1.ID=s1_0.SINGER_ID
      where s1_0.INSTRUMENT_ID=?;

```

```

select s1_0.INSTRUMENT_ID,s1_1.ID,s1_1.BIRTH_DATE,s1_1.FIRST_NAME,s1_1.GENRE,s1_1.LAST_
NAME,s1_1.PSEUDONYM,s1_1.VERSION
from SINGER_INSTRUMENT s1_0
  join SINGER s1_1 on s1_1.ID=s1_0.SINGER_ID
  where s1_0.INSTRUMENT_ID=?;

```

So, what happened? Well, JPA query generation is not that smart after all. If a SQL developer were to write a query to extract data from tables linked to each other via a many-to-many relationship like the one depicted in this application, the query would look like the one shown in Listing 16-24.

**Listing 16-24.** SQL Query with a Many-to-Many Relationship

```

select
  s1_0.ID,a1_0.SINGER_ID,a1_0.ID,
  a1_0.AWARD_NAME,
  a1_0.YEAR,
  s1_0.BIRTH_DATE,
  s1_0.FIRST_NAME,
  s1_0.LAST_NAME,
  I.INSTRUMENT_ID
from SINGER s1_0
  left join AWARD a1_0 on s1_0.ID=a1_0.SINGER_ID
  left join SINGER_INSTRUMENT SI on s1_0.ID = SI.SINGER_ID
  left join INSTRUMENT I on I.INSTRUMENT_ID = SI.INSTRUMENT_ID;

```

Also, if you look carefully at the generated queries, you might notice that, regardless of the fields specified in your GraphQL queries, when the query is generated for the database, unless you explicitly write a SQL native query to specify the name of the columns you get data from, JPA will generate a SQL query that includes all columns. You might conclude from this example that GraphQL is not as efficient as advertised. Still, it was efficient enough to make Facebook the most widely used social network in the world.

Let's look at other GraphQL queries we can support. For example, if we want all the details for a singer with a specific id, the query to write might look like the one depicted in Listing 16-25.

**Listing 16-25.** GraphQL Query for Retrieving Details for a Singer with id 1

```

query {
  singerById(id: 1){
    firstName
    lastName
    awards {
      awardName
      year
    }
    instruments{
      name
    }
  }
}

```

To support this query, we need to add the schema for it and the handler method. Also, this is a good opportunity to introduce the `@Argument` annotation. Listing 16-26 depicts the query schema and the handler method.



**Listing 16-26.** GraphQL handler method for Retrieving Details for a Singer with id 1 (GraphQL Query Declared in resources/graphql/singer.graphqls)

```

type Query {
    singerById(id: ID!) : Singer
}
package com.apress.prospring6.sixteen.boot.controllers;

import org.springframework.graphql.data.method.annotation.Argument;
// other import statements omitted

@Controller
public class SingerController {

    @QueryMapping
    public Singer singerById(@Argument Long id, DataFetchingEnvironment environment){
        Specification<Singer> spec = byId(id);
        DataFetchingFieldSelectionSet s = environment.getSelectionSet();
        if (s.contains("awards") && !s.contains("instruments"))
            spec = spec.and(fetchAwards());
        else if (s.contains("awards") && s.contains("instruments"))
            spec = spec.and(fetchAwards().and(fetchInstruments()));
        else if (!s.contains("awards") && s.contains("instruments"))
            spec = spec.and(fetchInstruments());

        return singerRepo.findOne(spec).orElse(null);
    }

    // other methods omitted
}

```

The Spring GraphQL `@Argument` annotation binds a named GraphQL argument onto a method parameter. The same JPA `Specification<Singer>` instances are used to provide support for loading lazy relationships for individual singers as well.

Until now, we've only done data retrieval, so it is time to introduce how to support operations like creating a new `Singer` object and updating and deleting existing `Singer` objects. All these operations are supported through a concept, or type, called `Mutation`. Similar to a `Query`, a `Mutation` declares the schema for a create, update, or delete operation. GraphQL queries for these operations are mapped to handler methods annotated with `@MutationMapping`.

Listing 16-27 show the necessary `Mutation` and the `SingerInput` type needed for create and update operations.

**Listing 16-27.** GraphQL handler method for Retrieving Details for a Singer with id 1 (GraphQL Query Declared in resources/graphql/singer.graphqls)

```

type Mutation {
    updateSinger(id: ID!, singer: SingerInput): Singer!
    deleteSinger(id: ID!): ID!
}

```

```

input SingerInput {
    firstName: String!
    lastName: String!
    pseudonym: String
    genre: String
    birthDate: String
}

package com.apress.prospring6.sixteen.boot.controllers;

import org.springframework.graphql.data.method.annotation.MutationMapping;
// other import statements omitted

@Controller
public class SingerController {

    // other methods omitted
    @MutationMapping
    public Singer newSinger(@Argument SingerInput singer){
        LocalDate date;
        try {
            date = LocalDate.parse(singer.birthDate(), DateTimeFormatter.ofPattern
                ("yyyy-MM-dd"));
        } catch (DateTimeParseException e) {
            throw new IllegalArgumentException("Bade date format");
        }
        var newSinger = new Singer(null, 0, singer.firstName,singer.lastName,
            singer.pseudonym, singer.genre, date, null, null);
        return singerRepo.save(newSinger);
    }

    @MutationMapping
    public Singer updateSinger(@Argument Long id, @Argument SingerInput singer) {
        var fromDb = singerRepo.findById(id).orElseThrow(() -> new NotFoundException
            (Singer.class, id ));
        fromDb.setFirstName(singer.firstName);
        fromDb.setLastName(singer.lastName);
        fromDb.setPseudonym(singer.pseudonym);
        fromDb.setGenre(singer.genre);
        LocalDate date;
        try {
            date = LocalDate.parse(singer.birthDate(), DateTimeFormatter.ofPattern
                ("yyyy-MM-dd"));
            fromDb.setBirthDate(date);
        } catch (DateTimeParseException e) {
            throw new IllegalArgumentException("Bade date format");
        }
        return singerRepo.save(fromDb);
    }

    @MutationMapping
    public Long deleteSinger(@Argument Long id) {
        singerRepo.findById(id).orElseThrow(() -> new NotFoundException(Singer.class, id ));
    }
}

```

```

        singerRepo.deleteById(id);
        return id;
    }

    record SingerInput(String firstName, String lastName, String pseudonym, String genre,
String birthDate){}
}

```



In the current version of GraphQL, you cannot declare a query or mutation without a return type. A workaround is to return a typical value that represents a successful operation, such a 0 (zero) or OK in the handler method, or just return null, and declare a nullable type in the schema.

---

The GraphQL queries for creating, updating, and deleting a singer are shown in Listing 16-28.

**Listing 16-28.** GraphQL Query for Creating, Updating, and Deleting a Singer

```

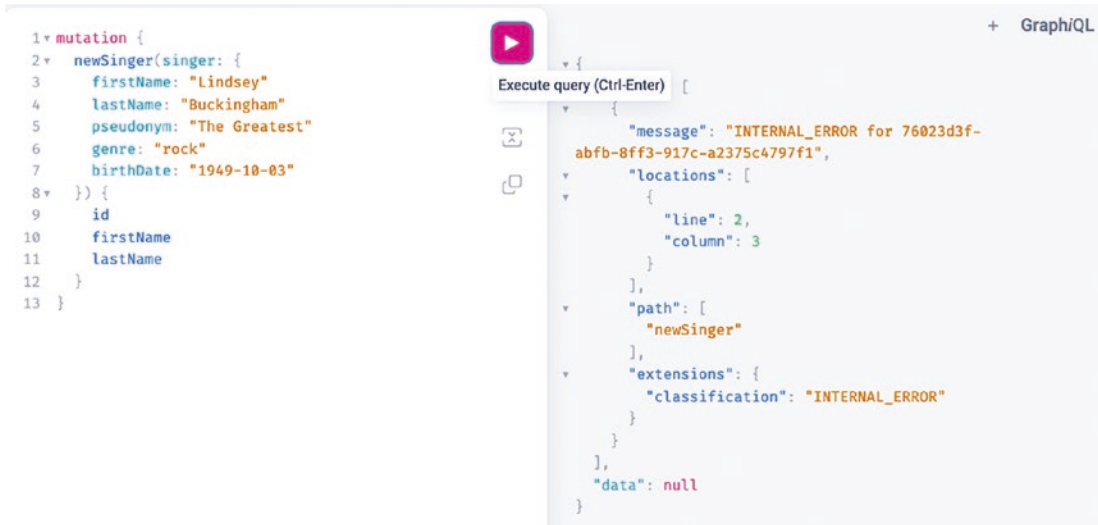
# create singer
mutation {
  newSinger(singer: {
    firstName: "Lindsey"
    lastName: "Buckingham"
    pseudonym: "The Greatest"
    genre: "rock"
    birthDate: "1949-10-03"
  }) {
    id
    firstName
    lastName
  }
}

# update singer
mutation {
  updateSinger(id: 16, singer: {
    firstName: "Lindsey"
    lastName: "Buckingham"
    genre: "rock"
    birthDate: "1949-10-03"
  }) {
    id
    firstName
    lastName
  }
}

#delete singer
mutation {
  deleteSinger(id: 16)
}

```

Now that we've explored how to create `Singer` instances via GraphQL queries, what happens if we try to execute the query to create a singer twice? That is clearly not allowed, because singers are supposed to be unique in our database. Trying to create a singer with the same `firstName` and `lastName` causes a `DataIntegrityViolationException` to be thrown, which we can see in the console log, but in GraphQL, the web console does not give a lot of details, as shown in Figure 16-12.



**Figure 16-12.** GraphQL web console showing an error when trying to execute the same mutation twice

We know the server has a problem executing what we asked it to, but we do not know why. Obviously, proper exception handling is needed. When working with GraphQL, we handle errors by extending the `org.springframework.graphql.execution.DataFetcherExceptionResolverAdapter` class and overriding the `resolveToSingleError(..)` or the `resolveToMultipleErrors(..)` method. Adding a bean of this type to the configuration provides a more concise way to represent data layer errors in the GraphQL response that is shown in the GraphQL web console. Listing 16-29 shows a custom implementation of `DataFetcherExceptionResolverAdapter`.

**Listing 16-29.** Custom Implementation for `DataFetcherExceptionResolverAdapter`

```

package com.apress.prospring6.sixteen.boot.problem;

import graphql.GraphQLError;
import graphql.GraphQLErrorBuilder;
import graphql.schema.DataFetchingEnvironment;
import org.springframework.dao.DataIntegrityViolationException;
import org.springframework.graphql.execution.DataFetcherExceptionResolverAdapter;
import org.springframework.graphql.execution.ErrorType;
import org.springframework.stereotype.Component;
  
```

```

@Component
public class CustomExceptionHandler extends DataFetcherExceptionHandlerAdapter {
    @Override
    protected GraphQLError resolveToSingleError(Throwable ex, DataFetchingEnvironment env) {
        if (ex instanceof DataIntegrityViolationException) {
            return GraphQLErrorBuilder.newError()
                .errorType(ErrorType.BAD_REQUEST)
                .message("Cannot create duplicate entry:" + ex.getCause().getCause().
                    getMessage())
                .path(env.getExecutionStepInfo().getPath())
                .location(env.getField().getSourceLocation())
                .build();
        }
        return super.resolveToSingleError(ex, env);
    }

    @Override
    protected List<GraphQLError> resolveToMultipleErrors(Throwable ex,
        DataFetchingEnvironment env) {
        return super.resolveToMultipleErrors(ex, env);
    }
}

```

Both `resolveToSingleError(..)` and `resolveToMultipleErrors(..)` have the same signature, and the only difference between them is that `resolveToSingleError(..)` resolves a thrown exception to a single GraphQL error, while `resolveToMultipleErrors(..)` does so to multiple GraphQL errors. The `DataFetchingEnvironment` argument provides details about the execution context in which the error happened. `GraphQLErrorBuilder` is a useful class used to build a GraphQL error. The `ErrorType` represents the error category and the values in this enum match the most common HTTP statuses: `BAD_REQUEST`, `UNAUTHORIZED`, `FORBIDDEN`, `NOT_FOUND`, and `INTERNAL_ERROR`. A customized message can be set to add details about the failure. The `path` is the name of the query or mutation that caused the issue. The `location` represents the GraphQL query lines that caused the error.

With this bean added to the configuration, the error becomes more readable, as shown in Figure 16-13, providing someone who sends a bad query with the information needed to correct it.

```

1 mutation {
2   newSinger(singer: {
3     firstName: "Lindsey"
4     lastName: "Buckingham"
5     pseudonym: "The Greatest"
6     genre: "rock"
7     birthDate: "1949-10-03"
8   }) {
9     id
10    firstName
11    lastName
12  }
13 }

```

```

+ GraphQL
{
  "errors": [
    {
      "message": "Cannot create duplicate entry:(conn=515) Duplicate entry 'Lindsey-Buckingham' for key 'FIRST_NAME'",
      "locations": [
        {
          "line": 2,
          "column": 3
        }
      ],
      "path": [
        "newSinger"
      ],
      "extensions": {
        "classification": "BAD_REQUEST"
      }
    }
  ],
  "data": null
}

```

**Figure 16-13.** GraphQL web console showing a customized error when trying to execute the same mutation twice

Testing GraphQL controllers can be done as shown in previous chapters for web applications, using `TestRestTemplate` or `MockMvc`, or `WebClient` for a Spring Boot Reactive GraphQL application, by sending POST requests containing GraphQL queries in the body.

This section just touched on the basics on how to get started with building GraphQL APIs in Spring. If you would like to learn more about Spring support for GraphQL, feel free to check out the Spring for GraphQL official project page.<sup>9</sup>

## Spring Kotlin Applications

Kotlin<sup>10</sup> is a JVM programming language developed by JetBrains<sup>11</sup>, the company that also produces the best Java editor, IntelliJ IDEA<sup>12</sup> (recommended to you repeatedly throughout this book). As mentioned at the beginning of this chapter, syntactically Kotlin is pretty much a cross between Java and Scala, combining the best of both worlds: the readability of Java, the elegance of Scala, and the ability to run it on a JVM, so it interoperates with Java too. Projects can be written to have both Java and Kotlin sources, and smart editors like Maven and Gradle know how to compile them and build them into bytecode that can run on any JVM. Kotlin is a cross-platform, statically typed, general-purpose, high-level programming language with type inference, allowing its syntax to be more concise.

The following are the main strong points of Kotlin that might convince a Java developer to give Kotlin a try:

- Kotlin has concise syntax, requiring less code to be written, thus avoiding boilerplate code. The Kotlin official page indicates approximately a 40% reduction in the number of lines of code compared to Java. Also, it supports string template expressions.

<sup>9</sup><https://spring.io/projects/spring-graphql>

<sup>10</sup><https://kotlinlang.org>

<sup>11</sup><https://www.jetbrains.com>

<sup>12</sup><https://www.jetbrains.com/idea>

- Kotlin has both object-oriented and functional constructs, which means you can write object-oriented and functional code using its higher-order functions, function types, and lambdas.
- Kotlin supports non-nullable types, which helps avoid `NullPointerException`s.
- Kotlin has classes and their members are `final` by default.
- Kotlin uses smart casts, which means the `is` operator checks the type of an object and the Kotlin compiler explicitly casts for immutable values and inserts (safe) casts automatically when necessary.
- Kotlin provides better control flow via the `when` expression and numeric ranges.
- The common superclass in Kotlin is named `Any`.
- By default, methods and properties are `final`, and the `override` keyword is needed to make them overridable, which makes inheritance code easier to read.
- Properties can be declared read-only using the `val` keyword, and declared mutable using the `var` keyword.
- Kotlin is adept of the *less is more* principle: getters, setters, and property types are optional.
- Interfaces can have properties and functions.
- Classes and interfaces can be enriched with new functionality without inheritance, through *extension functions*. To declare an extension function, prefix its name with a *receiver type*, which refers to the type being extended. Extensions can be called on an object variable even if its value is `null`, which means `toString()` can be invoked on objects without checking for nullability.
- Kotlin provides a solution for the diamond problem.<sup>13</sup>
- Accessors or visibility modifiers are similar to Java. There are four visibility modifiers in Kotlin: `private`, `protected`, `internal`, and `public`. The default visibility is `public`.
- If a top-level class, function, or interface is `private`, it will only be visible inside the file that contains the declaration.
- If a top-level class, function, or interface is `internal`, it will be visible everywhere in the same module.
- The `protected` modifier is not available for top-level declarations.
- Constructors are declared with the `constructor` keyword, and by default are `public`.
- Kotlin supports modules: a module is a set of Kotlin files compiled together.
- Kotlin supports companion objects; a companion object is similar to a static instance that allows calling methods without instantiating the type.
- Kotlin supports data classes: classes with standard functionality such as `equals()`, `hashCode()`, `toString()`, and so on.
- Kotlin supports sealed classes (and did so before Java did).

---

<sup>13</sup> <https://kotlinlang.org/docs/interfaces.html#resolving-overriding-conflicts>

- Kotlin supports inline classes.
- Kotlin provides support for asynchronous or non-blocking programming, via coroutines.
- Kotlin supports destructuring objects.

The application build for this section does not make use of all the features mentioned, but they are listed here to spark your interest. For further information on all the features, the official documentation and tutorials are very good,<sup>14</sup> as is the book *Learn to Program with Kotlin*<sup>15</sup> by Jim Lavers (Apress, 2021).

With the preceding introduction to Kotlin in mind, let's build a Spring Boot web application using Kotlin.

## The Configuration

A Kotlin application can be built with Gradle and Maven. The structure of the project is the typical Maven structure introduced to you at the beginning of this book, only Kotlin sources are located under a `kotlin` directory. Also, a few Kotlin plug-ins are necessary, depending on the type of the application built, to make sure the Kotlin sources are compiled into bytecode that the JVM can execute. The plug-ins needed for the Spring Boot application built in this section are listed and explained next.

First is the Kotlin Gradle plug-in (`kotlin-gradle-plugin`), which selects the appropriate JVM standard library depending on the `compilerOptions.jvmTarget` compiler option of your build script. For a multi-module Gradle project, the plug-in needs to be added as a classpath dependency in the parent project and used in the subproject `chapter16-kotlin-boot`. Listing 16-30 shows these two bits of Gradle configuration.

**Listing 16-30.** Gradle Configuration of the `kotlin-gradle-plugin` Plug-in

```
// pro-spring-6/build.gradle
buildscript {
    repositories {
        mavenLocal()
        mavenCentral()
    }

    dependencies {
        classpath 'io.spring.gradle:dependency-management-plugin:1.1.0'
        classpath 'org.jetbrains.kotlin:kotlin-gradle-plugin:1.8.10'
    }
}

// pro-spring-6/chapter16-kotlin-boot/chapter16-kotlin-boot.gradle
apply plugin: 'org.jetbrains.kotlin.jvm'

tasks.withType(KotlinCompile).configureEach {
    compileKotlin.compilerOptions.freeCompilerArgs.add('-Xjsr305=strict')
    compileKotlin.compilerOptions.jvmTarget.set(JvmTarget.JVM_19)
}
```

<sup>14</sup><https://kotlinlang.org/docs/getting-started.html>

<sup>15</sup><https://link.springer.com/book/10.1007/978-1-4842-6815-5>



```
tasks.withType(Test).configureEach {
    useJUnitPlatform()
    compileTestKotlin.compilerOptions.jvmTarget.set(JvmTarget.JVM_19)
}
```

The version of `kotlin-gradle-plugin` matches the supported Kotlin version, and the current Kotlin version at the time of writing is 1.8.10. Notice that the `KotlinCompile` task was configured with the version of the JVM that will run the application. This is necessary for the `Test` task as well if the tests are written in Kotlin. The `-Xjsr305` compile flag, when set to `strict`, is required to have null-safety taken into account in Kotlin types inferred from Spring API.

As previously mentioned, Kotlin has classes and their members final by default. This might be inconvenient for frameworks like Spring that need to proxy beans, and so they require classes to be open. This means for interoperability, another plug-in is required. The `kotlin-allopen` compile plug-in adapts Kotlin to the requirement of these frameworks. The configuration necessary for this plug-in is shown in 16-31.

**Listing 16-31.** Gradle Configuration of the `kotlin-allopen` Plug-in

```
// pro-spring-6/build.gradle
buildscript {
    repositories {
        mavenLocal()
        mavenCentral()
    }

    dependencies {
        classpath 'io.spring.gradle:dependency-management-plugin:1.1.0'
        classpath 'org.jetbrains.kotlin:kotlin-allopen:1.8.10'
    }
}

// pro-spring-6/chapter16-kotlin-boot/chapter16-kotlin-boot.gradle
apply plugin: 'org.jetbrains.kotlin.plugin.spring'
```

Two other frameworks that are likely to cause issues are JPA and Hibernate. These frameworks require entity classes to have a default, no-arguments constructor, because they create objects using it and then set the properties. Kotlin does not generate such a constructor by default, so the `kotlin-noarg` plug-in must be added to the configuration. The `no-arg` compiler plug-in generates an additional zero-argument constructor for classes with a specific annotation.

The generated constructor is synthetic, so it can't be directly called from Java or Kotlin, but it can be called using reflection. Listing 16-32 shows the configuration for this plug-in.

**Listing 16-32.** Gradle Configuration of the `kotlin-noarg` Plug-in

```
// pro-spring-6/build.gradle
buildscript {
    repositories {
        mavenLocal()
        mavenCentral()
    }
}
```

```
dependencies {
    classpath 'io.spring.gradle:dependency-management-plugin:1.1.0'
    classpath 'org.jetbrains.kotlin:kotlin-noarg:1.8.10'
}
}
```

// *pro-spring-6/chapter16-kotlin-boot/chapter16-kotlin-boot.gradle*  
apply plugin: 'org.jetbrains.kotlin.plugin.jpa'



The Gradle configuration is written in Groovy, but Gradle supports writing configuration files in Kotlin as well.

---



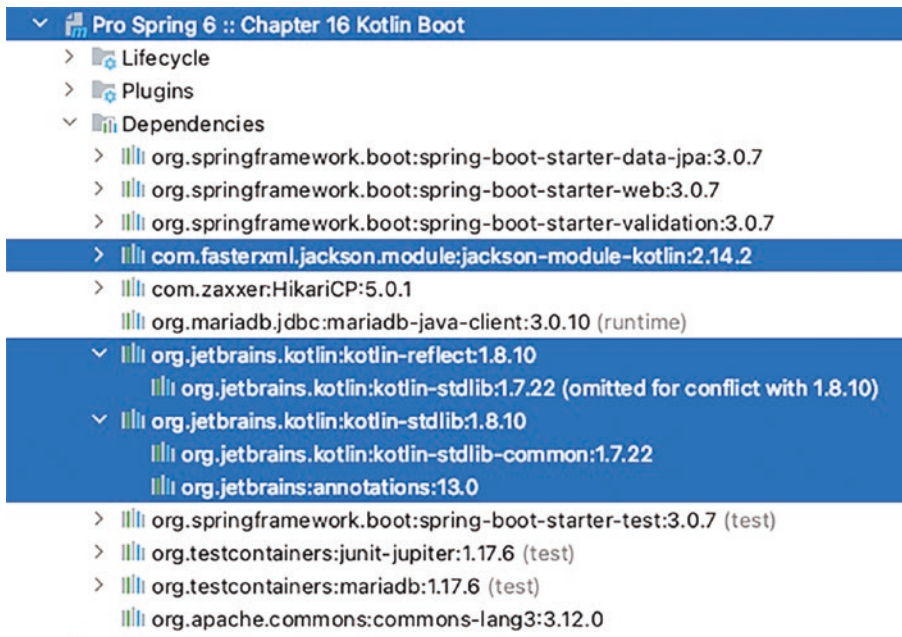
There is an equivalent configuration for Maven in `chapter16-kotlin-boot` project. Feel free to look if you are interested in building Kotlin applications with Maven.



For Spring Boot applications written with Kotlin, take advantage of <https://start.spring.io> to generate your project structure and configuration.

---

With all these plug-ins added to the configuration, we can now direct our attention to adding the required dependencies to the configuration, so we can build a Spring Boot web application with JPA. Figure 16-14 shows the dependencies of the project `chapter16-kotlin-boot`.



**Figure 16-14.** *chapter16-kotlin-boot* project dependencies

The `kotlin-stdlib` dependency contains the Kotlin standard library, and is necessary for any Kotlin project. The `kotlin-reflect` dependency is needed to add the runtime component required for using the reflection features on the JVM platform. Also, notice the `jackson-module-kotlin` dependency, which is needed to support Jackson annotations in Kotlin code.

Having covered the plug-ins and dependencies, it is time to take a look at the code.

## The Code

Let's start with the basics. The `Singer` entity class is very similar to its Java version, but simpler because there are no setters and getters, and no Lombok. Figure 16-15 shows the `chapter16-kotlin-boot` project structure.

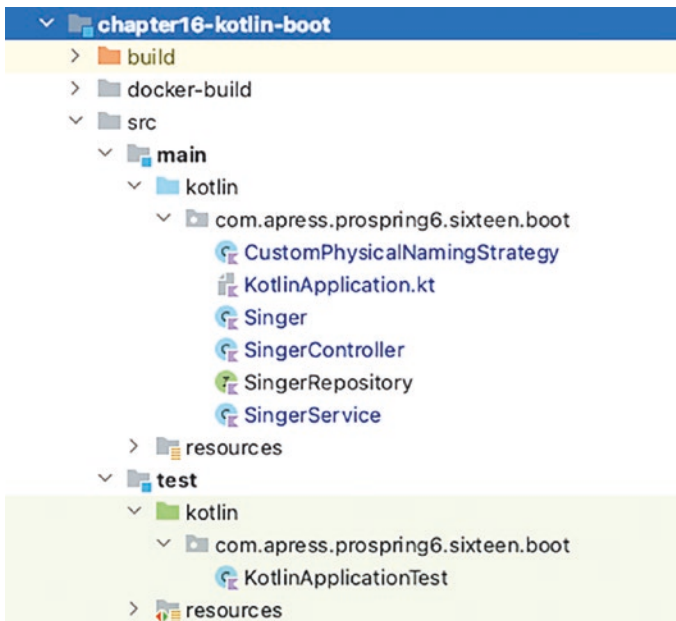


Figure 16-15. chapter16-kotlin-boot project structure

The Singer Kotlin entity class is shown in Listing 16-33.

Listing 16-33. Singer Kotlin Class

```

package com.apress.prospring6.sixteen.boot

import com.fasterxml.jackson.annotation.JsonIgnore
import jakarta.persistence.*
import jakarta.validation.constraints.NotEmpty
import jakarta.validation.constraints.Size
import org.springframework.format.annotation.DateTimeFormat
import java.time.LocalDate

@Entity
@Table(name = "SINGER")
data class Singer (
    @Id @GeneratedValue(strategy = GenerationType.IDENTITY)
    @Column(name = "ID")
    @JsonIgnore // do not serialize
    var id: Long? = null,

    @Version @Column(name = "VERSION")
    @JsonIgnore // do not serialize
    var version: Int = 0,

    @Column(name = "FIRST_NAME")
    @NotEmpty

```

```

@Size(min = 2, max = 30)
var firstName: String?,

@Column(name = "LAST_NAME")
var lastName: @NotEmpty @Size(min = 2, max = 30) String? = null,

@DateTimeFormat(pattern = "yyyy-MM-dd")
@Column(name = "BIRTH_DATE")
var birthDate: LocalDate? = null
)

```

The class is declared using the `data` class keywords. This tells the Kotlin compiler to generate `equals()`, `hashCode()`, `toString()`, destructuring, and `copy()` functions.

The `?` that appears after some types marks these properties as nullable; this is emphasized by initializing them with `null`.

Notice that the class has no actual body; everything is done between the `()`. This declaration also works as a constructor and is known as the *primary constructor*. Also notice that the variable type is declared after the variable name and is prefixed by `:`, and if initialized with a value, the assignment statement comes after the type declaration.

The `SingerRepository` interface is shown in Listing 16-34.

**Listing 16-34.** `SingerRepository` Kotlin Data Repository Interface

```

package com.apress.prospring6.sixteen.boot

import org.springframework.data.jpa.repository.Query
import org.springframework.data.repository.CrudRepository
import org.springframework.data.repository.query.Param

interface SingerRepository : CrudRepository<Singer, Long> {
    @Query("select s from Singer s where s.firstName=:fn")
    fun findByFirstName(@Param("fn") firstName: String?): Iterable<Singer?>?

    @Query("select s from Singer s where s.firstName like ?%1%")
    fun findByFirstNameLike(firstName: String?): Iterable<Singer?>?
}

```

The service looks a lot different from its Java version and is shown in Listing 16-35.

**Listing 16-35.** `SingerService` Kotlin Class

```

package com.apress.prospring6.sixteen.boot

import org.springframework.dao.DataIntegrityViolationException
import org.springframework.stereotype.Service
import org.springframework.transaction.annotation.Transactional
import java.util.*
import kotlin.jvm.Throws

@Transactional
@Service
class SingerService (private val repository: SingerRepository){

```

```

@Throws(NotFoundException::class)
fun findAll(): List<Singer> {
    val singers: List<Singer> = repository.findAll() as List<Singer>
    if (singers.isEmpty()) {
        throw NotFoundException(Singer::javaClass.name)
    }
    return singers
}

@Throws(NotFoundException::class)
fun findById(id: Long?): Singer? {
    return id?.let { repository.findById(id).orElseThrow { NotFoundException(Singer::
        javaClass.name, id) }}
}

@Throws(DataIntegrityViolationException::class)
fun save(singer: Singer?): Singer? {
    return singer?.let { repository.save(it) }
}

@Throws(NotFoundException::class, DataIntegrityViolationException::class)
fun update(id: Long?, singer: Singer): Singer? {
    return id?.let { repository.findById(id).map { update(it, singer, repository)
        }.orElseThrow { NotFoundException(Singer::javaClass.name, id) }}
}

@Throws(NotFoundException::class)
fun delete(id: Long?) {
    id?.let { repository.findById(id).orElseThrow { NotFoundException(Singer::javaClass.
        name, id) }}
    id?.let { repository.deleteById(id) }
}

fun update(it: Singer, singer: Singer, repository: SingerRepository): Singer {
    it.firstName = singer.firstName
    it.lastName = singer.lastName
    it.birthDate = singer.birthDate
    return repository.save(it)
}
}

```

The following list explains the most important constructs in the `SingerService` class. Notice that the `java.util.List<String>` is used in Kotlin code.

- The methods are declared with `fun` and the return type is declared at the end of the signature right before the body block. Hereafter in this section, methods are called *functions*, to switch to the Kotlin style.
- The `NotFoundException` is a custom exception thrown whenever a service function is invoked with an id that does not match a `Singer` instance. Kotlin does not require checked exceptions to be declared with a `throws` statement, but since Kotlin code is compiled to bytecode that needs to run on a JVM, it needs to be valid. The `@Throws` annotation indicates what exceptions should be declared by a function when compiled to a JVM method.

- The `Singer::javaClass.name` construct references the Java class object, so its name can be accessed and used as a parameter to create a `NotFoundException`.
- `id?.let { .. }` is made of two parts: `?.` is named the *safe call operator*, which allows `repository.findById(id)` to be invoked only when the `id` is not null; and `let` calls the specified function block with this value as its argument and returns its result.

Listing 16-36 shows the `SingerController` class.

**Listing 16-36.** `SingerController` Kotlin Class

```

package com.apress.prospring6.sixteen.boot

import jakarta.validation.Valid
import org.springframework.dao.DataIntegrityViolationException
import org.springframework.web.bind.annotation.*

@RestController
@RequestMapping("/singer")
class SingerController (private val service: SingerService) {

    @GetMapping
    fun all(): List<Singer> {
        return service.findAll()
    }

    @GetMapping("/{id}")
    fun findSingerById(@PathVariable id: Long) : Singer? {
        return service.findById(id)
    }

    @PostMapping
    fun create(@RequestBody @Valid singer:Singer) : Singer? {
        return service.save(singer)
    }

    @PutMapping("/{id}")
    fun update(@RequestBody @Valid singer: Singer, @PathVariable id: Long) : Singer? {
        return service.update(id, singer)
    }

    @DeleteMapping("/{id}")
    fun delete(@PathVariable id: Long) {
        service.delete(id)
    }
}

```

The `SingerController` class seems simpler in Kotlin too, but it's pretty similar to the one in Java, and it introduces nothing new.

But let's look at the configuration. In previous chapters, a bean of a type extending `PhysicalNamingStrategyStandardImpl` was necessary to convince Spring Data to recognize tables and columns with names in all caps. Converting the `CustomPhysicalNamingStrategy` to Kotlin provides the opportunity to use the `private` accessor and the `override` keyword. The Kotlin version of `CustomPhysicalNamingStrategy` is shown in Listing 16-37.

*Listing 16-37.* `CustomPhysicalNamingStrategy` Kotlin Class

```
package com.apress.prospring6.sixteen.boot

import org.hibernate.boot.model.naming.Identifier
import org.hibernate.boot.model.naming.PhysicalNamingStrategyStandardImpl
import org.hibernate.engine.jdbc.env.spi.JdbcEnvironment
import org.springframework.stereotype.Component
import java.io.Serializable
import java.util.*

@Component
class CustomPhysicalNamingStrategy : PhysicalNamingStrategyStandardImpl(), Serializable {

    override fun toPhysicalTableName(logicalName: Identifier?, context: JdbcEnvironment):
    Identifier? {
        return apply(logicalName)
    }

    override fun toPhysicalColumnName(logicalName: Identifier?, context: JdbcEnvironment):
    Identifier? {
        return apply(logicalName)
    }

    private fun apply(name: Identifier?): Identifier? {
        if (name == null) {
            return null
        }
        val builder = StringBuilder(name.text.replace('.', '_'))
        var i = 1
        while (i < builder.length - 1) {
            if (isUnderscoreRequired(builder[i - 1], builder[i], builder[i + 1])) {
                builder.insert(i++, '_')
            }
            i++
        }
        return Identifier.toIdentifier(builder.toString().uppercase(Locale.getDefault()))
    }

    private fun isUnderscoreRequired(before: Char, current: Char, after: Char): Boolean {
        return Character.isLowerCase(before) && Character.isUpperCase(current) && Character.
        isLowerCase(after)
    }
}
```



It doesn't simplify the Java code by much, but that might just be attributed to a lack of Kotlin expertise. Notice that in order to override a function, the declaration must be declared with the `override` keyword in front of `fun`. The `private` accessor, when used on a function, has the same effect as in Java, keeping it local to the class enclosing it.

The Spring Boot main class is shown in Listing 16-38.

**Listing 16-38.** Chapter16Application Kotlin Main Class

```
package com.apress.prospring6.sixteen.boot;

import org.springframework.boot.autoconfigure.SpringBootApplication
import org.springframework.boot.runApplication
import org.springframework.core.env.AbstractEnvironment
// some import statements omitted

@SpringBootApplication
class Chapter16Application

fun main(args: Array<String>) {
    System.setProperty(AbstractEnvironment.ACTIVE_PROFILES_PROPERTY_NAME, "dev")
    runApplication<Chapter16Application>(*args)
}

@ControllerAdvice
@ResponseBody
class RestErrorHandler {

    @ExceptionHandler(DataIntegrityViolationException::class)
    fun handleBadRequest(ex: DataIntegrityViolationException): ResponseEntity<Any?>? {
        return ResponseEntity.badRequest().body(ex.message)
    }
}

@ResponseStatus(value = HttpStatus.NOT_FOUND, reason = "Requested item(s) not found")
class NotFoundException : Exception {
    constructor(clsName: String) : super("table for $clsName is empty!")
    constructor(clsName: String, id: Long) : super("$clsName with id: $id does not exist!")
}
```

Kotlin does not enforce the name of the file to be the same as the top-level class declared within it, and this allows developers to put various classes of smaller sizes in the same file. For example, the classes in Listing 16-38 are declared in a file named `KotlinApplication.kt` (the Kotlin file extension is `kt`).

Now that you've been introduced to a not-so-simple Spring Boot web application with a REST controller and JPA, all that is left is to test it. Writing a Spring Boot test in Kotlin is not that different from writing one in Java, but it does provide the opportunity to introduce the companion object. Listing 16-39 shows a Kotlin Spring Boot test class.

**Listing 16-39.** KotlinApplicationTest Kotlin Spring Boot Test Class

```

package com.apress.prospring6.sixteen.boot
// import statements omitted

@ActiveProfiles("test")
@SpringBootTest(webEnvironment = SpringBootTest.WebEnvironment.RANDOM_PORT)
class KotlinApplicationTest(@Autowired val restTemplate: TestRestTemplate, @Value(value =
"\${local.server.port}") val port: Int) {

    val logger: Logger = LoggerFactory.getLogger(KotlinApplicationTest::class.java)

    companion object {
        @JvmStatic
        @BeforeAll
        fun setup() {
            println(">> Setup")
        }

        @JvmStatic
        @AfterAll
        fun teardown() {
            println(">> Tear down")
        }
    }

    @Test
    fun `find all singers`() {
        val singers: Array<Singer> = restTemplate.getForObject("/singer",
        Array<Singer>::class.java)
        Assertions.assertTrue(singers.size >= 15)
        for(it in singers) logger.info(it.toString())
    }

    @Test
    @Throws(URISyntaxException::class)
    fun `can't find Singer by id`() {
        logger.info("--> Testing retrieve a singer by id : 99")

        val req: RequestEntity<Singer> = RequestEntity<Singer>(HttpMethod.GET, URI("http://
        localhost:$port/singer/99"))
        val response: ResponseEntity<Singer> = restTemplate.exchange(req,
        Singer::class.java)
        Assertions.assertAll("testNegativeFindById",
            Executable { Assertions.assertEquals(HttpStatus.NOT_FOUND, response.
            statusCode) },
            Executable { Assertions.assertNull(response.body?.firstName) },
            Executable { Assertions.assertNull(response.body?.lastName) }
        )
    }
}

```

Here are the main observations about this class:

- Note the syntax `\$` in `@Value(value = "\${local.server.port}") val port: Int` toward the beginning of Listing 16-39. As mentioned at the beginning of this section, Kotlin supports string template expressions. Template expressions start with `$` (dollar sign), but so do references to Spring environment variables, so in Kotlin, when environment variables are referenced for injection in `@Value` annotations, for example, the dollar sign needs to be escaped by prefixing it with `\` (backslash).
- There is no `static` in Kotlin. Java-style statics are not supported, to encourage better coding practices. Since the `@BeforeAll` and `@AfterAll` annotations need to be placed on static methods, the solution for this is to declare a companion object for the `KotlinApplicationTest`, place the functions there, and annotate them with `@JvmStatic`. This annotation specifies that an additional static method needs to be generated from this element if it's a function.
- Since there is no `static` in Kotlin, there are no static imports, so assertions need to be invoked like this: `Assertions.assertThat(..)`.

Also in Kotlin, class, function, and variable names can contain spaces if declared between backticks, `` ``. It can be useful sometimes, but don't abuse it, because it might make the code less readable.

## Summary

GraalVM Native Images are an evolving technology, and not all libraries provide support. Spring Native support was experimental until Spring Boot 3. The Maven Daemon (`mvnd`)<sup>16</sup> is a good example of how quick native executables are compared to applications running on the JVM. It is also a good example of the limitations and restrictions involved, since Maven projects designed to be built with `mvnd` have to be configured carefully so that modules can be built in parallel. For small projects with a few modules, `mvnd` can provide a speedup of 7 to 10 times or more compared to stock Maven. For larger projects with many modules, `mvnd` can provide a speedup of 3 to 5 times or more, due to its ability to build modules in parallel and the optimization provided by the JIT compiler.

GraphQL's adoption by Spring is a clear sign that GraphQL is here to stay. There is one operation in GraphQL that was not covered in this chapter: *subscription*. Sometimes clients might want to receive updates from the server when data they care about changes. Subscription is the operation that provides this functionality. Another topic that was not touched upon is GraphQL on a reactive server like Netty. In a Spring Boot reactive application with GraphQL, testing is possible with `org.springframework.graphql.test.tester.GraphQLTester`.<sup>17</sup>

Kotlin has been developed by taking into account other things missing or implemented badly in other languages. Seasoned developers might recognize in its syntax inspiration from Closure or Python, but mostly Scala and Java. It is a modern and approachable language, with a great development team and a great community around it. There are security and performance concerns about the black magic Kotlin does to convert the code to bytecode runnable on JVM, and there is also the cost of the extra configuration required to interact with Java frameworks already established in the industry. Is Kotlin the future? Yet again, the fact that Spring has adopted it might be a sign that this is what developers want.

<sup>16</sup> <https://github.com/apache/maven-mvnd>

<sup>17</sup> <https://docs.spring.io/spring-graphql/docs/current/api/org/springframework/graphql/test/tester/GraphQLTester.html>

## CHAPTER 17



# Securing Spring Web Applications

**Chapter 14** explained how to build a Spring web application using classic, “manual”-style configuration and using Spring Boot with Thymeleaf. This chapter will take the application built in **Chapter 14** and add a security layer that will declare which users are allowed to access various parts of the application. For example, only those users who logged into the application with a valid user ID can add a new singer or update existing singers. Other users, known as *anonymous users*, can only view singer information.

Spring Security is the best choice for securing Spring-based applications. Spring Security provides authentication, authorization, and other security features for enterprise applications. Although mostly used in the presentation layer, Spring Security can help secure all layers within the application, including the service layer. In the following sections, we demonstrate how to use Spring Security to secure the singers application. For web applications, depending on the view technology used, there are tags that can be part of the view template to hide or show parts of the view based on the user rights.

Spring Security is a relatively complex framework that aims to make it easy for the developer to implement security in an application. Before being part of Spring, the project, started in late 2003, was named *Acegi Security*. The first Spring Security release was version 2.0.0 in April 2008.

When it comes to security in applications, there are two processes that are most important, and Spring Security can be used to configure both:

- *Authentication*: The process of proving that you are who you say you are. This means you submit your credentials to the application, and they are tested against a set of existing users, and if a match is found, you are given access to the application.
- *Authorization*: The process of granting an authenticated party permission to do something. Spring Security is essentially a framework composed of intercepting rules for granting, or not granting, access to resources.

These two processes revolve around a *principal* which signifies a user, device, or system that could perform an action within the application and, *credentials* which are identification keys that a principal uses to confirm its identity (e.g., a username and password).

This chapter shows how to configure authorization and authentication with Spring Security version 6.x.

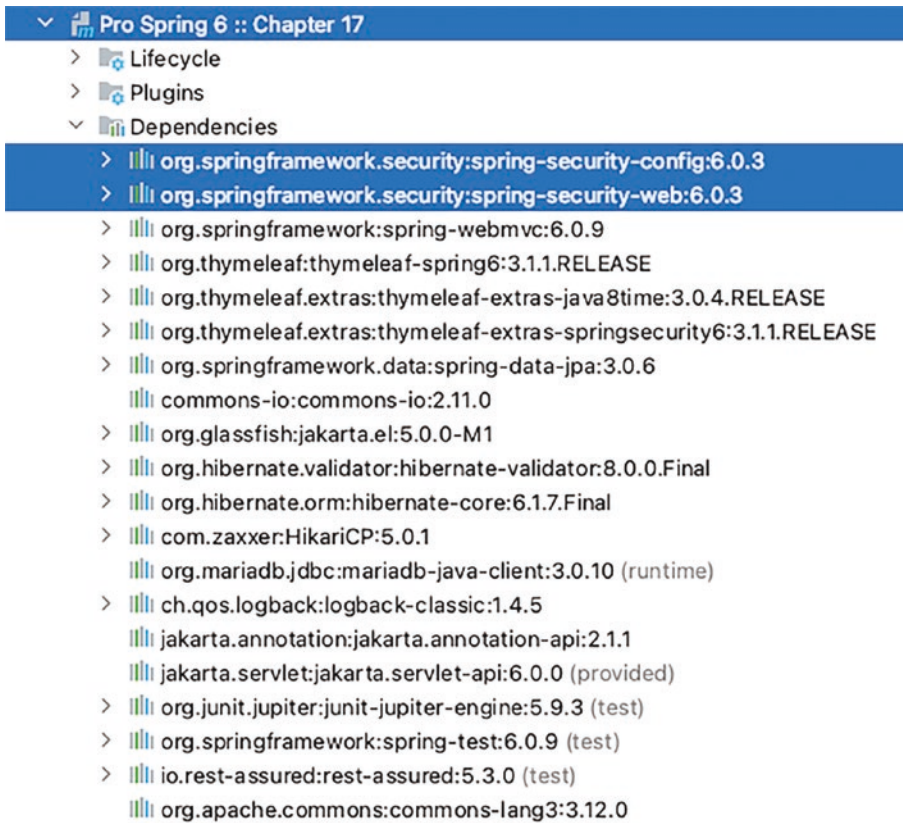


You can find Spring Security's source code on GitHub at <https://github.com/spring-projects/spring-security/>.

---

## Configuring Spring Security: The Classic Way

This section shows how to secure the application built in **Chapter 14**. To add Spring Security to it, we obviously need to add a few libraries to the classpath. A minimal Spring Security configuration for a Spring web application typically looks similar to the one depicted in Figure 17-1.



**Figure 17-1.** Project chapter17 dependencies

The `spring-security-config` library contains Java configuration support. The `spring-security-web` library contains web security infrastructure code, such as various filters and other Servlet API dependencies.

The internals of Spring Security are complex, and the official documentation explains them very well and in detail. For the purpose of this book, the only thing you need to know is that once Spring Security is configured, all HTTP requests are intercepted by a Security Interceptor and access to resources is decided based on the user making the request. The Security Interceptor works with a preprocessing step and a postprocessing step. In the preprocessing step, it looks to see whether the requested resource is secured with some metadata information represented by an `org.springframework.security.access.ConfigAttribute`<sup>1</sup>. If it is not, the request is allowed to continue its way either to the requested URL or method. If the requested

<sup>1</sup><https://github.com/spring-projects/spring-security/blob/main/core/src/main/java/org/springframework/security/access/ConfigAttribute.java>

resource is secured, the Security Interceptor retrieves the Authentication object from the current SecurityContext. If necessary, the Authentication object will be authenticated against the configured AuthenticationManager.

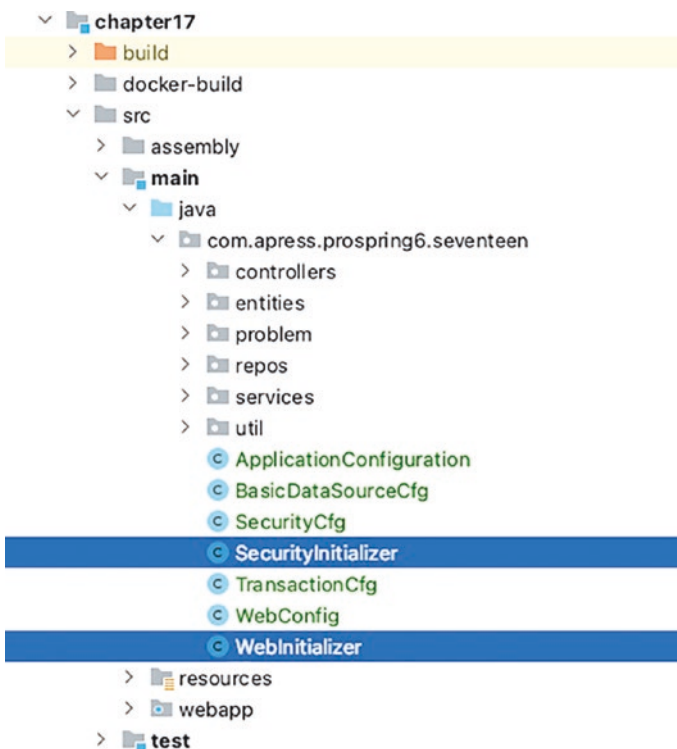
Intercepting all requests to a web application requires a special servlet filter. The Spring Security filter that needs to be configured is named `springSecurityFilterChain` and, as its name makes obvious, it is not a single filter but a collection of filters that are chained together to protect the application URLs, validate submitted usernames and passwords, redirect to the login form, and so on. Spring Security provides ways to configure this filter and customize its various functions, as in depth as necessary.

This being said, let's see how we can configure security support in a Spring web application with classic configuration.



If you need to, please review **Chapter 14** at this point to re-familiarize yourself with the components of a Spring web application with classic configuration and how to pack up an application as a WAR file and deploy it to Apache Tomcat 10.

Figure 17-2 shows the configuration classes for a secured Spring web application with classic configuration.



**Figure 17-2.** Project *chapter17* configuration classes

One of the first things that we need to do is to make sure `springSecurityFilterChain` is the entry point to the application, registered with the highest precedence, to be the first filter in the chain, before any other registered `jakarta.servlet.Filter`. This is done by adding a class that implements `org.springframework.web.WebApplicationInitializer` to the application. In Figure 17-2 the class is named `SecurityInitializer`. Its implementation is shown in Listing 17-1.

*Listing 17-1.* The `SecurityInitializer` Class

```
package com.apress.prospring6.seventeen;

import org.springframework.security.web.context.AbstractSecurityWebApplicationInitializer;

class SecurityInitializer extends AbstractSecurityWebApplicationInitializer {

    @Override
    protected boolean enableHttpSessionEventPublisher() {
        return true;
    }
}
```

Notice that the `SecurityInitializer` class does not implement `WebApplicationInitializer` directly, but by extending `AbstractSecurityWebApplicationInitializer` to benefit from the default Spring implementation and reduce the work a developer must do.



The `enableHttpSessionEventPublisher()` method is overridden to return `true`; by default it returns `false`, and we could have left it like that since this configuration is not really important for the rest of the chapter. This method should return `true` if session management has specified a maximum number of sessions, because in this case a `org.springframework.security.web.session.HttpSessionEventPublisher` is added to the configuration to notify the session registry when users logs out.

---

Now the security filter is in place, let's give it the required components to do its job.

Notice that we haven't added any view template for the login page—with Spring Security, we don't have to. With a default configuration, a default very simple login page is included, and any request requiring authentication is redirected to it. So, we can jump directly to the Spring Security configuration. Listing 17-2 shows the `SecurityCfg` class, explanation of which follows the listing.

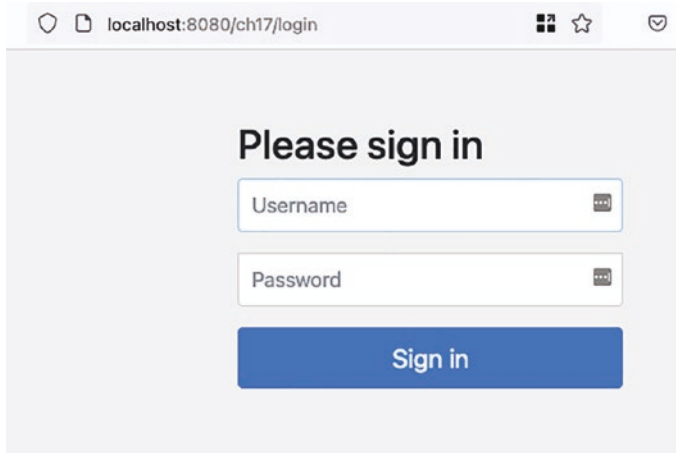
*Listing 17-2.* Basic Version of the `SecurityCfg` Class

```
package com.apress.prospring6.seventeen;

import org.springframework.context.annotation.Configuration;
import org.springframework.security.config.annotation.web.configuration.EnableWebSecurity;

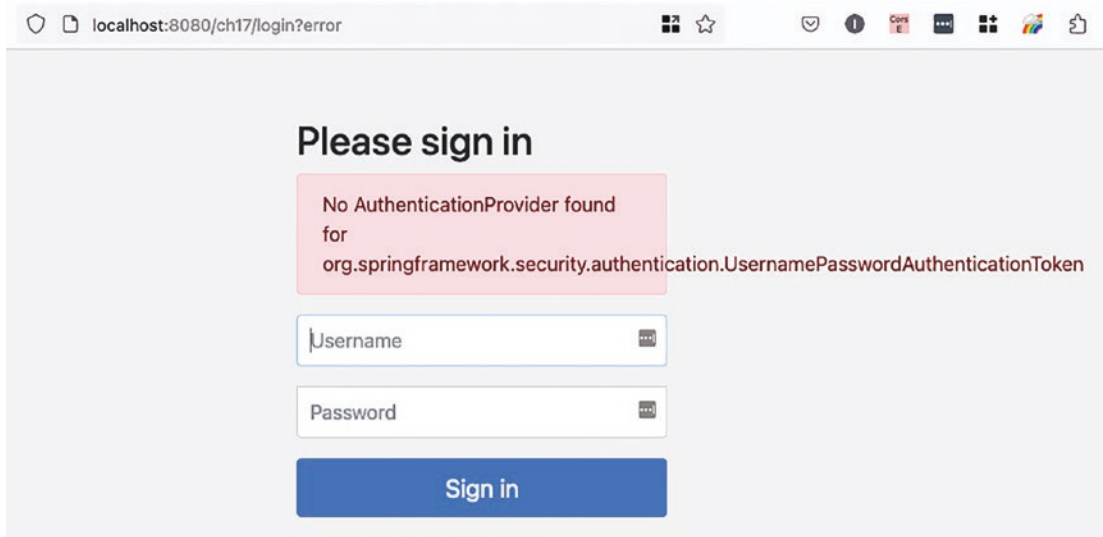
@Configuration
@EnableWebSecurity
public class SecurityCfg {
}
```

This is the simplest Spring Security configuration example possible. It sets up the `securityFilterChain` with a default configuration, so all requests are now blocked. If you deploy the project and try to access it at `http://localhost:8080/ch17`, you are redirected to the login screen shown in Figure 17-3.



**Figure 17-3.** Default login screen

This is a very simple login page written in HTML with Bootstrap<sup>2</sup> with a form for submitting a username and password. You can inspect the source in your browser if you want to. If you try to introduce a username and password, you will be redirected to the same page, but with an error message added, as shown in Figure 17-4.



**Figure 17-4.** Login screen with error message

<sup>2</sup><https://getbootstrap.com/>



What Spring is complaining about is that there is no `AuthenticationProvider` bean configured, and thus Spring does not know where to look for a username and a password to match the ones submitted so that your identity can be validated. To keep things as simple as possible as well, we'll configure a bean of type `UserDetailsService` to use in-memory authentication for teaching purposes. It declares a single user named "john" with password "doe" and role "USER". The bean is shown in Listing 17-3.

*Listing 17-3.* The `UserDetailsService` bean

```
package com.apress.prospring6.seventeen;

import org.springframework.security.core.userdetails.User;
import org.springframework.security.core.userdetails.UserDetails;
import org.springframework.security.core.userdetails.UserDetailsService;
import org.springframework.security.provisioning.InMemoryUserDetailsManager;
// some import statements omitted

@Configuration
@EnableWebSecurity
public class SecurityCfg {

    @Bean
    public UserDetailsService userDetailsService() {
        UserDetails user = User.withDefaultPasswordEncoder()
            .username("john")
            .password("doe")
            .roles("USER")
            .build();
        return new InMemoryUserDetailsManager(user);
    }
}
```

This configuration is compact, but it does a lot, a partial list of which follows:

- Blocks access to all application URLs
- Generates a login form
- Allows form-based authentication for a user named john with password password
- Allows for a user to log out as well
- Prevents CSRF<sup>3</sup> attack
- Provides Session Fixation<sup>4</sup> protection

The `UserDetailsService` bean is a very simple one as well, and the `User` object is built with `withDefaultPasswordEncoder()`, which delegates to `BCryptPasswordEncoder`. If you want to build a demo application, and you need multiple users and roles, you can explicitly declare a `BCryptPasswordEncoder` bean and use it. Listing 17-4 shows you how.

<sup>3</sup><https://portswigger.net/web-security/csrf>

<sup>4</sup>[https://owasp.org/www-community/attacks/Session\\_fixation](https://owasp.org/www-community/attacks/Session_fixation)

*Listing 17-4.* The SecurityCfg Class with a BCryptPasswordEncoder Bean

```

package com.apress.prospring6.seventeen;

import org.springframework.security.crypto.bcrypt.BCryptPasswordEncoder;
// some import statements omitted

@Configuration
@EnableWebSecurity
public class SecurityCfg {

    @Bean
    public PasswordEncoder encoder() {
        return new BCryptPasswordEncoder();
    }

    @Bean
    public UserDetailsService userDetailsService(PasswordEncoder encoder) {
        User.UserBuilder users = User.builder().passwordEncoder(encoder::encode);
        var joe = users
            .username("john")
            .password("doe")
            .roles("USER")
            .build();
        var jane = users
            .username("jane")
            .password("doe")
            .roles("USER")
            .build();
        var admin = users
            .username("admin")
            .password("admin")
            .roles("ADMIN")
            .build();
        return new InMemoryUserDetailsManager(jane, joe, admin);
    }
}

```

The class is annotated with the `@EnableWebSecurity` annotation to enable secured behavior in a Spring web application. This annotation exposes the `SecurityFilterChain` bean, so it can be customized. The configuration introduced so far does not show any of that. Every aspect of the `SecurityFilterChain` bean can be customized. Let's start small and add an explicit configuration for it that actually uses the defaults, just to have an idea of how it is done. Listing 17-5 introduces you to a custom `SecurityFilterChain` bean.

*Listing 17-5.* The SecurityCfg Class with a Simple SecurityFilterChain bean

```

package com.apress.prospring6.seventeen;

import org.springframework.security.config.Customizer;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.web.SecurityFilterChain;
// some import statements omitted

```

```

@Configuration
@EnableWebSecurity
public class SecurityCfg {

    @Bean
    public SecurityFilterChain securityFilterChain(HttpSecurity http) throws Exception {
        http
            .authorizeHttpRequests((authorize) -> authorize
                .anyRequest().authenticated()
            )
            // .httpBasic(Customizer.withDefaults())
            .formLogin(Customizer.withDefaults())
            .logout(Customizer.withDefaults());
        return http.build();
    }
    @Bean
    public PasswordEncoder encoder() {
        return new BCryptPasswordEncoder();
    }

    // userDetailsService omitted
}

```

One by one, here is an explanation of all the important bits of this configuration:

- `HttpSecurity`: This object allows configuration of web-based security for specific HTTP requests. Spring injects an instance of this object, which can be further configured.
- `authorizeHttpRequests(...)`: This method provides support for customizing access to various resources to authenticated users. The syntax is builder specific and multiple rules can be connected to each other through `.and()` methods.
- `httpBasic(Customizer.withDefaults())`: This is used to configure HTTP basic authentication for the application. The `withDefaults()` method returns an empty implementation of the `Customizer<T>` functional interface. This does not generate a login form, and authentication is enforced by the browser, by blocking access to the application via a dialog box that allows you to submit a username and password. Since it does not require a form, basic authentication is more suitable for REST requests. This method invocation is equivalent to `httpBasic()`.
- `formLogin(Customizer.withDefaults())`: This is used to configure a login form. With an empty `Customizer<T>`, it obviously defaults to the generic out-of-the-box form, but a `Customizer<FormLoginConfigurer<?>>` can configure the path of the login page, the names of the username and password form parameters. This method invocation is equivalent to `formLogin()`.
- `logout(Customizer.withDefaults())`: This is used to configure logout support. This functionality is automatically enabled when configuring security using `@EnableWebSecurity`. This invocation, equivalent to `logout()`, is added to this configuration for teaching purposes.

Now that we have some defaults, let's customize some of them. Let's start with the hardest: let's add a custom default form. For this we need to create a Thymeleaf view template containing a simple authentication form. The base of this is the `views/templates/layout.html` template that declares sections for the header, menu, and footer, thus the authentication form will represent only the central part of the page, the `pageContent` section. The form is shown in Listing 17-6.

**Listing 17-6.** A Thymeleaf Authentication Form (`views/auth.html`)

```
<!DOCTYPE HTML>
<html xmlns:th="http://www.thymeleaf.org">

  <head th:replace=~{templates/layout :: pageTitle('Login Page')}></head>

  <body>
    <div class="container">
      <header th:replace=~{templates/layout :: pageHeader}" ></header>

      <header th:replace=~{templates/layout :: pageMenu}" ></header>

      <section th:fragment=~{templates/layout :: pageContent}">
        <div class="content"> <!-- content -->
          <h5 th:text="#{command.login}">Log in</h5>
          <div class="container col-lg-12">
            <form th:action="@{/auth}" method="post">
              <div class="row mb-1">
                <input type="text" id="user" name="user"
                  autofocus="autofocus" class="form-control"
                  th:placeholder="#{label.username}" />
              </div>
              <div class="row mb-1">
                <input type="password" id="pass" name="pass"
                  class="form-control" th:placeholder="#{label.
                    password}" />
              </div>
              <div class="form-group mb-1 align-items-end">
                <input type="submit" th:value="#{command.signin}"
                  id="loginButton" class="btn btn-dark"/>
              </div>
            </form>
          </div>
        </div>
      </section>
      <footer th:replace=~{templates/layout :: pageFooter}" ></footer>
    </div>
  </body>
</html>
```

Intentionally, the URL for submitting the form is changed to `/auth`, the username and password fields are renamed to `user` and `pass`, and the file is named `auth.html` to provide as much configuration as possible.

To configure Spring Security to use this form as a login form, the `.formLogin()` invocation must be replaced with the configuration in Listing 17-7.

**Listing 17-7.** Spring Security Configuration with a Custom Form

```

.formLogin(loginConfigurer -> loginConfigurer
    .loginPage("/auth")
    .loginProcessingUrl("/auth")
    .usernameParameter("user")
    .passwordParameter("pass")
    .defaultSuccessUrl("/home")
    .permitAll())
.csrf().disable();

```

The name of each of these methods makes it very obvious as to which part of the configuration it covers:

- `loginPage("/auth")` configures the login form to be a view named `auth`. We can map this view name to the `views/auth.html` template, either via a `@GetMapping` handler method or by adding the mapping to the `ViewControllerRegistry` in the web configuration, like shown in Listing 17-8.

**Listing 17-8.** Mapping the `/auth` Path to the `views/auth.html` View File

```

package com.apress.prospring6.seventeen;

import org.springframework.web.servlet.config.annotation.ViewControllerRegistry;

//other import statements omitted

@Configuration
@EnableWebMvc
public class WebConfig implements WebMvcConfigurer, ApplicationContextAware {
    @Override
    public void addViewControllers(ViewControllerRegistry registry) {
        registry.addRedirectViewController("/", "/home");
        registry.addViewController("/auth").setViewName("auth");
    }

    // other bits of configuration omitted
}

```

- `loginProcessingUrl("/auth")` is needed to declare the `/auth` as the URL where the credentials are submitted, and is the one in `th:action="@{/auth}"` Thymeleaf form declaration.
- `defaultSuccessUrl("/home")` is needed to redirect the user to the main page when the authentication succeeds. By default, the user is redirected to the root of the application, `/`, and in this example it is the same page we configured by this method too.
- `csrf().disable()` is needed to disable the generation of a CSRF token. As mentioned at the beginning of this section, by default CSRF protection is enabled, and to keep our form simple, and the configuration too, we decided to disable it.

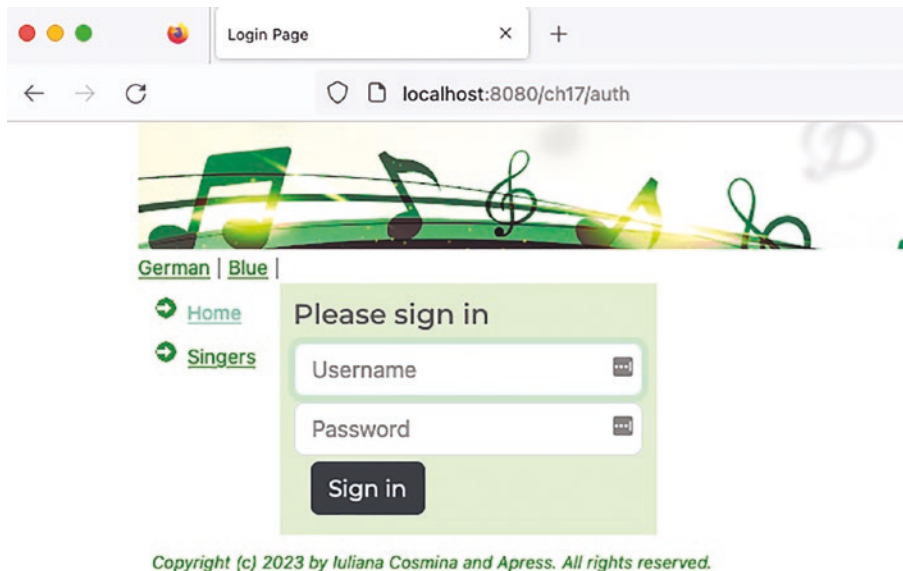


Spring Security 4 introduced the possibility of using CSRF tokens in Spring forms to prevent cross-site request forgery. In this example, because we wanted to keep things simple, the usage of CSRF tokens was disabled by calling `csrf().disable()`. By default, a configuration without a CSRF element configuration is invalid, and any login request will direct you to a 403 error page stating the following:

Invalid CSRF Token 'null' was found on the request parameter '\_csrf' or header 'X-CSRF-TOKEN'.

- `permitAll()` is needed to make sure unauthenticated users have access to the authentication form.

Now that we have a custom form, when we try to access the application at `http://localhost:8080/ch17` instead of the Spring Security default form, the custom form is the one we get redirected to, shown in Figure 17-5.



**Figure 17-5.** Custom login form configured with Spring Security

Each of the default configurations shown until now in this section will probably require small changes and adjustments in real applications. For example, the `authorizeHttpRequests(...)` method is used to set up authorization for specific URL paths, exclude some of them from this process like CSS and images. The URL path for logging out of the application can be changed to something else and some extra cleanup steps can be added, such as deleting authentication details from the browser cache or deleting some cookies. Listing 17-9 shows the customized spring security configuration.

*Listing 17-9.* Customized Version of the SecurityFilterChain

```

package com.apress.prospring6.seventeen;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.configuration.EnableWebSecurity;
import org.springframework.security.core.userdetails.User;
import org.springframework.security.core.userdetails.UserDetailsService;
import org.springframework.security.crypto.bcrypt.BCryptPasswordEncoder;
import org.springframework.security.crypto.password.PasswordEncoder;
import org.springframework.security.provisioning.InMemoryUserDetailsManager;
import org.springframework.security.web.SecurityFilterChain;

@Configuration
@EnableWebSecurity
public class SecurityCfg {

    @Bean
    public SecurityFilterChain securityFilterChain(HttpSecurity http) throws Exception {
        http
            // authorization
            .authorizeHttpRequests((authorize) -> authorize
                .requestMatchers( "/styles/**", "/images/**").permitAll()
                .anyRequest().authenticated())
            // logout
            .logout(httpSecurityLogoutConfigurer -> httpSecurityLogoutConfigurer
                .logoutUrl("/exit")
                .permitAll()
                .clearAuthentication(true))
            // login form
            .formLogin(loginConfigurer -> loginConfigurer
                .loginPage("/auth")
                .loginProcessingUrl("/auth")
                .usernameParameter("user")
                .passwordParameter("pass")
                .defaultSuccessUrl("/home")
                .permitAll())
            // CSRF protection disabled
            .csrf().disable();
        return http.build();
    }
    // other configuration elements omitted
}

```

Notice that the logout behavior has been configured as well, by providing a customizer as an argument for the `logout(..)` method; besides changing the logout URL from `/logout` to `/exit`, it also adds the `clearAuthentication(true)` call that tells Spring to clear the `Authentication` (default) when a user logs out.

Now that we have the full configuration, how do we tell Spring about it? To make sure it is used correctly, we need to add the `SecurityCfg` class to the collection of configuration classes that define our application context. In **Chapter 14** the `WebInitializer` class was used to register a `DispatcherServlet`. Java-based Spring configuration was used for declaring the root application as being configured via the `BasicDataSourceCfg` and `TransactionCfg` classes. The web application context was configured by the `WebConfig` class. This configuration is shown in Listing 17-10.

*Listing 17-10. Chapter 14 Web Application Configuration*

```
package com.apress.prospring6.fifteen;

import jakarta.servlet.Filter;
import org.springframework.web.filter.CharacterEncodingFilter;
import org.springframework.web.filter.HiddenHttpMethodFilter;
import org.springframework.web.servlet.support.
AbstractAnnotationConfigDispatcherServletInitializer;

import java.nio.charset.StandardCharsets;

public class WebInitializer extends AbstractAnnotationConfigDispatcherServletInitializer {

    @Override
    protected Class<?>[] getRootConfigClasses() {
        return new Class[]{BasicDataSourceCfg.class, TransactionCfg.class};
    }

    @Override
    protected Class<?>[] getServletConfigClasses() {
        return new Class[]{WebConfig.class};
    }

    @Override
    protected String[] getServletMappings() {
        return new String[]{"/*"};
    }

    @Override
    protected Filter[] getServletFilters() {
        final CharacterEncodingFilter cef = new CharacterEncodingFilter();
        cef.setEncoding(StandardCharsets.UTF_8.name());
        cef.setForceEncoding(true);
        return new Filter[]{new HiddenHttpMethodFilter(), cef};
    }
}
```

When we know that security is implemented only for the web layer the `SecurityCfg` class must be added to the web context. But there are situations when the security context spans through multiple layers, the most obvious examples being when the users accessing the application have their credentials stored in the database and when the service layer supports remote calls. In situations like these, a configuration class picking up all configuration is introduced and used to declare a single huge and all-powerful web application context. Listing 17-11 shows the `ApplicationConfiguration` class.



*Listing 17-11.* The `ApplicationConfiguration` Class

```
package com.apress.prospring6.seventeen;

import org.springframework.context.annotation.ComponentScan;
import org.springframework.context.annotation.Configuration;

@Configuration
@ComponentScan
public class ApplicationConfiguration {
}
```

The `ApplicationConfiguration` class is used as a single configuration entry point in the `WebInitializer` for the `chapter17` project, shown in [Listing 17-12](#).

*Listing 17-12.* **Chapter 17** Web Application Configuration

```
package com.apress.prospring6.seventeen;
// import statements omitted

public class WebInitializer extends AbstractAnnotationConfigDispatcherServletInitializer {

    @Override
    protected Class<?>[] getRootConfigClasses() {
        return new Class[]{};
    }

    @Override
    protected Class<?>[] getServletConfigClasses() {
        return new Class[]{ApplicationConfiguration.class};
    }

    @Override
    protected String[] getServletMappings() {
        return new String[]{"/*"};
    }

    // some configuration omitted
}
```

With the configuration in place, what is left to do is tweak bits of the UI to provide some logout option displaying the logged-in user and so on. Since we are using Thymeleaf, this is quite easy to do, but it requires the `thymeleaf-extras-springsecurity6` library to be added to the classpath. This library adds the Spring Security integration module to the application, which allows using the Spring Security dialect constructs in the Thymeleaf templates. This means beside the attributes prefixed with `th:`, we can now use properties prefixed with `sec:` to access the security context and make decisions about how the view appear to users with different roles.

Since we now have authenticated users, we can add two things to our layout template (`views/templates/layout.html`):

- A logout menu item
- A section where the name of the authenticated user is shown

These two modifications are shown in Listing 17-13.

**Listing 17-13.** Thymeleaf Security Constructs in views/templates/layout.html

```
<!DOCTYPE HTML>
<html xmlns:th="http://www.thymeleaf.org" th:with="lang=${#locale.language},
theme=${#themes.code('name')}}" th:lang="${lang}" th:theme="${theme}">
  <head th:fragment="pageTitle(title)">
    <!-- head contents omitted -->
  </head>
  <body>
    <header th:fragment="pageHeader" class="page-header">
      <div class="row">
        <div class="col-lg-8 col-md-7 col-sm-6">
          <div class="banner"></div>
          <div class="themelocal">
            <!-- theming links omitted -->
            <span sec:authorize="isAuthenticated()">
              Authenticated: <em sec:authentication="name"></em>
            </span>
          </div>
        </div>
      </div>
    </header>

    <section th:fragment="pageMenu">
      <div class="menu">
        <ul>
          <!-- other elements configuration omitted -->
          <li sec:authorize="isAuthenticated()">
            <a th:href="@{/exit}" th:text="#{command.logout}">Sign Out</a>
          </li>
        </ul>
      </div>
    </section>

    <section th:fragment="pageContent">
      <div class="content">
        <p>Page Content</p>
      </div>
    </section>

    <footer th:fragment="pageFooter">
      <div class="footer">
        <p th:text="#{footer.text}"></p>
      </div>
    </footer>
  </body>
</html>
```

**Listing 17-14.** Configuration Snippet to Register the `SpringSecurityDialect` with the `SpringTemplateEngine`

```
package com.apress.prospring6.seventeen;

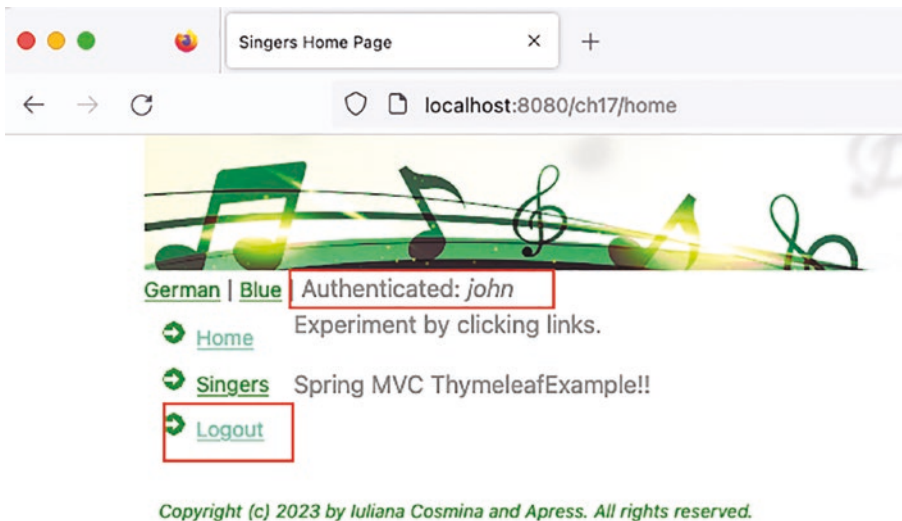
import org.thymeleaf.extras.java8time.dialect.Java8TimeDialect;
import org.thymeleaf.extras.springsecurity6.dialect.SpringSecurityDialect;
import org.thymeleaf.spring6.SpringTemplateEngine;
// other import statements omitted

@Configuration
@EnableWebMvc
public class WebConfig implements WebMvcConfigurer, ApplicationContextAware {

    @Bean
    @Description("Thymeleaf Template Engine")
    public SpringTemplateEngine templateEngine() {
        var engine = new SpringTemplateEngine();
        engine.addDialect(new Java8TimeDialect());
        engine.setTemplateResolver(templateResolver());
        engine.setTemplateEngineMessageSource(messageSource());
        engine.addDialect(new SpringSecurityDialect());
        engine.setEnableSpringELCompiler(true);
        return engine;
    }

    // other configurations omitted
}
```

With this configuration in place, when a user has successfully logged into the application, the home page will show the user's name and the logout option, as shown in Figure 17-6.



**Figure 17-6.** Home page shown to an authenticated user

In our configuration we have defined two roles, USER and ADMIN, but we are not using them for anything, because currently there is no configuration that is specific only to a certain role. Just to show how this can be done, let's allow only users with the ADMIN right to delete singers. This means we must do two things:

- Make sure the Delete button is not rendered for users that are not ADMIN
- Reject delete requests for users that are not ADMIN, by securing the controller method

Preventing the rendering of the Delete button is easily done by using a combination of Thymeleaf security constructs and SpEL expressions, as shown in Listing 17-15.

**Listing 17-15.** views/show.html Hiding the Delete Button for Non-ADMIN Users

```
<!DOCTYPE HTML>
<html xmlns:th="http://www.thymeleaf.org">

  <head th:replace=~{templates/layout :: pageTitle('Singer Page')}></head>

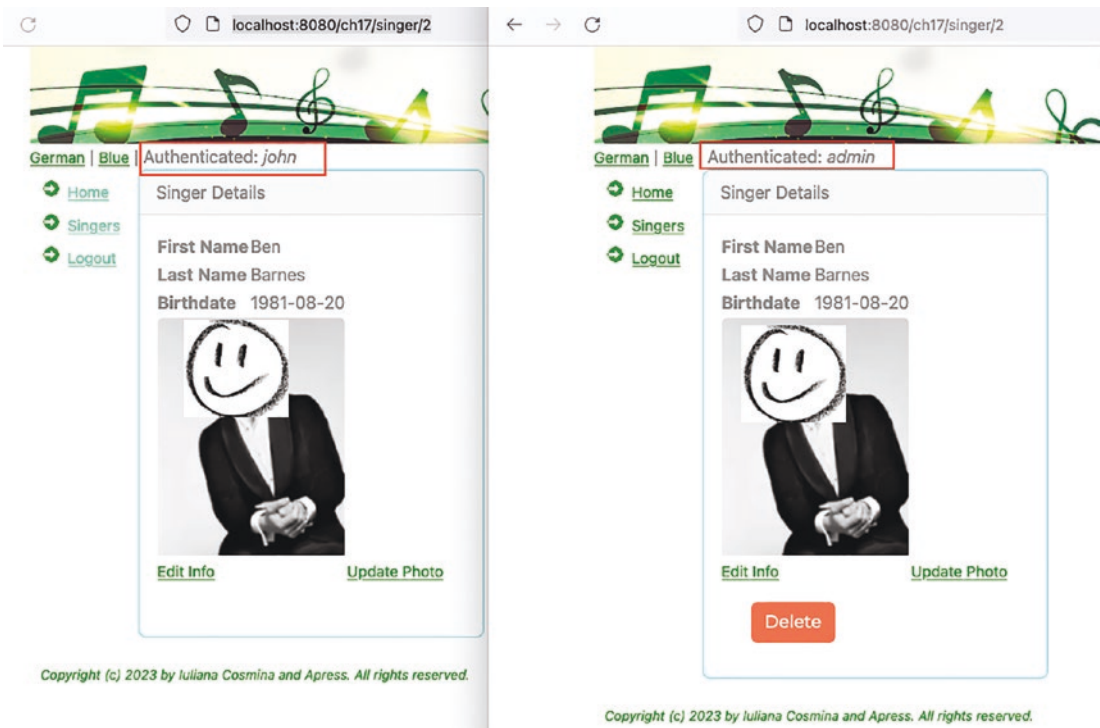
  <body>
    <div class="container">
      <header th:replace=~{templates/layout :: pageHeader}" ></header>

      <header th:replace=~{templates/layout :: pageMenu}" ></header>

      <section th:fragment=~{templates/layout :: pageContent}">
        <!-- some elements omitted -->
        <div class="container col-lg-12">
          <form th:object="{singer}" th:action="@{/singer/} + {singer.id}"
                th:method="delete" class="col p-3">
            <input sec:authorize="hasRole('admin')"
                  type="submit" th:value="#{command.delete}"
                  id="deleteButton"
                  class="btn btn-danger"/>
          </form>
        </div>
      </div>
    </div>
  </div>
  </section>

  <footer th:replace=~{templates/layout :: pageFooter}" ></footer>
</div>
</body>
</html>
```

With this configuration, user john no longer can see the Delete button, while the admin user still can see it, as verified by Figure 17-7.



**Figure 17-7.** Comparison of page display for user with role USER (left) and user with role ADMIN

The Spring Security SpEL expression is quite versatile. The role name is not case sensitive, so `hasRole('admin')` is treated the same way as `hasRole('ADMIN')`. Also, if the role name does not have a `ROLE_` prefix, it is added by default, such as `hasRole('ROLE_ADMIN')`. This makes it quite practical to configure authorization using SpEL expressions.



In Spring Security there are two ways to describe what a user can and cannot do. For each application user, *authorities* and *roles* are configured. Both roles and authorities are represented by a `List<GrantedAuthority>`, where the `org.springframework.security.core.GrantedAuthority` interface represents an authority granted to an `Authentication` object, thus a *permission*. A role is nothing else than a `GrantedAuthority` with name prefixed with `ROLE_`. Why are there two ways? Because under the hood, Spring security might be configured to treat roles differently than authorities. Authorities are fine-grained permissions targeting a specific action coupled sometimes with a specific data scope or context. For instance, `Read`, `Write`, and `Manage` can represent various levels of permissions to a given scope of information. On the other hand, roles are coarse-grained representations of a set of permissions. A `ROLE_USER` would only have `Read` or `View` authority, while a `ROLE_ADMIN` would have `Read`, `Write`, and `Delete`.

There is quite a long list of Spring Security SpEL expressions for configuring authorization, and their syntax and purpose are shown and described in Table 17-1.

**Table 17-1.** Spring Security SpEL Expressions

Expression	Description
<code>hasRole(String role)</code>	Returns true if the current principal has the specified role; e.g., <code>hasRole('admin')</code> . The role is not case sensitive, and if <code>ROLE_</code> is not present, it is added by default. This behavior is customizable by modifying the <code>defaultRolePrefix</code> on <code>DefaultWebSecurityExpressionHandler</code> <sup>5</sup> .
<code>hasAnyRole(String... roles)</code>	Returns true if the current principal has any of the specified roles; e.g., <code>hasAnyRole('admin', 'manager')</code> .
<code>hasAuthority(String authority)</code>	Returns true if the current principal has the specified authority; e.g., <code>hasAuthority('read')</code> .
<code>hasAnyAuthority(String... authorities)</code>	Returns true if the current principal has any of the specified authorities; e.g., <code>hasAnyAuthority('read', 'write')</code> .
<code>principal</code>	Allows direct access to the principal object that represents the current user.
<code>authentication</code>	Allows direct access to the current <code>Authentication</code> object obtained from the <code>SecurityContext</code> .
<code>isAnonymous()</code>	Returns true if the current principal is an anonymous user.
<code>isRememberMe()</code>	Returns true if the current principal is a remember-me user.
<code>isAuthenticated()</code>	Returns true if the user is not anonymous.
<code>isFullyAuthenticated()</code>	Returns true if the user is not anonymous and is not a remember-me user.
<code>hasPermission(Object target, Object permission)</code>	Returns true if the user has access to the provided target for the given permission; e.g., <code>hasPermission(domainObject, 'read')</code> .
<code>hasPermission(Object targetId, String targetType, Object permission)</code>	Returns true if the user has access to the provided target, identified by its id and type, for the given permission; e.g., <code>hasPermission(1, 'com.apress.Singer', 'read')</code> .

The `hasRole('admin')` Spring Security SpEL expression can be used to secure the delete handler method when provided as an attribute value to the `@PreAuthorize` annotation. This annotation and a few other annotations discussed later are part of the `org.springframework.security.access.prepost` package, which allows you to define security-specific actions before and after the execution of the annotated method. The `@PreAuthorize` annotation is configured with a method access-control expression that will be evaluated to decide whether a method invocation is allowed or not. Listing 17-16 shows the controller method annotated with `@PreAuthorize`.

<sup>5</sup><https://github.com/spring-projects/spring-security/blob/main/web/src/main/java/org/springframework/security/web/access/expression/DefaultWebSecurityExpressionHandler.java>

**Listing 17-16.** Secured Controller Method

```

package com.apress.prospring6.seventeen.controllers;

import org.springframework.security.access.prepost.PreAuthorize;
import org.springframework.stereotype.Controller;
// other import statements omitted

@Controller
@RequestMapping("/singer/{id}")
public class OneSingerController {
private final Logger LOGGER = LoggerFactory.getLogger(OneSingerController.class);
    private final SingerService singerService;

    @PreAuthorize("hasRole('admin')")
    @DeleteMapping
    public String deleteSinger(@PathVariable("id") Long id) {
        singerService.findById(id);
        singerService.delete(id);
        return "redirect:/singers/list";
    }

    // other methods omitted
}

```

In order to see this method not being executed for a user with a role different than admin, we have to temporarily remove `sec:authorize="hasRole('ADMIN')"` from the Delete button in `views/singers/show.html`. Since non-admin users are prohibited from executing this method, when clicking the Delete button, we are redirected to an Apache Tomcat default page for the 403 (Forbidden) error. Since we want to redirect the user to the `views/error.html`, we need to add a method in the class annotated with `@ControllerAdvice` as shown in Listing 17-17.

**Listing 17-17.** Handler for an `org.springframework.security.access.AccessDeniedException` in a Spring Web Application

```

package com.apress.prospring6.seventeen.problem;

import org.springframework.http.HttpStatus;
import org.springframework.security.access.AccessDeniedException;
// other import statements omitted

@ControllerAdvice
public class GlobalExceptionHandler {

    @ExceptionHandler(AccessDeniedException.class)
    @ResponseStatus(HttpStatus.FORBIDDEN)
    public ModelAndView forbidden(HttpServletRequest req) {
        ModelAndView mav = new ModelAndView();
        mav.addObject("problem", "Method not allowed " + req.getRequestURI());
        mav.setViewName("error");
        return mav;
    }
}

```

But wait! We also need to configure support for these types of annotations. The `@EnableWebSecurity` annotation only configures support for secured web requests, so to secure method invocations, we need to add the `@EnableMethodSecurity` annotation on the `SecurityCfg` class. The new configuration is shown in Listing 17-18.

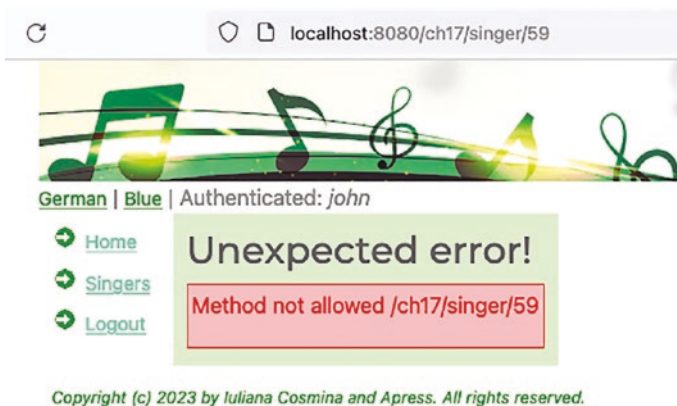
**Listing 17-18.** `SecurityCfg` Configured to Support Secure Methods

```
package com.apress.prospring6.seventeen;

import org.springframework.security.config.annotation.method.configuration.
EnableMethodSecurity;
// other import statements omitted

@Configuration
@EnableWebSecurity
@EnableMethodSecurity
public class SecurityCfg {
    // configuration beans omitted
}
```

With this configuration, when a non-admin user clicks the Delete button, the user is redirected to the page shown in Figure 17-8.



**Figure 17-8.** Error page that a non-admin user is redirected to after attempting to delete a singer record

Securing methods is done via proxying. Security annotations are picked up and a proxy is created around the bean containing the annotated methods, to inject security checks where necessary.

As mentioned, the `org.springframework.security.access.prepost` package contains four annotations that support expression attributes to allow pre- and post-invocation authorization checks and also to support filtering of submitted collection arguments or return values: `@PreAuthorize`, `@PreFilter`, `@PostAuthorize`, and `@PostFilter`. By default, the support for these methods is enabled by the `@EnableMethodSecurity` annotation. But they can be disabled by configuring it like this: `@EnableMethodSecurity(prePostEnabled= false)`.



To enable support for the `@Secured` annotation from package `org.springframework.security.access`, annotation, we configure `@EnableMethodSecurity(secured = true)`. By default, the `secured` attribute is set to `false`.

Spring also provides support for Jakarta Annotations<sup>6</sup> (previously known as JSR-250 annotations). This library contains security annotations in the `jakarta.annotation.security` package that provide somewhat similar functionalities to the Spring Security annotations. However, they are standards-based annotations and allow simple role-based constraints to be applied, but do not have the power of Spring Security’s native annotations. The Jakarta Security annotations are `@RolesAllowed`, `@DenyAll`, `@PermitAll`, `@RunAs`, and `@DeclareRoles`. Support for these methods is enabled by this configuration: `@EnableMethodSecurity(jsr250Enabled=true)`; by default, `jsr250Enabled` is `false`.

Both approaches will lead to Spring Security wrapping the service class in a secure proxy. Figure 17-9 depicts the abstract schema of how a secured method executes and the components involved.

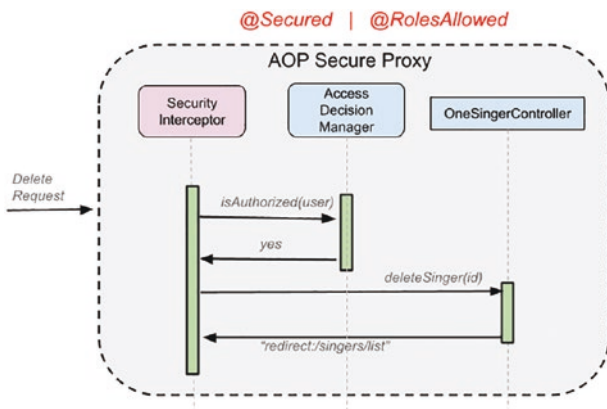


Figure 17-9. Abstract schema of a secured method execution

Feel free to read more about method security in the official documentation<sup>7</sup>, since the subject is wider than the scope of this book.

## JDBC Authentication

Thus far, you have been introduced to the quickest and easiest authentication mode, where the user credentials are stored in memory. For production applications, credentials are stored in relational databases, custom data stores, or LDAP. Since the application already stores the rest of the data in a database, it is very practical to add the necessary tables for storing credentials and groups. The focus of this section is JDBC authentication and storing authentication data in a MariaDB database.

Spring Security provides default queries for JDBC-based authentication, but for them to work, the tables must be created according to the schema provided by Spring Security. The schema is actually packed in the `spring-security-core.jar` that is the core Spring Security library and a dependency of `spring-security-config.jar`. The schema files are exposed as a classpath resource named `org.springframework.security/core/userdetails/jdbc/users.ddl`. The contents of this file are shown in Listing 17-19.

<sup>6</sup><https://jakarta.ee/specifications/annotations/2.1>

<sup>7</sup><https://docs.spring.io/spring-security/reference/servlet/authorization/method-security.html>

**Listing 17-19.** The Spring Security JDBC Schema<sup>8</sup>

```

create table users(
    username varchar(50) not null primary key,
    password varchar(500) not null,
    enabled boolean not null
);

create table authorities (
    username varchar(50) not null,
    authority varchar(50) not null,
    constraint fk_authorities_users foreign key(username) references users(username)
);

create unique index ix_auth_username on authorities (username,authority);

```

To create these tables, the contents of this file were added to the configuration for the chapter17 project. There is more than one way to populate these tables, but Spring makes this easy as well, by providing a class named `UserDetailsManager` that extends `UserDetailsService` introduced in the previous section. A bean of this type, configured with a data source containing the Spring Security users and authorities tables as declared in Listing 17-19, is able to load credentials to facilitate the authentication process. The same class can also be used to initialize the tables. When starting a Spring Web-secured application for the first time, to easily populate the security tables, the `UserDetailsManager` bean can be configured as shown in Listing 17-20.

**Listing 17-20.** The Spring Security `UserDetailsManager` Configuration for Initializing Security Tables

```

package com.apress.prospring6.seventeen;

import org.springframework.security.provisioning.JdbcUserDetailsManager;
import org.springframework.security.provisioning.UserDetailsManager;
// other import statements omitted

@Configuration
@EnableWebSecurity
@EnableMethodSecurity
public class SecurityCfg2 {

    // other configuration beans omitted

    @Bean
    UserDetailsManager users(DataSource dataSource) {
        User.UserBuilder users = User.builder().passwordEncoder(encoder()::encode);
        var joe = users
            .username("john")
            .password("doe")
            .roles("USER")
            .build();
    }
}

```

<sup>8</sup><https://github.com/spring-projects/spring-security/blob/main/core/src/main/resources/org/springframework/security/core/userdetails/jdbc/users.ddl>

```

        var jane = users
            .username("jane")
            .password("doe")
            .roles("USER", "ADMIN")
            .build();
        var admin = users
            .username("admin")
            .password("admin")
            .roles("ADMIN")
            .build();
        var manager = new JdbcUserDetailsManager(dataSource);
        manager.createUser(joe);
        manager.createUser(jane);
        manager.createUser(admin);
        return manager;
    }
}

```

The next time the application is started with the same data source, the user creation should be removed, and the users created during the previous run will still be in our database and thus will work as expected. This reduces the Spring configuration to the one shown in Listing 17-21.

**Listing 17-21.** The Spring Security UserDetailsManager Configuration Without Initialization

```

package com.apress.prospring6.seventeen;
// import statements omitted

@Configuration
@EnableWebSecurity
@EnableMethodSecurity
public class SecurityCfg2 {

    @Bean
    public SecurityFilterChain securityFilterChain(HttpSecurity http) throws Exception {
        // request configuration omitted
        return http.build();
    }

    @Bean
    public PasswordEncoder encoder() {
        return new BCryptPasswordEncoder();
    }

    @Bean
    UserDetailsManager users(DataSource dataSource) {
        return new JdbcUserDetailsManager(dataSource);
    }
}

```

So far, you've been introduced to the Spring Security in-memory and JDBC implementations of `UserDetailsService`. If for some reason you cannot use the Spring Security default schema, you must provide a custom implementation of `UserDetailsService` that is responsible for retrieving users and authorities based on user-provided data. An alternative to this is to configure an `AuthenticationManagerBuilder` bean, like shown in Listing 17-22.

**Listing 17-22.** The Spring Security `AuthenticationManagerBuilder` Configuration

```
package com.apress.prospring6.seventeen;

import org.springframework.security.config.annotation.ObjectPostProcessor;
import org.springframework.security.config.annotation.authentication.builders.
AuthenticationManagerBuilder;
// import statements omitted

@Configuration
@EnableWebSecurity
@EnableMethodSecurity
public class SecurityCfg3 {

    @Bean
    public SecurityFilterChain securityFilterChain(HttpSecurity http) throws Exception {
        // request configuration omitted
        return http.build();
    }

    @Bean
    public PasswordEncoder encoder() {
        return new BCryptPasswordEncoder();
    }

    @Bean
    AuthenticationManagerBuilder authenticationManagerBuilder(ObjectPostProcessor<Object>
objectPostProcessor, DataSource dataSource) {
        var authenticationManagerBuilder = new AuthenticationManagerBuilder(objectPost
Processor);

        final String findUserQuery =
            """
                select username, password, enabled
                from users where username = ?
            """;
        final String findRoles =
            """
                select username,authority from authorities
                where username = ?
            """;

        try {
            authenticationManagerBuilder.jdbcAuthentication().dataSource(dataSource)
                .passwordEncoder(encoder())
                .usersByUsernameQuery(findUserQuery)
```

```

        .authoritiesByUsernameQuery(findRoles);
    } return authenticationManagerBuilder;
} catch (Exception e) {
    throw new RuntimeException("Could not initialize
        'AuthenticationManagerBuilder'");
}
}
}

```

Another shortcut was taken in Listing 17-22: `findUserQuery` and `findRoles` are queries written for the Spring Security tables created previously, but this bean allows for users and authorities to be saved in tables with different names and different structures—as long as `username`, `password`, `enabled`, and `authority` columns exist, or the queries return them, the authentication process works as normal. For example, take a look at the alternative `findUserQuery` and `findRoles` queries in Listing 17-23, which are run on tables named `staff` and `roles` but rename the column to the one expected by the Spring Security authentication manager bean.

**Listing 17-23.** Alternative Queries for Retrieving Credentials

```

-- findUserQuery
select staff_id as username,
    staff_credentials as password,
    active as enabled
from staff where staff_id = ?

-- findRoles
select staff_id as username,
    role as authority
from roles where staff_id = ?

```

Spring Security configuration is flexible, varied, and powerful, and you can even implement `UserDetailsService` to use Spring DATA repositories for managing security data, or even use a NoSQL database as storage. It's really up to your development needs and your imaginations; they are all just configurable beans after all.

## Testing Secured Web Applications

Testing a secured Spring web application can be done in multiple ways as well. Integration tests for an application that gets deployed to Apache Tomcat require a lot of setup, so the easiest way is to use a web client that supports form authentication and use it to submit requests and test your assumptions. For this purpose, this chapter presents REST Assured<sup>9</sup>.

REST Assured provides a very simple API for validating REST services in Java. In Listing 17-24 you can see that three tests were written to cover the secured elements introduced in this section.

---

<sup>9</sup><https://rest-assured.io>

*Listing 17-24.* Testing secured components using REST Assured

```

package com.apress.prospring6.seventeen.controllers;

import io.restassured.RestAssured;
import io.restassured.authentication.FormAuthConfig;
import io.restassured.http.ContentType;
import org.junit.jupiter.api.BeforeEach;
import org.junit.jupiter.api.Test;
import org.springframework.http.HttpStatus;

import static io.restassured.RestAssured.given;
import static org.junit.jupiter.api.Assertions.*;

public class SingerControllerTest {

    @BeforeEach
    void setUp() {
        RestAssured.port = 8080;
        RestAssured.baseURI = "http://localhost";
    }

    @Test
    void johnShouldNotSeeTheDeleteButton() {
        var cfg = new FormAuthConfig("/ch17/auth", "user", "pass")
            .withLoggingEnabled();

        String responseStr = given()
            .contentType(ContentType.URLENC)
            .auth().form("john", "doe", cfg)
            .when().get("/ch17/singer/1")
            .then()
            .assertThat().statusCode(HttpStatus.OK.value())
            .extract().body().asString();

        assertAll(
            () -> assertTrue(responseStr.contains("<div class=\"card-header\">Singer  
Details</div>")),
            () -> assertTrue(responseStr.contains("<td>Mayer</td>")),
            () -> assertFalse(responseStr.contains("Delete"));
        );
    }

    @Test
    void johnShouldNotBeAllowedToDeleteSinger() {
        var cfg = new FormAuthConfig("/ch17/auth", "user", "pass")
            .withLoggingEnabled();

        String responseStr = given()
            .contentType(ContentType.URLENC)
            .auth().form("john", "doe", cfg)
            .when().delete("/ch17/singer/1")

```

```

        .then()
        .assertThat().statusCode(HttpStatus.FORBIDDEN.value())
        .extract().body().asString();
    }

    @Test
    void adminShouldSeeTheDeleteButton() {
        var cfg = new FormAuthConfig("/ch17/auth", "user", "pass")
            .withLoggingEnabled();

        String responseStr = given()
            .contentType(ContentType.URLENC)
            .auth().form("admin", "admin", cfg)
            .when().get("/ch17/singer/1")
            .then()
            .assertThat().statusCode(HttpStatus.OK.value())
            .extract().body().asString();

        assertAll(
            () -> assertTrue(responseStr.contains("<div class=\"card-header\">Singer
                Details</div>")),
            () -> assertTrue(responseStr.contains("<td>Mayer</td>")),
            () -> assertTrue(responseStr.contains("Delete"));
        );
    }
}

```

The `FormAuthConfig` object is configured to create a form authorization configuration with a predefined form action, username input tag, and password input tag. This object maps to the form in the `/views/auth.html` view template. The `johnShouldNotSeeTheDeleteButton` test checks that user `john`, a non-administrator, is not able to see the `Delete` button, which proves that the Thymeleaf security element is behaving as desired. The `johnShouldNotBeAllowedToDeleteSinger` test checks that user `john` cannot submit a delete request. This proves that the `@PreAuthorize` annotation is configured correctly as well. The `adminShouldSeeTheDeleteButton` test checks that user `admin` (an administrator) can see the `Delete` button.

To wrap up this section, let's look at the security filters. As mentioned at the beginning of this section, the `securityFilterChain` bean is an entry point for a collection of security filters. If you want to make Spring show you the order of these filters being applied to your requests, simply configure TRACE logging for `org.springframework` in your `resources/logback.xml` file. This will print a lot of logging messages, but among them you should see a succession of logs similar to the ones in Listing 17-25.

**Listing 17-25.** Spring Security Filters Being Applied to the GET /singers Request

```

22:22:50.635 [http-nio-8080-exec-8] TRACE o.s.s.w.FilterChainProxy - Trying to match request
against DefaultSecurityFilterChain
[
  RequestMatcher=any request,
  Filters= [
    org.springframework.security.web.session.DisableEncodeUrlFilter@125ebc0d,
    org.springframework.security.web.context.request.async.WebAsyncManagerIntegrationFi
lter@6525ad0,

```

```

org.springframework.security.web.context.SecurityContextHolderFilter@3a7c81e1,
org.springframework.security.web.header.HeaderWriterFilter@309cde68,
org.springframework.security.web.authentication.logout.LogoutFilter@7111e25c,
org.springframework.security.web.authentication.UsernamePasswordAuthenticationFilter@5d008ea9,
org.springframework.security.web.savedrequest.RequestCacheAwareFilter@202ba409,
org.springframework.security.web.servletapi.SecurityContextHolderAwareRequestFilter@2d073dc4,
org.springframework.security.web.authentication.AnonymousAuthenticationFilter@77286aac,
org.springframework.security.web.access.ExceptionTranslationFilter@2f8c1059,
org.springframework.security.web.access.intercept.AuthorizationFilter@7f9494a
]
] (1/1)
22:22:50.636 DEBUG o.s.s.w.FilterChainProxy - Securing GET /singers
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking DisableEncodeUrlFilter (1/11)
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking
WebAsyncManagerIntegrationFilter (2/11)
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking SecurityContextHolderFilter (3/11)
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking HeaderWriterFilter (4/11)
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking LogoutFilter (5/11)
22:22:50.636 TRACE o.s.s.w.a.l.LogoutFilter - Did not match request to Or [Ant [pattern='/
exit', GET], Ant [pattern='/exit', POST], Ant [pattern='/exit', PUT], Ant [pattern='/exit',
DELETE]]
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking
UsernamePasswordAuthenticationFilter (6/11)
22:22:50.636 TRACE o.s.s.w.a.UsernamePasswordAuthenticationFilter - Did not match request
to Ant [pattern='/auth', POST]
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking RequestCacheAwareFilter (7/11)
22:22:50.636 TRACE o.s.s.w.s.HttpSessionRequestCache - matchingRequestParameterName is
required for getMatchingRequest to lookup a value, but not provided
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking
SecurityContextHolderAwareRequestFilter (8/11)
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking AnonymousAuthenticationFilter (9/11)
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking ExceptionTranslationFilter (10/11)
22:22:50.636 TRACE o.s.s.w.FilterChainProxy - Invoking AuthorizationFilter (11/11)
...

```

The log snippet in Listing 17-25 shows a successful authenticated request of a user accessing something that user is authorized to access, which is why you can see all the filters being invoked to process the request.



The first snippet of the log in Listing 17-25 shows all the types of the filters in the security chain. Feel free to inspect the code for each of them on GitHub<sup>10</sup>.

---

<sup>10</sup><https://github.com/spring-projects/spring-security/tree/main/web/src/main/java/org/springframework/security/web>



As the name of the bean indicates, the filters are chained, and they are executed in a fixed order. The request object is passed from one filter to the next through the chain, just like an item on a conveyor belt in a factory goes through various machines. Some filters are critical, and if they find something wrong with the request, they throw an exception and the whole process stops; the rest of the filters are not applied to the request. Some of filters are not critical, but they make changes to the request before sending it down the chain.



The list of filters varies depending on what is configured in the application. For example, because we've disabled CSRF support, the `CsrfFilter` filter does not appear in the list in Listing 17-25.

---

For example, introducing a wrong username/password combination causes the `UsernamePasswordAuthenticationFilter` filter to throw a `BadCredentialsException`. This is the sixth filter in the chain, and is where the process stops, so the five filters after it are not applied to the request because, as this filter makes clear, the request does not contain credentials recognized by the application, as shown in Listing 17-26.

**Listing 17-26.** Spring Security Filters Being Applied to the POST /auth Request with Wrong User and Password

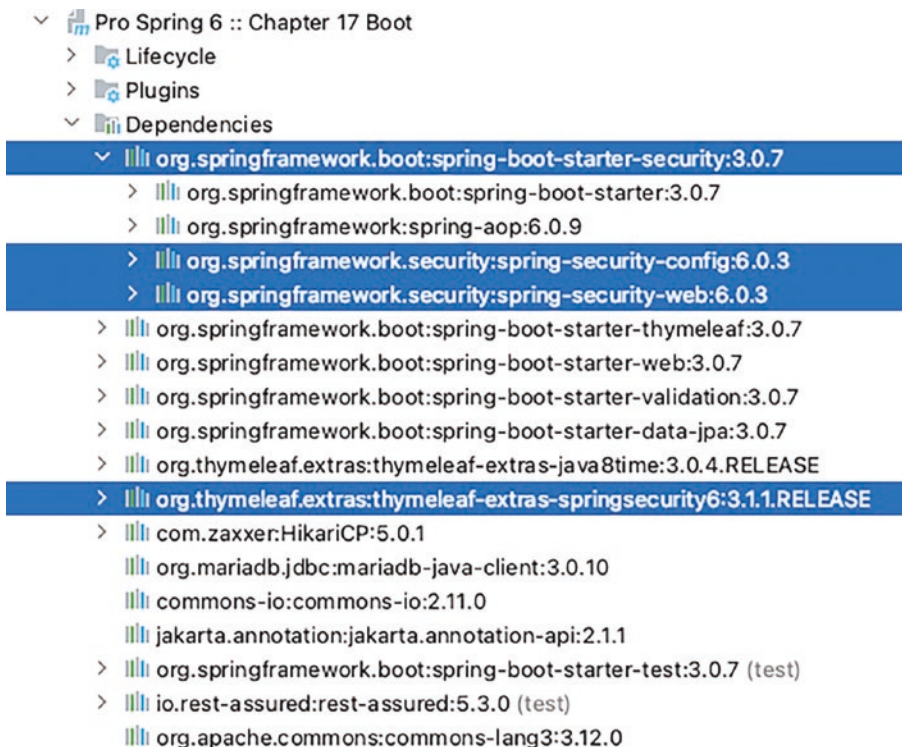
```
22:34:23.027 DEBUG o.s.s.w.FilterChainProxy - Securing POST /auth
22:34:23.027 TRACE o.s.s.w.FilterChainProxy - Invoking DisableEncodeUrlFilter (1/11)
22:34:23.027 TRACE o.s.s.w.FilterChainProxy - Invoking
WebAsyncManagerIntegrationFilter (2/11)
22:34:23.027 TRACE o.s.s.w.FilterChainProxy - Invoking SecurityContextHolderFilter (3/11)
22:34:23.027 TRACE o.s.s.w.FilterChainProxy - Invoking HeaderWriterFilter (4/11)
22:34:23.027 TRACE o.s.s.w.FilterChainProxy - Invoking LogoutFilter (5/11)
22:34:23.027 TRACE o.s.s.w.a.l.LogoutFilter - Did not match request to Or [Ant [pattern='/
exit', GET], Ant [pattern='/exit', POST], Ant [pattern='/exit', PUT], Ant [pattern='/exit',
DELETE]]
22:34:23.027 TRACE o.s.s.w.FilterChainProxy - Invoking
UsernamePasswordAuthenticationFilter (6/11)
22:34:23.027 TRACE o.s.s.a.ProviderManager - Authenticating request with
DaoAuthenticationProvider (1/1)
22:34:23.096 DEBUG o.s.s.a.d.DaoAuthenticationProvider - Failed to find user 'sfsfsf'
22:34:23.108 TRACE o.s.b.f.s.DefaultListableBeanFactory - Returning cached instance of
singleton bean 'delegatingApplicationListener'
22:34:23.108 TRACE o.s.s.w.a.UsernamePasswordAuthenticationFilter - Failed to process
authentication request
org.springframework.security.authentication.BadCredentialsException: Bad credentials
.. // exception stacktrace omitted
22:34:23.108 TRACE o.s.s.w.a.UsernamePasswordAuthenticationFilter - Cleared
SecurityContextHolder
22:34:23.108 TRACE o.s.s.w.a.UsernamePasswordAuthenticationFilter - Handling
authentication failure
22:34:23.108 DEBUG o.s.s.w.s.HttpSessionEventPublisher - Publishing event: org.
springframework.security.web.session.HttpSessionCreatedEvent[source=org.apache.catalina.
session.StandardSessionFacade@587e2789]
22:34:23.108 DEBUG o.s.s.w.DefaultRedirectStrategy - Redirecting to /ch17/auth?error
```

As mentioned at the beginning of this section, each of the filters in the chain can be replaced with customized implementations. If you want to read more about Spring Security filter chain architecture and configuration, check out the official documentation<sup>11</sup>.

## Configuring Spring Security: The Spring Boot Way

Securing a Spring Boot web application is easy too. Simply adding the `spring-boot-starter-security` dependency to the classpath adds default security configuration to your application. The Spring Security default configuration for a servlet-based Spring application is represented by the `SecurityAutoConfiguration` class from package `org.springframework.boot.autoconfigure.security.servlet`. By default, authentication gets enabled for the application and content negotiation is used to determine if basic or form login should be used. If the former is detected, a very simple default login form is generated.

Let's start with the basics: since we are reusing the UI from the non-Spring Boot project, we also need to add the `thymeleaf-extras-springsecurity6` library to the classpath. This makes the project classpath look like the one shown in Figure 17-10.



**Figure 17-10.** *chapter17-boot* project dependencies in IntelliJ IDEA Gradle View

<sup>11</sup><https://docs.spring.io/spring-security/reference/servlet/architecture.html>

The Spring Boot configuration file (chapter17-boot/src/main/resources/application-dev.yaml) is identical to the one covered in **Chapter 15**, but because the classpath contains the `spring-boot-starter-security` dependency, when starting the application and accessing it at `http://localhost:8081`, the default login form is shown. Without any specific security configuration, Spring Boot sets up in-memory authentication and generates a password for you that can be used with a user named `user`. The password is shown in the console log, as shown in Listing 17-27.

**Listing 17-27.** Spring Boot Default-Generated Password for Spring Security Authentication

```
WARN : UserDetailsServiceImplAutoConfiguration -
Using generated security password: 82155279-ce4c-4670-9d86-4990370ea728
```

This generated password is for development use only. Your security configuration must be updated before running your application in production.

As you can see, you are also warned that before production you must configure security properly. If you want to customize the default user and password, this is possible via the `spring.security.user.username` and `spring.security.user.password` properties. Listing 17-28 shows the YAML configuration to declare a user named `john` and password named `doe`. (Roles can also be configured.)

**Listing 17-28.** Spring Boot Default User Configuration for Spring Security Authentication (application-dev.yaml)

```
spring:
  security:
    user:
      name: john
      roles: user,admin
```

The limitation of this configuration is, of course, that you can only have one user, so the configuration with three users introduced in the previous section is not possible only with Spring Boot properties. When it comes to configuring security, Spring Boot properties cannot help that much. So, unfortunately, the easiest way to customize security configuration in a Spring Boot application is to disable security autoconfiguration all together and build our classes from scratch. To disable Spring Boot security autoconfiguration, we need to exclude the `SecurityAutoConfiguration` class from the application configuration. This can be done by customizing the `@SpringBootApplication`, as shown in Listing 17-29.

**Listing 17-29.** Excluding Spring Boot Default Security Configuration Class

```
package com.apress.prospring6.seventeen.boot;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.boot.autoconfigure.security.servlet.SecurityAutoConfiguration;
import org.springframework.core.env.AbstractEnvironment;

@SpringBootApplication(exclude = { SecurityAutoConfiguration.class })
public class Chapter17Application {
```

```

public static void main(String... args) {
    System.setProperty(AbstractEnvironment.ACTIVE_PROFILES_PROPERTY_NAME, "dev");
    SpringApplication.run(Chapter17Application.class, args);
}
}

```

The exclusion also can be done via configuration of Spring Boot properties, as shown in Listing 17-30.

**Listing 17-30.** Disabling Spring Security Default Configuration in a Spring Boot Application (application-dev.yaml)

```

spring:
  autoconfigure:
    exclude: org.springframework.boot.autoconfigure.security.servlet.
             SecurityAutoConfiguration

```

With the default configuration removed, any of the security configuration classes introduced in the previous section can be added to the application, and they get the job done just fine. As for testing, the REST Assured test class from the previous section works for the Spring Boot application too.

Of course, there are multiple ways to test secured applications, but the crux of the matter with web applications is the type of authentication used. Form-based authentication is tricky to mock, so you are better off just starting your application normally and then submitting some authenticated REST Assured requests and checking the assumption.

## Summary

Application security is one of the most important aspects that needs to be incorporated when building an application designed to be used by the public over the Internet. Access to users' personal info must be restricted to validated parties; otherwise, there is a risk of identity theft that could destroy somebody's life and a company's reputation. Leaked financial information could tear down global economies. Making it practical for developers to set up and maintain secure applications is something Spring Security shines at. This chapter has barely scratched the surface. If you want to read about Spring Security in depth and learn how to configure Spring Security with OAuth or JWT tokens, Apress should publish *Pro Spring Security for Spring 6 and Spring Boot 3* soon<sup>12</sup>.

If you are interested in seeing more ways of configuring and testing Spring Security in classic and Spring Boot web applications, take a look at this repository: <https://github.com/spring-projects/spring-security-samples>.

<sup>12</sup><https://link.springer.com/book/10.1007/978-1-4842-5052-5>



# Monitoring Spring Applications

A typical JEE application contains a number of layers and components, such as the presentation layer, service layer, persistence layer, and back-end data source. During the development stage, or after the application has been deployed to the quality assurance (QA) or production environment, we want to ensure that the application is in a healthy state without any potential problems or bottlenecks.

In a Java application, various areas may cause performance problems or overload server resources (such as CPU, memory, or I/O). Examples include inefficient Java code, memory leaks (for example, Java code that keeps allocating new objects without releasing the reference and prevents the underlying JVM from freeing up the memory during the garbage collection process), miscalculated JVM parameters, miscalculated thread pool parameters, too generous data source configurations (for example, too many concurrent database connections allowed), improper database setup, and long-running SQL queries.

Consequently, we need to understand an application's runtime behavior and identify whether any potential bottlenecks or problems exist. In the Java world, a lot of tools can help monitor the detailed runtime behavior of JEE applications. Most of them are built on top of the Java Management Extensions (JMX) technology.

In this chapter, we present common techniques for monitoring Spring-based JEE applications. Specifically, this chapter covers the following topics:

- *Spring support of JMX:* We discuss Spring's comprehensive support of JMX and demonstrate how to expose Spring beans for monitoring with JMX tools. In this chapter, we show how to use the `VisualVM`<sup>1</sup> as the application-monitoring tool.
- *Monitoring Hibernate statistics:* Hibernate and many other packages provide support classes and infrastructure for exposing the operational status and performance metrics using JMX. We show how to enable the JMX monitoring of those commonly used components in Spring-powered JEE applications.
- *Spring Boot JMX support:* Spring Boot provides a starter library for JMX support that comes with full default configuration out of the box. This library is called Actuator and is mainly used to expose operational information about the running application—health, metrics, info, dump, env, and so on. It uses HTTP endpoints or JMX beans to enable us to interact with it. Spring Boot Actuator is the focus of this chapter.

Remember that this chapter is not intended to be an introduction to JMX, and a basic understanding of JMX is assumed. For detailed information, please refer to Oracle's online resources<sup>2</sup>.

---

<sup>1</sup><https://visualvm.github.io>

<sup>2</sup><https://www.oracle.com/technical-resources/articles/javase/jmx.html>

## JMX Support in Spring

In JMX, the classes that are exposed for JMX monitoring and management are called *managed beans* (generally referred to as *MBeans*). The Spring Framework supports several mechanisms for exposing MBeans. This chapter focuses on exposing Spring beans (which were developed as simple POJOs) as MBeans for JMX monitoring.

In the following sections, we discuss the procedure for exposing a bean containing application-related statistics as an MBean for JMX monitoring. Topics include implementing the Spring bean, exposing the Spring bean as an MBean in Spring ApplicationContext, and using VisualVM to monitor the MBean.

### Exporting a Spring Bean to JMX

As an example, we will use the REST sample from **Chapter 15**. Review that chapter for the sample application code or jump directly to the book's source companion, which provides the source code we will use to build upon.

Just for fun, let's expose some property values and some methods via JMX and declare them via an interface named `AppStatistics` as shown in Listing 18-1.

*Listing 18-1.* The `AppStatistics` Interface

```
package com.apress.prospring6.eighteen.audit;

public interface AppStatistics {

    int getTotalSingerCount();

    String findJohn();

    String findSinger(String firstName, String lastName);
}
```

The implementation of the `AppStatistics` interface is a class named `AppStatisticsImpl`, and since this class is the one exposing attributes and operations via JMX, we need to add the proper annotations. The `AppStatisticsImpl` class is shown in Listing 18-2.

*Listing 18-2.* The `AppStatisticsImpl` Class

```
package com.apress.prospring6.eighteen.audit;
import org.springframework.jmx.export.annotation.*;
// other import statements omitted

@Component
@ManagedResource(description = "JMX managed resource",
    objectName = "jmxDemo:name=ProSpring6SingerApp")
public class AppStatisticsImpl implements AppStatistics{

    private final SingerService singerService;

    public AppStatisticsImpl(SingerService singerService) {
        this.singerService = singerService;
    }
}
```

```

@ManagedAttribute(description = "Number of singers in the application")
@Override
public int getTotalSingerCount() {
    return singerService.findAll().size();
}

@ManagedOperation
public String findJohn() {
    List<Singer> singers = singerService.findByFirstNameAndLastName("John", "Mayer");
    if (!singers.isEmpty()) {
        return singers.get(0).getFirstName() + " " + singers.get(0).getLastName() + " "
            + singers.get(0).getBirthDate();
    }
    return "not found";
}

@ManagedOperation(description="Find Singer by first name and last name")
@ManagedOperationParameters({
    @ManagedOperationParameter(name = "firstName", description = "Singer's
        first name"),
    @ManagedOperationParameter(name = "lastName", description = "Singer's last
        name")})
public String findSinger(String firstName, String lastName) {
    List<Singer> singers = singerService.findByFirstNameAndLastName(firstName,
        lastName);
    if (!singers.isEmpty()) {
        return singers.get(0).getFirstName() + " " + singers.get(0).getLastName() + " "
            + singers.get(0).getBirthDate();
    }
    return "not found";
}
}
}

```

In this example, the `@ManagedResource` annotation has an attribute called `objectName`, and its value represents the domain and name of the MBean. The `@ManagedAttribute` annotation is used to expose the given bean property as a JMX attribute. `@ManagedOperation` is used to expose a given method as a JMX operation. In this example, a few methods are defined to access database data and properties, such as the number of records in the SINGER table.

To expose the Spring bean as JMX, we need to add configuration in Spring's `ApplicationContext`. This is done by annotating a configuration class with `@EnableMBeanExport`. This annotation enables the default exporting of all standard MBeans from the Spring context, as well as all `@ManagedResource` annotated beans. Basically, this annotation is what tells Spring to create an `MBeanExporter` bean with the name of `mbeanExporter`. To keep things neatly scoped, we add a new class named `MonitoringCfg` on which we add the `@EnableMBeanExport` annotation. This class is shown in Listing 18-3.

**Listing 18-3.** The `MonitoringCfg` Configuration Class

```

package com.apress.prospring6.eighteen;

import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.EnableMBeanExport;
import org.springframework.jmx.support.RegistrationPolicy;

```

```

@EnableMBeanExport(registration = RegistrationPolicy.REPLACE_EXISTING)
@Configuration
public class MonitoringCfg {
}

```

The `@EnableMBeanExport` annotation is responsible for registering Spring beans with a JMX MBean server (a server that implements JDK's `javax.management.MbeanServer` interface, which exists in most commonly used web and JEE containers, such as Apache Tomcat and WebSphere). When exposing a Spring bean as an MBean, Spring will attempt to locate a running `MbeanServer` instance within the server and register the Mbean with it. We can control what happens when an MBean is registered with an `MbeanServer` instance. Spring's JMX support allows for three different registration behaviors when the registration process finds that an MBean has already been registered under the same `ObjectName`:

- `FAIL_ON_EXISTING`: The MBean is not registered and an `InstanceAlreadyExistsException` exception is thrown.
- `IGNORE_EXISTING`: The MBean is not registered. The existing MBean is unaffected, and no exception is thrown.
- `REPLACE_EXISTING`: The MBean is registered, overwriting the already registered MBean.

If not configured explicitly, the registration policy defaults to `FAIL_ON_EXISTING`.

With Apache Tomcat, an `MbeanServer` instance will be created automatically, so no additional configuration is required. By default, all public properties of the bean are exposed as attributes, and all public methods are exposed as operations.

Now the MBean is available for monitoring via JMX. Let's proceed to set up VisualVM and use its JMX client for monitoring purposes.

## Using VisualVM for JMX Monitoring

VisualVM is a useful (free) tool that can help in monitoring Java applications in various aspects. It used to reside under the `bin` folder in the JDK installation folder, but since it was removed from more recent versions of the JDK, you can download a stand-alone version from the project website<sup>3</sup>.

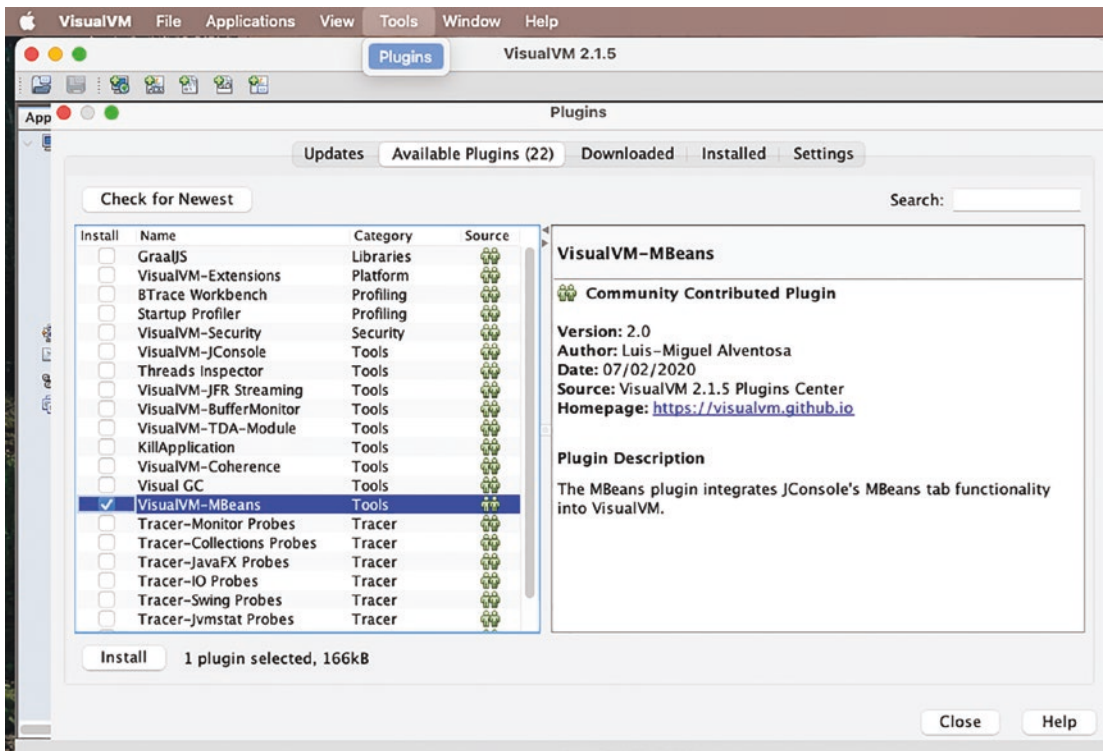
VisualVM uses a plug-in system to support various monitoring functions. To support monitoring MBeans of Java applications, we need to install the MBeans plug-in. To install the plug-in, follow these steps:

1. From VisualVM's menu, choose `Tools` ► `Plugins` to open the `Plugins` dialog shown in Figure 18-1.
2. Click the `Available Plugins` tab.
3. Click the `Check for Newest` button.
4. Select the plug-in `VisualVM-MBeans` and then click the `Install` button.

---

<sup>3</sup><https://visualvm.github.io>





**Figure 18-1.** VisualVM-MBeans plug-in selected for installation

After completing the installation of the VisualVM-MBeans plug-in, verify that Apache Tomcat is up and that the sample application is running.

By default, VisualVM scans for the Java applications that are running on the JDK platform. Double-clicking the desired node brings up the monitoring screen. Double-click the Tomcat node in the Applications pane. After the installation of the VisualVM-MBeans plug-in, the MBeans tab is available. Clicking this tab shows the available MBeans. You should see the node called `jmxDemo`. When you expand it, it will show the `Prospring6SingerApp` MBean that was exposed through the configuration in Listing 18-1. On the Attributes tab on the right side, you will see that for the method that we implemented in the bean, an attribute named `TotalSingerCount` was automatically derived from the `getTotalSingerCount()` method. The value should be the same as the number of singers in the `SINGER` table, as shown in Figure 18-2.

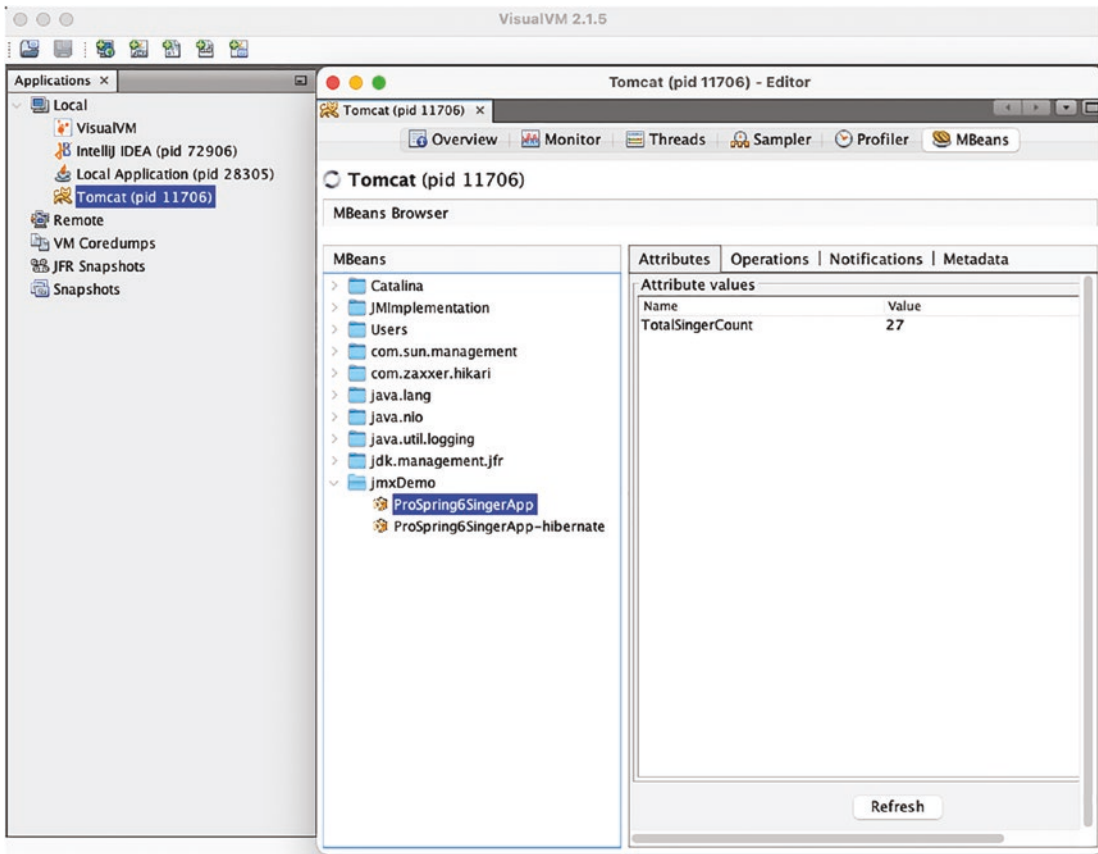


Figure 18-2. The Prospring6SingerApp MBean exposed in VisualVM

In a regular application, this number would change based on the number of singers added during the application runtime. To test how the MBean reflects the changes in the table, we can use a repeated test method to create a number of singers. Listing 18-4 shows the RestClientTest class containing a test method to create ten singers and a method to delete them.

Listing 18-4. The RestClientTest Class

```

package com.apress.prospring6.eighteen;

import org.junit.jupiter.api.RepeatedTest;
// other import statements omitted

public class RestClientTest {

    final Logger LOGGER = LoggerFactory.getLogger(RestClientTest.class);
    private static final String URI_SINGER_ROOT = "http://localhost:8080/ch18/singer/";
    private static final String URI_SINGER_WITH_ID = "http://localhost:8080/ch18/
singer/{id}";
    
```

```

RestTemplate restTemplate = new RestTemplate();

@RepeatedTest(10)
@Test
public void testCreate() {
    LOGGER.info("--> Testing create singer");
    Singer singerNew = new Singer();
    singerNew.setFirstName("TEST" + System.currentTimeMillis());
    singerNew.setLastName("Singer" + System.currentTimeMillis());
    singerNew.setBirthDate(LocalDate.now());
    singerNew = restTemplate.postForObject(URI_SINGER_ROOT, singerNew, Singer.class);
    LOGGER.info("Singer created successfully: " + singerNew);
}

@Test
public void testDelete() {
    LOGGER.info("--> Deleting singers with id > 15");
    for (int i = 16; i < 70; i++) {
        try {
            restTemplate.delete(URI_SINGER_WITH_ID, i);
        } catch (Exception e) {
            // no need to treat
        }
    }
}
}

```

To see the MBean value change, run the `testCreate()` method and then click the Refresh button. You can also retrieve the current number of singers by going to the Operations tab and clicking the button labeled with the method name: `getTotalSingerCount()`. A pop-up with the operation return value is displayed, as shown in Figure 18-3.

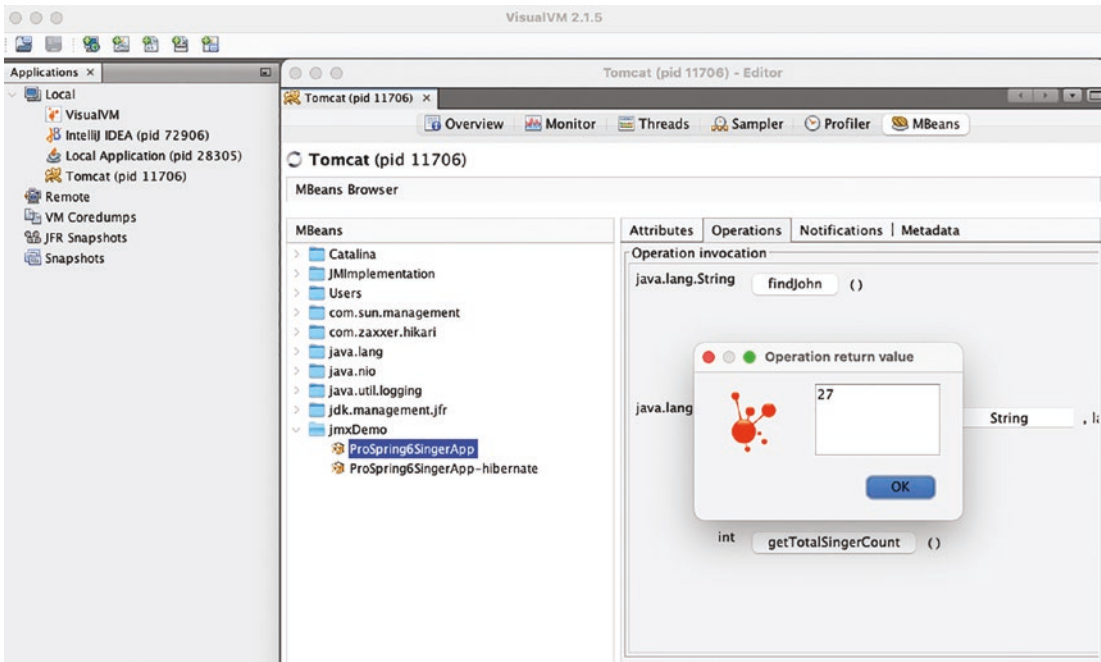


Figure 18-3. Result of the MBean `getTotalSingerCount()` operation

Feel free to try the other exposed operations: `findJohn()` and `findSinger({"John", "Mayer"})`.

## Monitoring Hibernate Statistics

Hibernate also supports the maintenance and exposure of persistence-related metrics to JMX. To enable this, we need to set a few Hibernate properties in the JPA configuration, as shown in Listing 18-5.

Listing 18-5. Hibernate Configuration with Statistics-Enabled Class

```

package com.apress.prospring6.eighteen;

import org.hibernate.cfg.Environment;
// other import statements omitted

@Import(BasicDataSourceCfg.class)
@Configuration
@EnableJpaRepositories(basePackages = {"com.apress.prospring6.eighteen.repos"})
@EnableTransactionManagement
@ComponentScan(basePackages = {"com.apress.prospring6.eighteen.repos"})
public class TransactionCfg {
    // other configurations omitted

    @Bean
    public LocalContainerEntityManagerFactoryBean entityManagerFactory() {
        var factory = new LocalContainerEntityManagerFactoryBean();
    }
}

```

```

        factory.setPersistenceProviderClass(HibernatePersistenceProvider.class);
        factory.setPackagesToScan("com.apress.prospring6.eighteen.entities");
        factory.setDataSource(dataSource);
        factory.setJpaProperties(jpaProperties());
        factory.setJpaVendorAdapter(jpaVendorAdapter());
        return factory;
    }

    @Bean
    public Properties jpaProperties() {
        Properties jpaProps = new Properties();
        jpaProps.put(Environment.HBM2DDL_AUTO, "none");
        jpaProps.put(Environment.FORMAT_SQL, false);
        jpaProps.put(Environment.STATEMENT_BATCH_SIZE, 30);
        jpaProps.put(Environment.USE_SQL_COMMENTS, false);
        jpaProps.put(Environment.GENERATE_STATISTICS, true);
        jpaProps.put("hibernate.jmx.enabled", true);
        jpaProps.put("hibernate.jmx.usePlatformServer", true);
        jpaProps.put(Environment.SESSION_FACTORY_NAME, "sessionFactory");
        return jpaProps;
    }
}

```

The properties `hibernate.jmx.enabled` and `hibernate.jmx.usePlatformServer` are used to expose the Hibernate metrics via JMX. The property `hibernate.generate_statistics` instructs Hibernate to generate statistics for its JPA persistence provider, while the property `hibernate.session_factory_name` (`Environment.SESSION_FACTORY_NAME`) defines the name of the session factory required by the Hibernate statistics MBean.

Finally, we need to declare a Spring bean and configure it as an MBean to expose all the Hibernate statistics and metrics. Listing 18-6 shows a snippet of a class named `CustomHibernateStatistics` that exposes Hibernate statistics and metrics.

**Listing 18-6.** `MonitoringCfg` Declaring an MBean to Expose Hibernate Statistics

```

package com.apress.prospring6.eighteen.audit;

import org.hibernate.SessionFactory;
import org.hibernate.stat.*;
import org.springframework.jmx.export.annotation.*;
// other import statements omitted

@Component
@ManagedResource(description = "JMX managed resource",
    objectName = "jmxDemo:name=ProSpring6SingerApp-hibernate")
public class CustomHibernateStatistics {

    private final SessionFactory sessionFactory;

    public CustomHibernateStatistics(SessionFactory sessionFactory) {
        this.sessionFactory = sessionFactory;
    }
}

```

```

private Statistics stats;

@PostConstruct
private void init() {
    stats = sessionFactory.getStatistics();
}

@ManagedOperation(description="Get statistics for entity name")
@ManagedOperationParameter(name = "entityName", description = "Full class name for the
entity")
public EntityStatistics getEntityStatistics(String entityName) {
    return stats.getEntityStatistics(entityName);
}

@ManagedAttribute
public long getEntityDeleteCount() {
    return stats.getEntityDeleteCount();
}

@ManagedAttribute
public long getEntityInsertCount() {
    return stats.getEntityInsertCount();
}

@ManagedAttribute
public String[] getEntityNames() {
    return stats.getEntityNames();
}

@ManagedAttribute
public String[] getQueries() {
    return stats.getQueries();
}

@ManagedAttribute
public long getTransactionCount() {
    return stats.getTransactionCount();
}

@ManagedAttribute
public long getPrepareStatementCount(){
    return stats.getPrepareStatementCount();
}
// other methods omitted
}

```

Now that the Hibernate statistics are enabled and available via JMX, reload the application and refresh VisualVM; you will be able to see the Hibernate statistics MBean. Clicking the node displays the detail statistics on the right side. Note that for the information that is not of a Java primitive type (for example, a `List`), you can click in the field to expand it and show the content.

In VisualVM, you can see many other metrics, such as `EntityNames`, `EntityInsertCount`, `Queries`, `PrepareStatementCount`, and `TransactionCount`. Those metrics are useful for understanding the persistence behavior within your application and can assist you in troubleshooting and performance-tuning exercises.

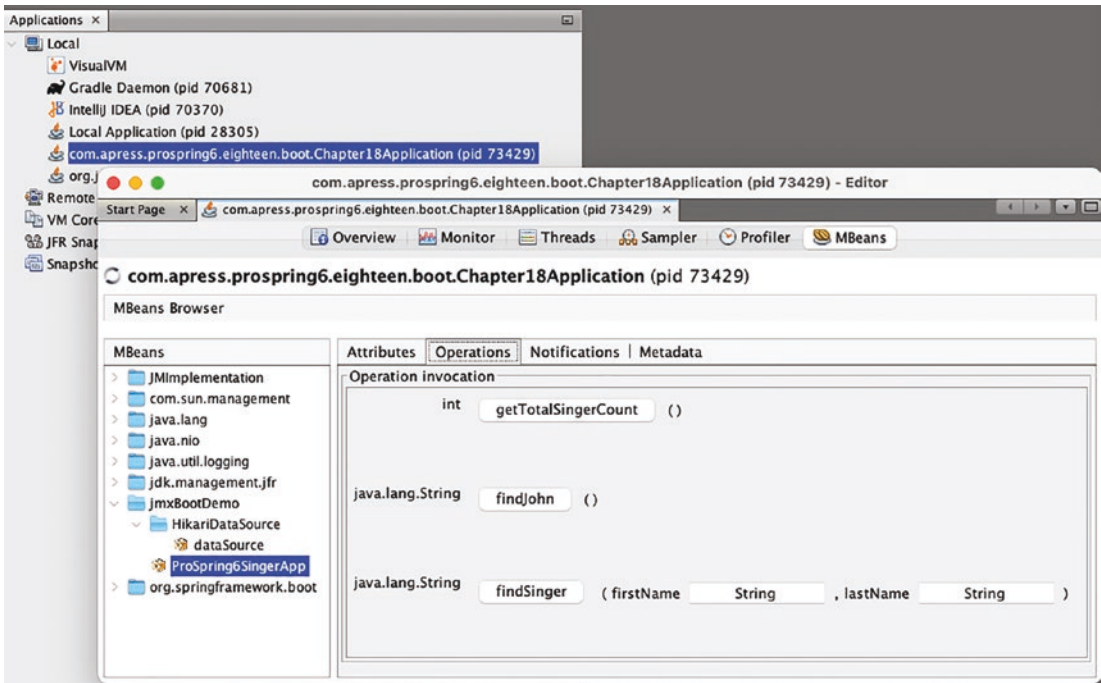
If you run the `testCreate()` method again, you'll notice that the values change. Creating singers requires Hibernate to persist the instances, thus you will see increases in the values of `TransactionCount`, `PrepareStatementCount`, `EntityInsertCount`, and a few others too.

## JMX with Spring Boot

Migrating the previous application to Spring Boot is easy, and the dependencies are provided and automatically configured. For JMX, no starter dependency is needed, but to enable JMX to expose MBeans, we need to add the `spring.jmx.enable=true` property to the configuration. To keep this application aligned to the previous section, we also add `spring.jmx.default-domain=jmxBootDemo` to change the domain name from `bean` to `jmxBootDemo` to identify easily the place where our MBeans are.

The application for this section is the same as the Spring Boot Web REST application from **Chapter 15**. With the `spring.jmx.enable=true` property added to the configuration, the `org.springframework.boot.autoconfigure.jmx.JmxAutoConfiguration` class is added to the application that declares an `MBeanServer` with a bean ID of `mbeanServer` and exposes any of the beans that are annotated with Spring JMX annotations.

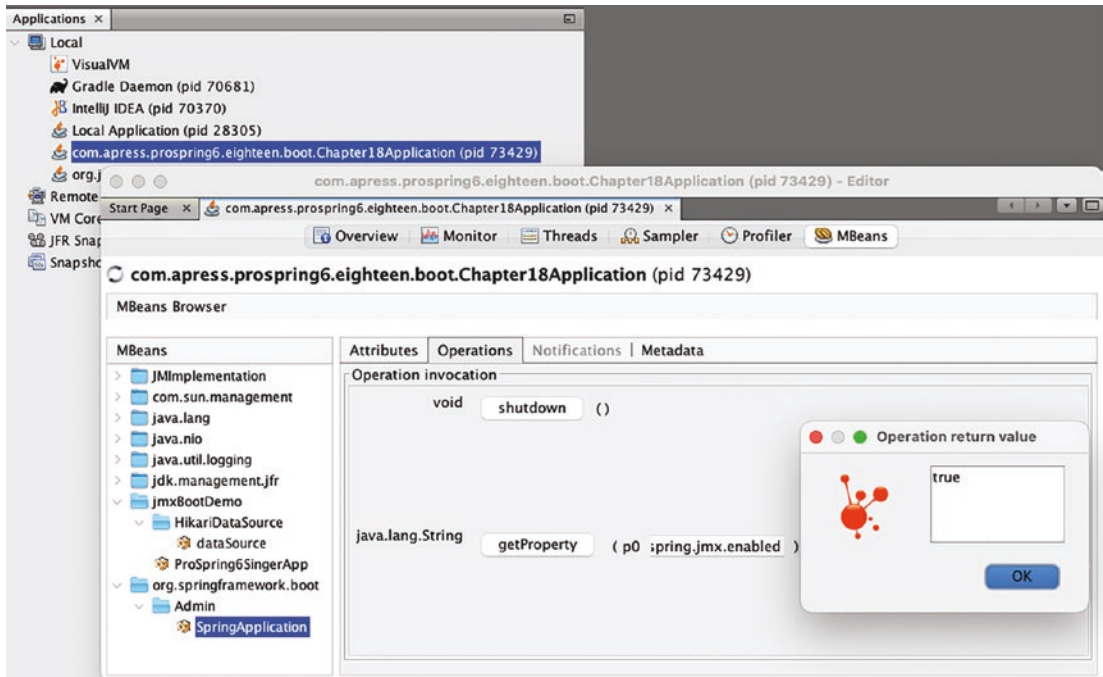
By default, Spring Boot will expose management endpoints as JMX MBeans under the `org.springframework.boot` domain. The `AppStatisticsImpl` class is identical to the one introduced in the previous section. And since Spring Boot exposes all JMX MBeans, if any of the libraries in the classpath contain them, they will be available under the `jmxDemo` domain. Now, if you open VisualVM and access the `Chapter18Application` node, you should see in the MBeans tab that the `jmxBootDemo` domain includes the `HikariDataSource` MBeans, as shown in Figure 18-4.



**Figure 18-4.** Operations for the *ProSpring6SingerApp* MBean declared in the *chapter18-boot* project

Notice that there is also an `org.springframework.boot` domain in the MBeans tab. There is not much under this domain, except management endpoints exposed as JMX Beans. In a simple application such as this, there are not many attributes and operations available. You can inspect the values of the Spring Boot properties if you want by invoking the `getProperty(..)` operation with the name of a property, such as `spring.jmx.enabled` as shown in Figure 18-5.



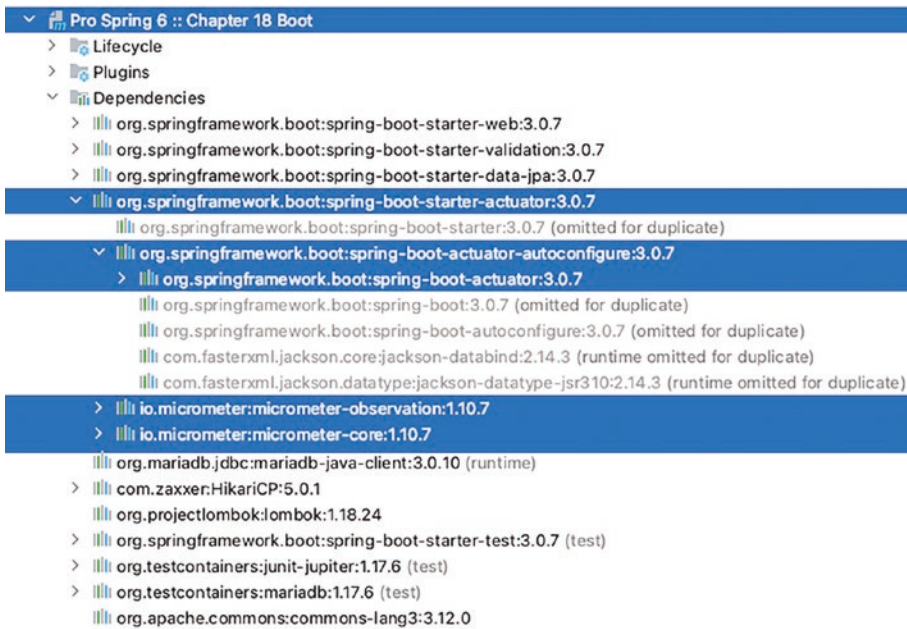


**Figure 18-5.** Using `getProperty(..)` operation to inspect the value of the `spring.jmx.enabled` property

It doesn't look like Spring Boot brings much extra to the table, but that changes when Spring Boot Actuator is added to the application.

## Monitoring Applications with Spring Boot Actuator

Spring Boot provides additional features for monitoring an application via JMX. Auditing, health, and metrics gathering are automatically applied to an application once `spring-boot-actuator.jar` is on the classpath. The `spring-boot-actuator` module provides a list of production-ready features. The recommended way to enable them is by adding the `spring-boot-starter-actuator` to the classpath. Figure 18-6 shows the dependencies of the `chapter18-boot` project, with the `spring-boot-starter-actuator` expanded to see all the transitive dependencies.



**Figure 18-6.** Project `chapter18-boot` dependencies

The Spring reference documentation defines an actuator as follows: “An actuator is a manufacturing term that refers to a mechanical device for moving or controlling something. Actuators can generate a large amount of motion from a small change.”<sup>4</sup>

## Spring Boot Actuator Endpoints

Spring Boot Actuator adds a collection of endpoints to an application that are used to monitor and interact with the application. Via configuration, we can expose these endpoints via JMX or HTTP and we can also decide if we want to expose all of them or only some of them. The configuration in Listing 18-7 is part of the `application.yaml` Spring Boot configuration file and enables exposing all Actuator endpoints over JMX under the `jmxBootDemo` domain.

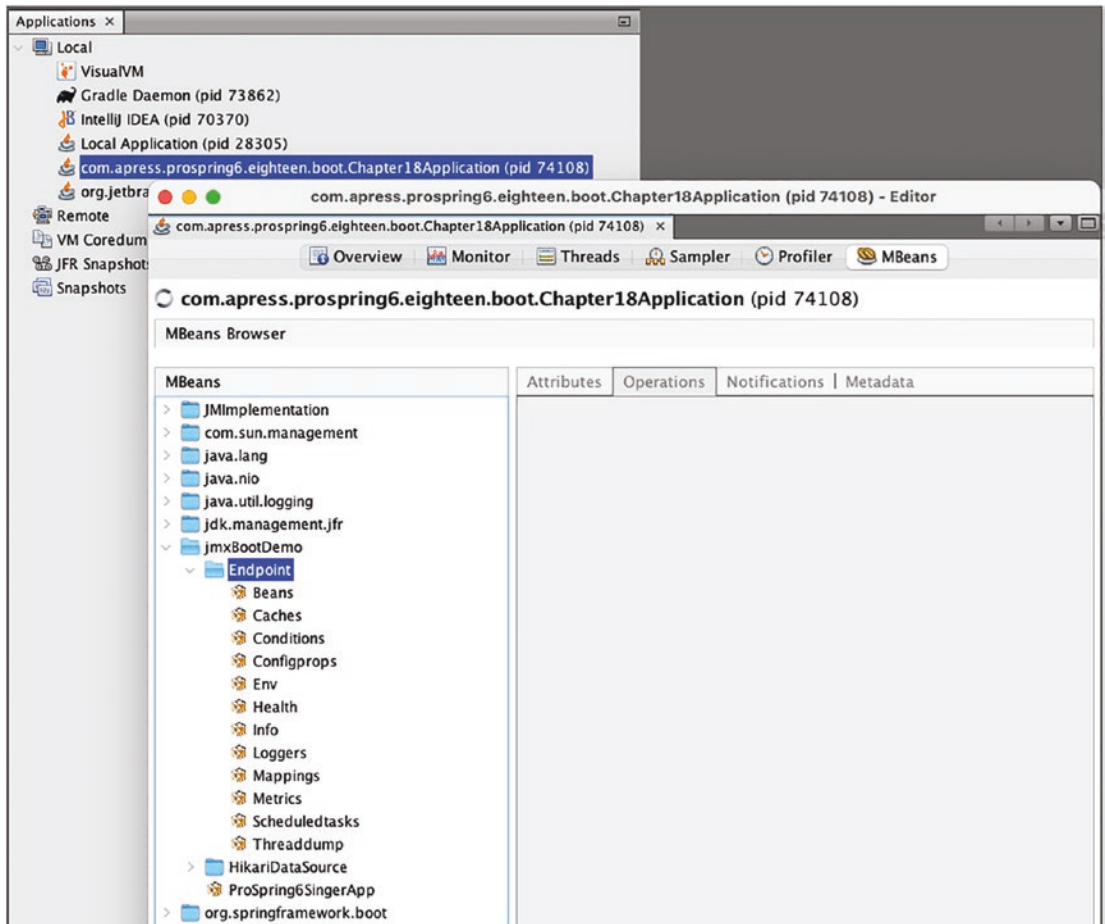
**Listing 18-7.** Configuration to Expose All Actuator Endpoints over JMX Under the `jmxBootDemo` Domain

```
management:
  endpoints:
    jmx:
      domain: jmxBootDemo
      exposure:
        include: "*"

```

<sup>4</sup><https://docs.spring.io/spring-boot/docs/current/reference/html/actuator.html>

With this configuration in place, when restarting the application and connecting VisualVM to it, a list of MBeans is added under the `jmxBootDemo` domain, grouped under the `Endpoint` node, as shown in Figure 18-7.



**Figure 18-7.** Spring Boot Actuator JMX endpoints shown in VisualVM

Table 18-1 lists the Spring Boot Actuator JMX endpoints and provides a short explanation of operations they expose.

**Table 18-1.** *Spring Boot Actuator JMX Endpoints*

Endpoint	Description
Beans	Operation <code>beans()</code> lists a complete list of all the Spring beans in your application.
Caches	Exposes operations to list and clear existing caches.
Conditions	Operation <code>conditions()</code> lists the conditions evaluated for the configuration of the Spring Boot application.
Configprops	Exposes operations to retrieve a collated list of configuration properties.
Env	Exposes operations to list properties from Spring's <code>ConfigurableEnvironment</code> .
Health	Operation <code>health()</code> lists application health information.
Info	Operation <code>info()</code> lists arbitrary application information.
Loggers	Exposes operations to show and modify the configuration of loggers in the application.
Mappings	Operation <code>mappings()</code> lists all <code>@RequestMapping</code> paths. Funny enough, this list includes the Actuator HTTP endpoints.
Metrics	Operation <code>listNames()</code> lists all metrics configured for the application.
Scheduledtasks	Operation <code>scheduledTasks()</code> lists all the scheduled tasks in the application.
Threaddump	Exposes operations to perform a thread dump.

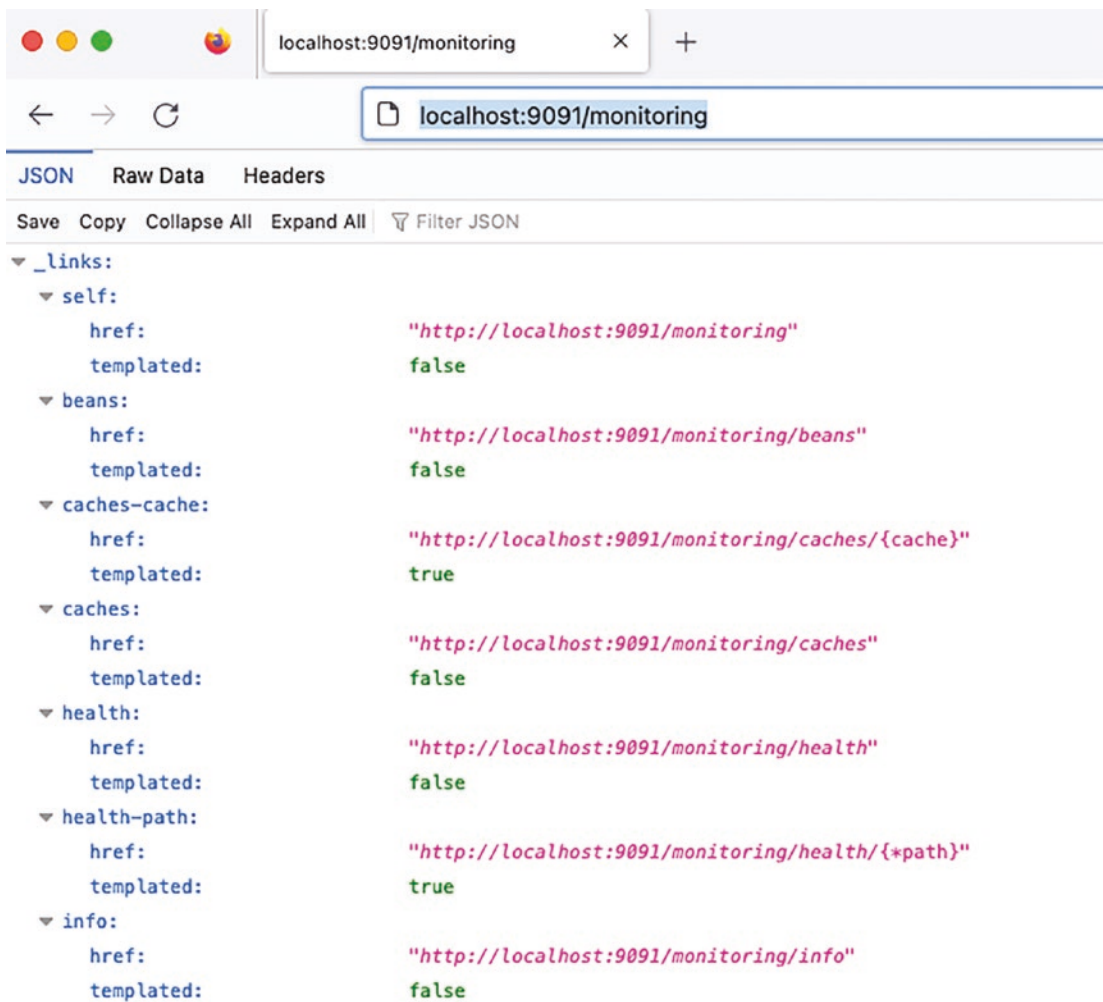
If you've clicked and tried to invoke operations in the VisualVM UI you've probably realized the JMX endpoints are tedious to work with. The good news is that Spring Boot Actuator exposes these endpoints, and a few more, over HTTP as well, all grouped under the `/actuator` path by default. The path under which the endpoints are grouped and the port can be customized via configuration.

Listing 18-8 shows the configuration for exposing all Actuator endpoints over HTTP under path `/monitoring` and on port 9091.

**Listing 18-8.** Configuration to Expose All Actuator Endpoints over HTTP

```
management:
  endpoints:
    web:
      exposure:
        include: "*"
      base-path: /monitoring
  server:
    port: 9091
```

To check the result of this configuration, simply open `http://localhost:9091/monitoring` in a browser. The response format is JSON, and it contains a list of endpoints. Some of them match the JMX endpoints introduced previously, while others are endpoints specific to the Web. In a browser that displays JSON nicely, like Firefox, this page looks like the one depicted in Figure 18-8.



**Figure 18-8.** Spring Boot Actuator HTTP endpoints

For example, the `/health` endpoint exposes basic information about the application's health. By default, it just returns `{"status": "UP"}`—yes, really basic. To view more details, the property `management.endpoint.health.show-details` must be set to `always` in the Spring Boot configuration file `application.yml` or in the `applications.properties` file. With this setting in place, details about the database used and its status are provided, along with details about the disk space. (Iuliana) Listing 18-9 shows what I see on the `/health` page when I run the application locally.

**Listing 18-9.** `/health` Page Contents Sample

```

{
  "status": "UP",
  "components": {
    "db": {
      "status": "UP",

```

```

        "details":{
            "database":"MariaDB",
            "validationQuery":"isValid()"
        }
    },
    "diskSpace":{
        "status":"UP",
        "details":{
            "total":499963174912,
            "free":320641298432,
            "threshold":10485760,
            "path":"/workspace/pro-spring-6/.",
            "exists":true
        }
    },
    "ping":{
        "status":"UP"
    }
}
}

```

Most endpoints are sensitive, they are not public by default, so if the application is secured, most information exposed by them will be omitted. The grouping of all endpoints under `/actuator` was introduced in Spring Boot 2.x. In the previous version, each available endpoint was exposed directly under the application context, so the `/health` endpoint was exposed under `http://localhost:8081/health`.

In this configuration the `/actuator` path was renamed to `/monitoring` via Spring Boot configuration. The same can be done for any of the endpoints; for example, via configuration we can rename the `/health` endpoint to `/salud` by setting the `management.endpoints.web.path-mapping.health` to this value.

If for security reasons we want these endpoints to be accessible only internally, we can configure the IP address by setting the `management.server.address` property to `127.0.0.1`.

Another simple endpoint is the `/info` endpoint. This endpoint displays general information about the project that is being read from `META-INF/build-info.properties` (generated at build time) or Git files like `git.properties` (generated if there is a plug-in configured for this), or through any environment property under the `info` key. The information exposed by this endpoint can be configured using the Spring Boot configuration file. By default, as expected, accessing this endpoint displays the JSON equivalent of nothing, `{}`. Adding the properties shown in Listing 18-10 to the configuration file makes this endpoint a little more useful.

**Listing 18-10.** Spring Boot Configuration for the `/info` Endpoint

```

management:
  info:
    java:
      enabled: true # enable Java info
    env:
      enabled: true # enable environment info - from 'application.yml' file

info:
  app:
    name: chapter18-boot
    description: "Pro Spring 6 - Chapter 18 :: Spring Actuator Application"
    version: 6.0-SNAPSHOT
    author: "Iuliana Cosmina"

```

When accessing the /info endpoint, the text in Listing 18-11 is returned.

**Listing 18-11.** Information exposed by the /info Endpoint

```
{
  "app":{
    "name":"chapter18-boot",
    "description":"Pro Spring 6 - Chapter 18 :: Spring Actuator Application",
    "version":"6.0-SNAPSHOT"
  },
  "author":"Iuliana Cosmina",
  "build":{
    "artifact":"chapter18-boot",
    "name":"chapter18-boot",
    "time":"2023-03-25T00:32:55.002Z",
    "version":"6.0-SNAPSHOT",
    "group":"pro-spring-6"
  },
  "java":{
    "version":"19.0.1",
    "vendor":{
      "name":"Amazon.com Inc.",
      "version":"Corretto-19.0.1.10.1"
    },
    "runtime":{
      "name":"OpenJDK Runtime Environment",
      "version":"19.0.1+10-FR"
    },
    "jvm":{
      "name":"OpenJDK 64-Bit Server VM",
      "vendor":"Amazon.com Inc.",
      "version":"19.0.1+10-FR"
    }
  }
}
```

Other endpoints' contents can be customized as well, and not only through Spring Boot configuration properties, but also by implementing interfaces or extending specific classes from the `org.springframework.boot.actuate` package. For example, a custom implementation of `org.springframework.boot.actuate.health.HealthIndicator` can add additional information to the /health endpoint.

As expected, Spring Boot Actuator provides the option to create your own endpoints. This is done by annotating a bean with `@Endpoint` from the `org.springframework.boot.actuate.endpoint.annotation` package. Annotating its methods with `@ReadOperation` (handling GET requests), `@WriteOperation` (handling POST requests), and `@DeleteOperation` (handling DELETE requests) exposes them over JMX and HTTP both.



In this book, some endpoints were mentioned to support filtering, because the data they display can be reduced by adding component names as suffixes to their URIs. Depending on the endpoint in question, those values can be bean names, fully qualified class names, property names, and so on. You might think of them as path variables, or filters, but the Spring team prefers to call them *tags*.

Spring Boot Actuator is really powerful and very customizable. To read more about it, check out the official documentation<sup>5</sup>.

## Using Spring Boot Actuator with Micrometer

In Figure 18-6 (earlier in the chapter), the `spring-boot-starter-actuator` library is shown with two transitive dependencies: `micrometer-core` and `micrometer-observation`. Micrometer<sup>6</sup> is an open source metrics facade that provides a vendor-neutral metrics collection API (the parent abstract implementations is `io.micrometer.core.instrument.MeterRegistry`<sup>7</sup>) and implementations for a variety of monitoring systems that were mentioned at the beginning of this chapter. It can be used with Spring Boot Actuator, but it is an independent platform that can be used by itself.

If it's hard to wrap your head around Micrometer, think of SLF4J, a facade or abstraction for various logging frameworks. This means the developer can use SLF4J to write log messages that will be gathered and written to the desired support by the framework configured by the application. In this book SLF4J is used together with Logback Classic, but we could easily swap Logback Classic with Log4j2, without any need of changes in the code. You could have the same for metrics starting with Spring Boot Actuator 2.x—Micrometer can be used to gather metrics and expose them in a format that any (almost) advanced monitoring system can interpret. Spring Boot 3 autoconfigures quite a long list of metrics out of the box. This list is returned by a GET request to the `http://0.0.0.0:9091/monitoring/metrics` endpoint (as configured in the previous section). Listing 18-12 lists the names of these metrics.

**Listing 18-12.** Spring Boot Metrics Listed by the `/metrics` Endpoint

```
{
  "names": [
    "application.ready.time",
    "application.started.time",
    "disk.free",
    "disk.total",
    "executor.active",
    "executor.completed",
    "executor.pool.core",
    "executor.pool.max",
    "executor.pool.size",
    "executor.queue.remaining",
    "executor.queued",
  ]
}
```

<sup>5</sup><https://docs.spring.io/spring-boot/docs/current/reference/html/actuator.html>

<sup>6</sup><https://micrometer.io>

<sup>7</sup><https://github.com/micrometer-metrics/micrometer/blob/main/micrometer-core/src/main/java/io/micrometer/core/instrument/MeterRegistry.java>



```

"hikaricp.connections",
"hikaricp.connections.acquire",
"hikaricp.connections.active",
"hikaricp.connections.creation",
"hikaricp.connections.idle",
"hikaricp.connections.max",
"hikaricp.connections.min",
"hikaricp.connections.pending",
"hikaricp.connections.timeout",
"hikaricp.connections.usage",
"jdbc.connections.active",
"jdbc.connections.idle",
"jdbc.connections.max",
"jdbc.connections.min",
"jvm.buffer.count",
"jvm.buffer.memory.used",
"jvm.buffer.total.capacity",
"jvm.classes.loaded",
"jvm.classes.unloaded",
"jvm.compilation.time",
"jvm.gc.live.data.size",
"jvm.gc.max.data.size",
"jvm.gc.memory.allocated",
"jvm.gc.memory.promoted",
"jvm.gc.overhead",
"jvm.info",
"jvm.memory.committed",
"jvm.memory.max",
"jvm.memory.usage.after.gc",
"jvm.memory.used",
"jvm.threads.daemon",
"jvm.threads.live",
"jvm.threads.peak",
"jvm.threads.states",
"logback.events",
"process.cpu.usage",
"process.files.max",
"process.files.open",
"process.start.time",
"process.uptime",
"system.cpu.count",
"system.cpu.usage",
"system.load.average.1m",
"tomcat.sessions.active.current",
"tomcat.sessions.active.max",
"tomcat.sessions.alive.max",
"tomcat.sessions.created",
"tomcat.sessions.expired",
"tomcat.sessions.rejected"
]
}

```

The metrics can be grouped in a few categories:

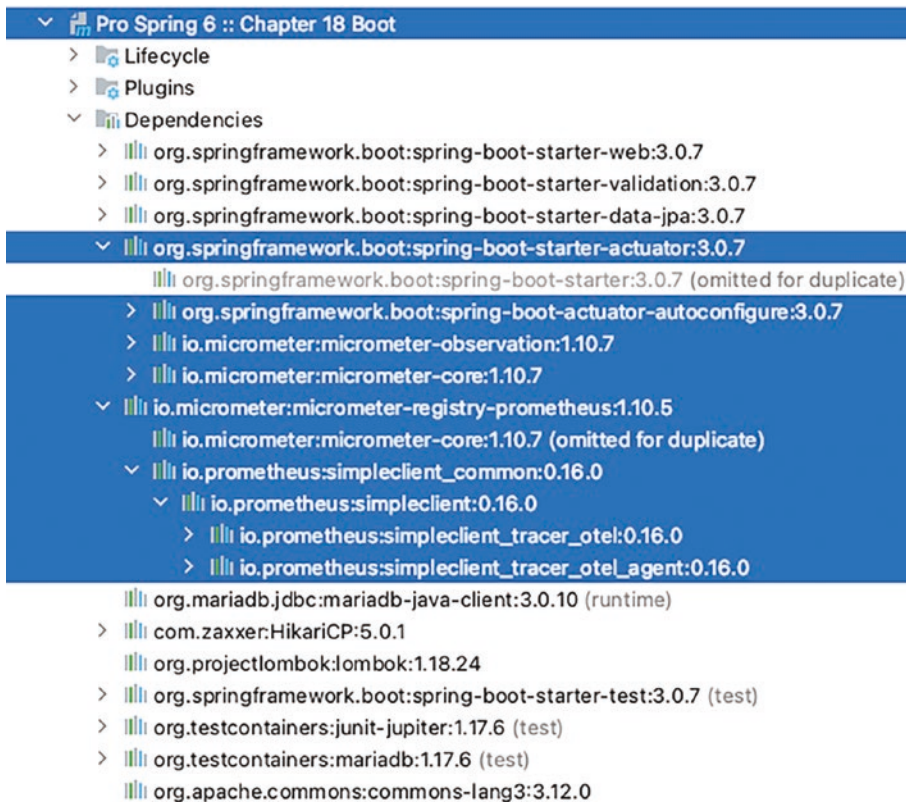
- Application times
- Uptime
- JVM—garbage collector activity, memory consumption, thread utilization, number of classes, etc.
- CPU usage
- Spring-specific components activity
- Cache activity
- Data source and HikariCP activity
- Tomcat usage
- Spring MVC and WebFlux request latencies (available only for Spring Boot MVC and WebFlux applications)
- Other custom components activity: RestTemplate latencies, file descriptor usage, event logging, RabbitMQ or ApacheMQ (if used) connection factories, etc.

So, when running the application generates a lot of data, what can we do with it? Well, we process it into reports and graphs that can be viewed with the naked eye, and that in turn can be used to predict future behavior. Micrometer cannot help with this, but there's a very easy-to-use tool that does the trick and integrates perfectly with Spring Boot Actuator and Micrometer: Prometheus<sup>8</sup>. Prometheus is an open source system-monitoring and alerting toolkit build at SoundCloud. It was released in 2012 and since then it has become a stand-alone open source project with a big and active developer and user community.

To integrate our Spring Boot application with Prometheus, we need to add the `micrometer-registry-prometheus` dependency. After adding this dependency, it should appear in the IntelliJ IDEA Gradle View, together with its transitive dependencies, as depicted in Figure 18-9.

---

<sup>8</sup><https://prometheus.io>



**Figure 18-9.** Spring Boot Actuator and Prometheus application dependencies

After adding the dependency and rebuilding the application, start the Spring Boot application by running the `Chapter18Application` main class. When opening the `http://localhost:9091/monitoring` URL, notice the Prometheus endpoint with URL `http://localhost:9091/monitoring/prometheus`. This endpoint is provided by the `PrometheusScrapeEndpoint` class, from package `org.springframework.boot.actuate.metrics.export.prometheus` that is part of the Spring Boot Actuator project. This endpoint translates the metrics provided by Micrometer into a format that can be scraped by the Prometheus server. You can see a summary of the exposed metrics by accessing the Prometheus endpoint in Listing 18-13.

**Listing 18-13.** Snippet of Spring Boot Metrics Listed on the `/prometheus` Endpoint

```
# HELP hikaricp_connections_max Max connections
# TYPE hikaricp_connections_max gauge
hikaricp_connections_max{pool="HikariPool-1",} 25.0
# HELP jvm_threads_live_threads The current number of live threads including both daemon and
non-daemon threads
# TYPE jvm_threads_live_threads gauge
jvm_threads_live_threads 39.0
# HELP http_server_requests_seconds
# TYPE http_server_requests_seconds summary
http_server_requests_seconds_count{error="none",exception="none",method="GET",outcome="SUCCESS",status="200",uri="/singer/{id}",} 100.0
```

```

http_server_requests_seconds_sum{error="none",exception="none",method="GET",outcome="SUCCESS",status="200",uri="/singer/{id}",} 1.069158702
http_server_requests_seconds_count{error="none",exception="none",method="POST",outcome="SUCCESS",status="201",uri="/singer/",} 1000.0
http_server_requests_seconds_sum{error="none",exception="none",method="POST",outcome="SUCCESS",status="201",uri="/singer/",} 6.119599968
http_server_requests_seconds_count{error="none",exception="none",method="GET",outcome="SUCCESS",status="200",uri="/singer/",} 100.0
http_server_requests_seconds_sum{error="none",exception="none",method="GET",outcome="SUCCESS",status="200",uri="/singer/",} 1.052652658
...

```

The next step is to run Prometheus to plot the data. For this you need to install Prometheus as explained on the official page<sup>9</sup>. To keep things practical, we recommend to go the Docker route and run it in a container. In the chapter18-boot folder you will find a file named CHAPTER18-BOOT.adoc explaining how to set up Prometheus in a Docker container; these steps will be skipped here to avoid derailing the focus of the chapter.



Before starting the container, continue reading this section, because you need to tell Prometheus where the metrics are coming from via a configuration file.

---

The Prometheus configuration file is named `prometheus.yaml`. The name is not mandatory, but it does make its purpose obvious. According to the official documentation, we have to define a job that tells Prometheus how often to query the metrics and from where. The syntax is YAML and the most important properties are listed in Listing 18-14.

**Listing 18-14.** Contents of the `prometheus.yaml` file

```

global:
  scrape_interval:    15s # By default, scrape targets every 15 seconds.

# Prometheus itself self-monitoring configuration
scrape_configs:
  - job_name: 'prometheus'

    # Override the global default and scrape targets from this job every 5 seconds.
    scrape_interval: 5s

    static_configs:
      - targets: ['0.0.0.0:9090']
  - job_name: 'chapter18-boot'
    metrics_path: '/monitoring/prometheus'
    # Override the global default and scrape targets from this job every 5 seconds.
    scrape_interval: 5s

    static_configs:

```

---

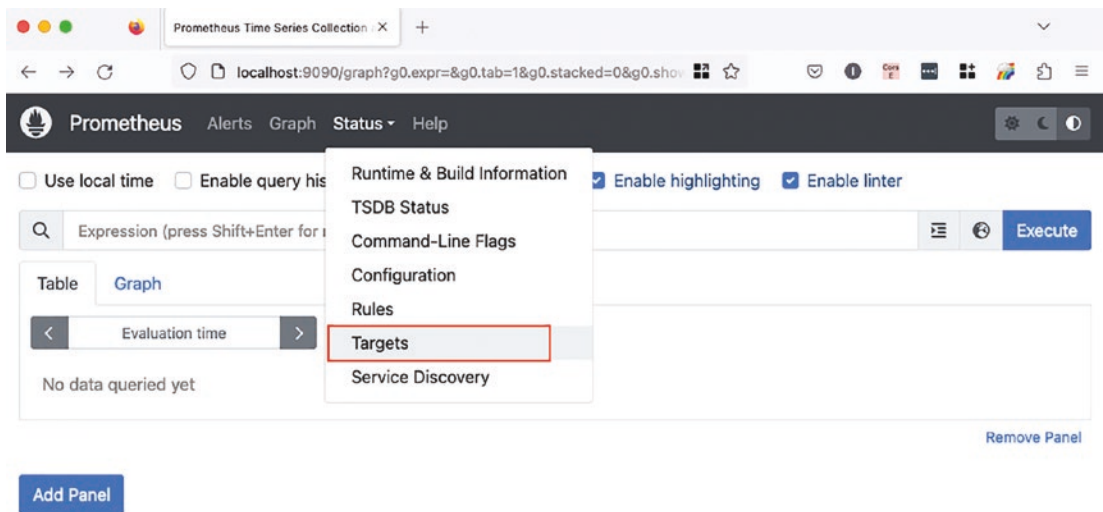
<sup>9</sup><https://prometheus.io/docs/prometheus/latest/installation>

```
# When Prometheus is run in a Docker container the real IP within the network
must be used
- targets: ['192.168.0.6:9091']
```

Notice that for the `chapter18-boot` job, the `metrics_path` property is set to the Prometheus Actuator endpoint and `targets` is set to the IP and port where the `chapter18-boot` application is running.

Before starting the Prometheus container, start the `chapter18-boot` application. By default, the Prometheus web console is available at `http://localhost:9090`. In the `prometheus.yml` file, the job named `prometheus` represents the configuration of the Prometheus application itself, and the configurations of this job can be customized to start Prometheus on a different IP and port.

The Prometheus web UI is pretty simplistic. The option of most interest for this discussion is **Status** ➤ **Targets**, highlighted in Figure 18-10.



**Figure 18-10.** Prometheus web UI

Choosing the **Targets** menu item directs you to the page shown in Figure 18-11 confirming that `chapter18-boot` is UP, and listing the job configurations and the most recent time the metrics were refreshed. If the text is **DOWN** and highlighted in red, either the application is not started or `static_configs.targets` was not set properly for the `chapter18-boot` job.

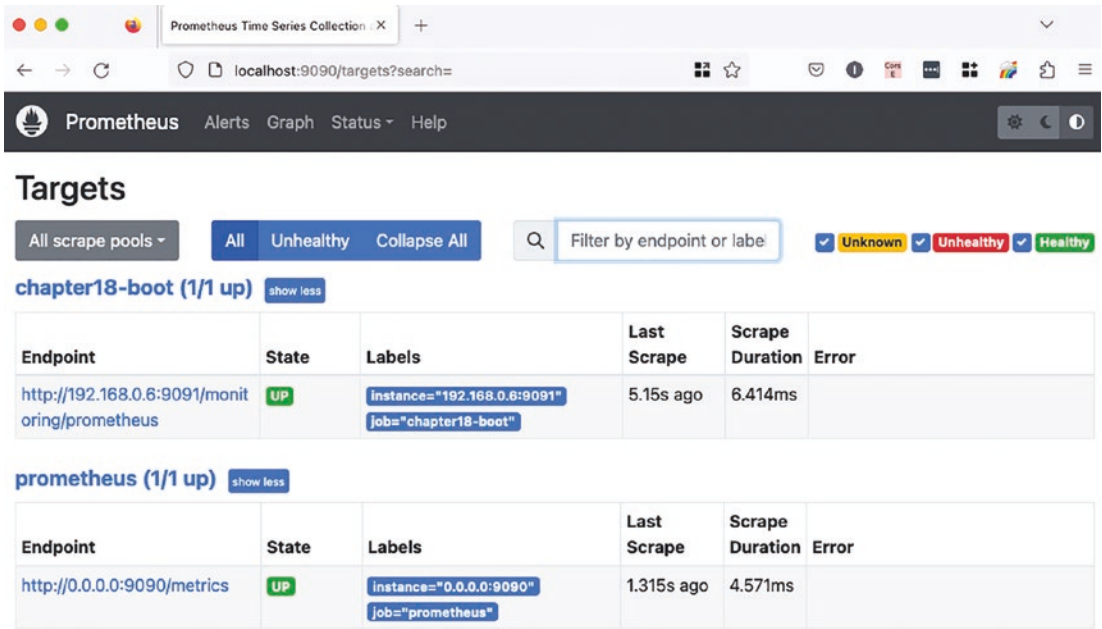
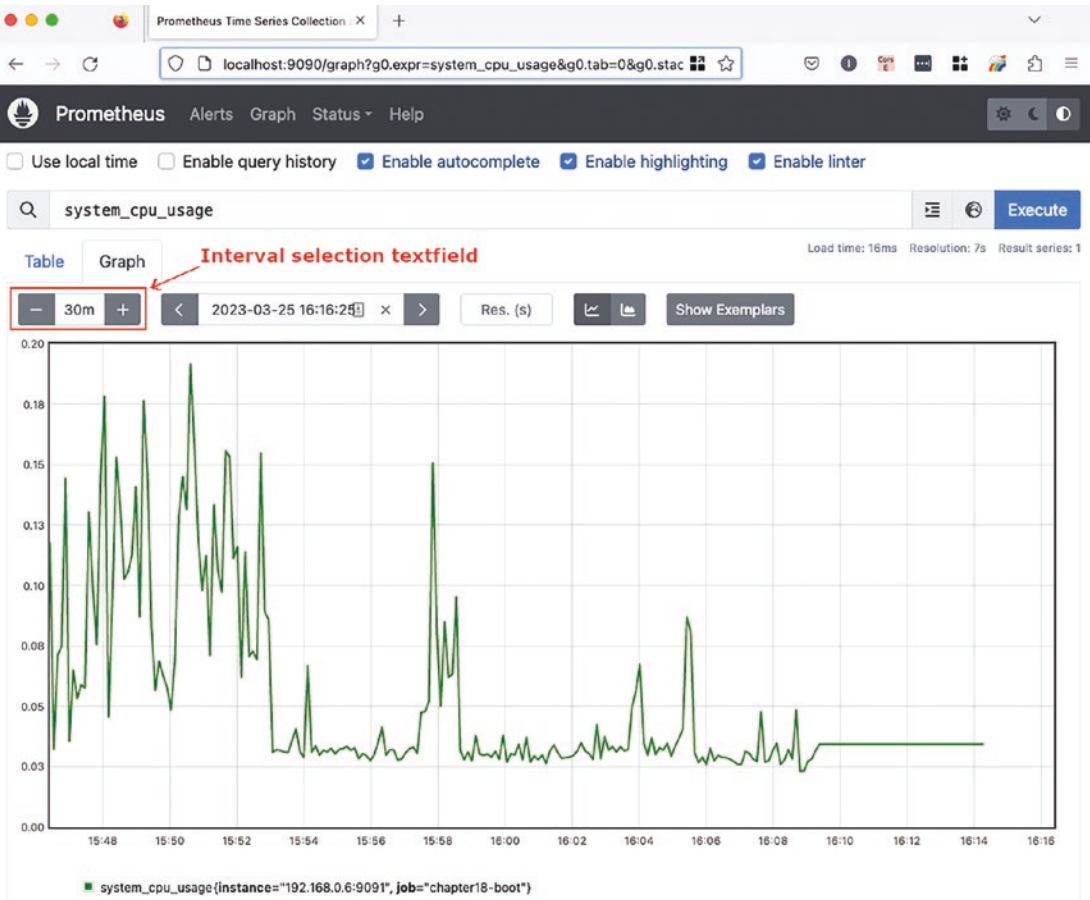


Figure 18-11. Prometheus web UI showing chapter18-boot and Prometheus apps running

If everything is okay, you can go back to the main page and select a metric. One of the most visible metrics is `system_cpu_usage`, so select that from the list of metrics and click the Execute button. The information is not really visible in the Graph tab until we reduce the interval for the metrics analysis by setting a sensible value, such as 15 or 30 minutes, in the first text field. The graph should be quite interesting, similar to what is depicted in Figure 18-12.



**Figure 18-12.** Prometheus web UI showing graph for the `system_cpu_usage` metric

As previously shown in Listing 18-13, several metrics related to the number of requests are available. To simulate a situation in which the server takes variable times to resolve requests, so that we can see the graph for the `http_server_requests_seconds_count`, we can modify the `SingerController` to introduce a different delay for each of the `Singer` instances returned when a GET request with the `http://localhost:9091/singer/{id}` URL is received. This is done by adding a `Thread.sleep()` in the handler method for this URI, that pauses the execution for a random time based on the record id. The handler method is shown in Listing 18-15.

**Listing 18-15.** Custom Handler Method for Request Path `/singer{id}` with Various Delays

```
package com.apress.prospring6.eighteen.boot.controllers;
// import statements omitted

@RestController
@RequestMapping(value="/singer")
public class SingerController {

    @GetMapping(path =("/{id}")
    public Singer findSingerById(@PathVariable Long id) {
        var singer = singerService.findById(id);
    }
}
```

```

    if (singer != null) {
        int msec = 10;
        try {
            Thread.sleep(Duration.ofMillis(msec * id));
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }
    return singer;
}
// other methods and fields omitted
}

```

Now, in order to submit a lot of requests and produce a lot of data so that Prometheus has something to plot on the graph, the test class in Listing 18-16 has two very useful methods.

**Listing 18-16.** Test Methods to Generate Metric Data

```

package com.apress.prospring6.eighteen.boot;
// import statements omitted

public class SingerControllerTest {

    private static String BASE_URL = "http://localhost:8081/singer/";

    private RestTemplate restTemplate = new RestTemplate();

    @RepeatedTest(500)
    public void testCreate() throws URISyntaxException {
        Singer singerNew = new Singer();
        singerNew.setFirstName(UUID.randomUUID().toString().substring(0,8));
        singerNew.setLastName(UUID.randomUUID().toString().substring(0,8));
        singerNew.setBirthDate(LocalDate.now());

        RequestEntity<Singer> req = new RequestEntity<>(singerNew, HttpMethod.POST, new
        URI(BASE_URL));

        ResponseEntity<String> response = restTemplate.exchange(req, String.class);
        assertEquals(HttpStatus.CREATED, response.getStatusCode());
    }

    @RepeatedTest(10)
    public void testPositiveFindById() throws URISyntaxException {
        HttpHeaders headers = new HttpHeaders();
        headers.setAccept(List.of(MediaType.APPLICATION_JSON));
        for (int i = 1; i < 250; i++) {
            RequestEntity<HttpHeaders> req = new RequestEntity<>(headers, HttpMethod.GET,
            new URI(BASE_URL + i));
            ResponseEntity<Singer> response = restTemplate.exchange(req, Singer.class);
            assertAll("testPositiveFindById",
                () -> assertEquals(HttpStatus.OK, response.getStatusCode()),

```





Notice that the duration of a GET request to `/singer/` (shown in green at the bottom) never increases. Notice that the duration of the POST request to `/singer/` (shown in red) increases as the table gets bigger. The duration of the GET request to `/singer/{id}` (shown in blue) is the one that shows the most increase, considering that is where the `Thread.sleep(...)` is.

The Prometheus graphs are quite simple, and the default Micrometer metrics are basic too. In a production application, teams can define their own metrics depending on the services the application provides. For example, for a banking application, login failures coupled with certain originating IPs might reveal some type of hacking attempt, so a must-have metric is one that groups together failed logins and a class of IPs where requests are generated from.

The leading solution in visualizing metrics at the moment seems to be Grafana<sup>10</sup>, and the good news is that it knows how to interpret Prometheus metrics. So, the Prometheus metrics can be forwarded to Grafana to plot some higher-definition graphs.

## Summary

In this chapter, we covered the high-level topics of monitoring a Spring-powered JEE application. First, we discussed Spring's support of JMX, the standard in monitoring Java applications. We discussed implementing custom MBeans for exposing application-related information, as well as exposing statistics of common components such as Hibernate; and we showed how JMX can be used in a Spring Boot application.

Next, we showed the full power of Spring Boot Actuator in generating application metrics and how to plot those metrics using Prometheus. This is all the space we have in this book for application monitoring. The next chapter introduces you to WebSocket, a protocol that allows bi-directional communication between a web client and a web server.

---

<sup>10</sup><https://grafana.com>



# Spring WebSocket Support

Traditionally, web applications have utilized the standard request/response HTTP functionality to provide communication between the client and server. As the Web has evolved, more interactive abilities have been required, some of which demand push/pull or real-time updates from the server. Over time, various methods have been implemented, such as continuous polling, long polling, and Comet. Each has its pros and cons, and the WebSocket Protocol<sup>1</sup> is an attempt to learn from those needs and deficiencies, creating a simpler and more robust way to build interactive applications. The HTML5 WebSocket specification defines an API that enables web pages to use the WebSocket protocol for two-way communication with a remote host.

This chapter presents a high-level overview of the WebSocket protocol, and the main functionality provided by the Spring Framework. Specifically, this chapter covers the following topics:

- *Introduction to WebSocket:* We provide a general introduction of the WebSocket protocol. This chapter is not intended to serve as a detailed reference of the WebSocket protocol but rather as a high-level overview.
- *Using WebSocket with Spring:* We dive into some details of using WebSocket with the Spring Framework; specifically, we cover using Spring's WebSocket API, utilizing SockJS as a fallback option for non-WebSocket-enabled browsers, and sending messages using Simple (or Streaming) Text-Oriented Message Protocol (STOMP) over SockJS/WebSocket.

## Introducing WebSocket

WebSocket is a specification developed as part of the HTML5 initiative, allowing for a full-duplex single-socket connection in which messages can be sent between a client and a server. In the past, web applications requiring the functionality of real-time updates would poll a server-side component periodically to obtain this data, opening multiple connections or using long polling.

Using WebSocket for bidirectional communication avoids the need to perform HTTP polling for two-way communications between a client (for example, a web browser) and an HTTP server. The WebSocket protocol is meant to supersede all existing bidirectional communication methods utilizing HTTP for

---

<sup>1</sup><https://www.rfc-editor.org/rfc/rfc6455>

transport. The single-socket model of WebSocket results in a simpler solution, avoiding the need for multiple connections for each client and the corresponding overhead—for example, not needing to send an HTTP header with each message.

WebSocket utilizes HTTP during its initial handshake, which in turn allows it to be used over standard HTTP (80) and HTTPS (443) ports. The WebSocket specification defines a `ws://` and a `wss://` scheme to indicate non-secure and secure connections. The WebSocket protocol has two parts: a handshake between the client and server and then data transfer. A WebSocket connection is established by making an upgrade request from HTTP to the WebSocket protocol during the initial handshake between the client and the server, over the same underlying TCP/IP connection. During the data transfer portion of the communication, both the client and server can send messages to each other simultaneously, opening the door to add more-robust real-time communication functionality to your applications.

## Using WebSocket with Spring

As of version 4.1, the Spring Framework supports WebSocket-style messaging as well as STOMP as an application-level subprotocol. Within the framework, you can find support for WebSocket in the `spring-websocket` module, which is compatible with JSR-356 (“Java WebSocket” recently renamed to “Jakarta WebSocket API”)<sup>2</sup>.

Application developers must also recognize that although WebSocket brings new and exciting opportunities, not all web browsers support the protocol. Given this, the application must continue to work for the user and utilize some sort of fallback technology to simulate the intended functionality as best as possible. To handle this case, the Spring Framework provides transparent fallback options via the SockJS protocol, which will we go into later in this chapter.

Unlike REST-based applications, where services are represented by different URLs, WebSocket uses a single URL to establish the initial handshake, and data flows over that same connection. This type of message-passing functionality is more along the lines of traditional messaging systems. As of Spring Framework 4, core message-based interfaces such as `Message` have been migrated from the Spring Integration project into a new module called `spring-messaging` to support WebSocket-style messaging applications.

When we refer to using STOMP as an application-level subprotocol, we are talking about the protocol that is transported via WebSocket. WebSocket itself is a low-level protocol that simply transforms bytes into messages. The application needs to understand what is being sent across the wire, which is where a subprotocol such as STOMP comes into play. During the initial handshake, the client and server can use the `Sec-WebSocket-Protocol` header to define what subprotocol to use. While the Spring Framework provides support for STOMP, WebSocket does not mandate anything specific.

Now that you have an understanding of what WebSocket is and the support Spring provides, you’re likely wondering where you might use this technology. Given the single-socket nature of WebSocket and its ability to provide a continuous bidirectional data flow, WebSocket lends itself well to applications that have a high frequency of message passing and require low-latency communications. Applications that may be good candidates for WebSocket could include gaming, real-time group collaboration tools, messaging systems, time-sensitive pricing information such as financial updates, and so on. When designing your application with the consideration of using WebSocket, you must take into account both the frequency of messages and latency requirements. This will help determine whether to use WebSocket or, for example, HTTP long polling.

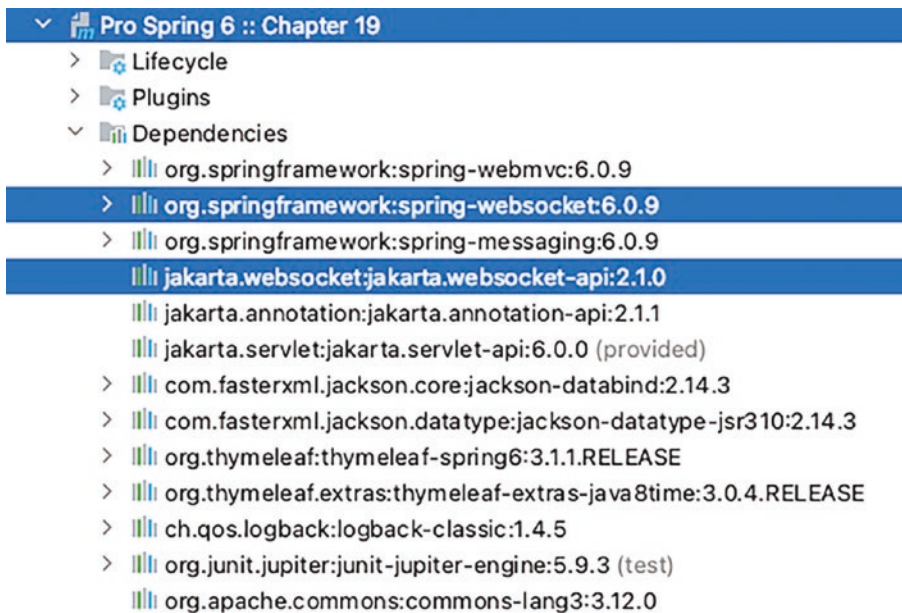
---

<sup>2</sup><https://www.oracle.com/technical-resources/articles/java/jsr356.html>

## Using the WebSocket API

As mentioned in the previous discussion, WebSocket simply transforms bytes into messages and transports them between client and server. Those messages still need to be understood by the application itself, which is where subprotocols such as STOMP come into play. If you want to work with the lower-level WebSocket API directly, the Spring Framework provides an API that you can interact with to do so. When working with Spring's WebSocket API, you would typically implement the `WebSocketHandler` interface or use convenience subclasses such as `BinaryWebSocketHandler` for handling binary messages, `SockJsWebSocketHandler` for SockJS messages, or `TextWebSocketHandler` for working with text-based messages. In this example, for simplicity we will use a `TextWebSocketHandler` to pass text-based messages via WebSocket. Let's start by taking a look at how we can receive and work with WebSocket messages at a low level, utilizing the Spring WebSocket API.

Obviously, we need to add to the classpath libraries that support WebSocket communication. Figure 19-1 shows the dependencies of a Spring web application that uses the WebSocket protocol to send messages to itself.



**Figure 19-1.** Project chapter19 dependencies

As you can see, the dependencies are typical for a Spring Web application, like the one introduced in **Chapter 14**. The Jakarta WebSocket API provides a platform-independent WebSocket protocol API to build bidirectional communications over the Web. The `jakarta.websocket-api` library contains the Jakarta WebSocket API for Server and Client (API only; it does not include an implementation). The `spring-websocket` library contains the Spring WebSocket API needed to write client- and server-side applications that handle WebSocket messages.

To send the messages and display them, a simple web page is created, named `index.html`. This page is built from a default Thymeleaf layout and contains static HTML and JavaScript that is used to communicate with the back-end WebSocket service. To handle the communication, we need to declare a special type that implements `WebSocketHandler` and a bean of that type. Figure 19-2 shows the hierarchy of types that implement `org.springframework.web.socket.WebSocketHandler`.

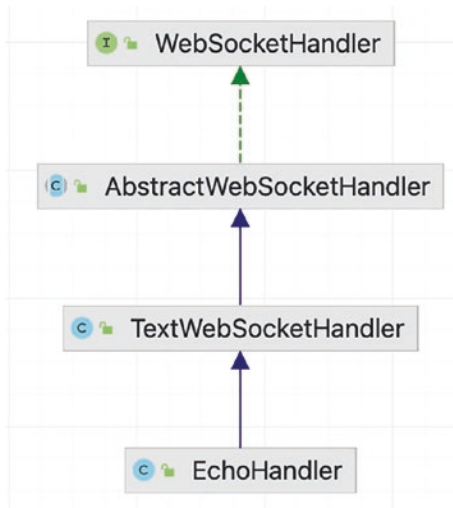


Figure 19-2. `WebSocketHandler` implementations

To keep things simple, and benefit from out-of-the-box Spring code, instead of implementing the `WebSocketHandler` directly, our `EchoHandler` class will instead extend the `TextWebSocketHandler`. This keeps our implementation concise, as the only method that needs to be implemented is `handleTextMessage(..)`, as shown in Listing 19-1.

Listing 19-1. The `EchoHandler` Class

```

package com.apress.prospring6.nineteen;

import org.springframework.web.socket.TextMessage;
import org.springframework.web.socket.WebSocketSession;
import org.springframework.web.socket.handler.TextWebSocketHandler;

import java.io.IOException;

public class EchoHandler extends TextWebSocketHandler {
    @Override
    public void handleTextMessage(WebSocketSession session, TextMessage textMessage) throws
        IOException {
        session.sendMessage(new TextMessage(textMessage.getPayload()));
    }
}
  
```

As you can see, this is a basic handler that takes the provided message and simply echoes it back to the client. The content of the received WebSocket message is contained in the `getPayload()` method.

Now that we have the type, we need to define a single handler mapping in this example, which receives requests at `/echoHandler` and uses the bean with the ID of `echoHandler` to receive a message and respond by echoing the provided message back to the client. To keep the WebSocket configuration separate from the MVC configuration, we introduce a class named `WebSocketConfig` that declares the mapping, the bean, and also enables support for communication using WebSocket, as shown in Listing 19-2.

*Listing 19-2.* The `WebSocketConfig` Configuration Class

```
package com.apress.prospring6.nineteen;

import org.springframework.web.socket.config.annotation.EnableWebSocket;
import org.springframework.web.socket.config.annotation.WebSocketConfigurer;
import org.springframework.web.socket.config.annotation.WebSocketHandlerRegistry;
// other import statements omitted

@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {
    @Override
    public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
        registry.addHandler(echoHandler(), "/echoHandler");
    }

    @Bean
    public EchoHandler echoHandler() {
        return new EchoHandler();
    }
}
```

The `@EnableWebSocket` annotation enables support for processing WebSocket requests, while the `WebSocketConfig` configuration class implements Spring's `WebSocketConfigurer` interface that defines callback methods to configure the WebSocket request handling.

The Spring MVC configuration is nothing special (refer to **Chapter 14** if you need to jog your memory), but we do need to map the `index.html` page to the `/index` path. The controller is shown in Listing 19-3.

*Listing 19-3.* The `IndexController` Configuration Class

```
package com.apress.prospring6.nineteen;

import jakarta.servlet.http.HttpServletRequest;
import org.springframework.stereotype.Controller;
import org.springframework.ui.Model;
import org.springframework.web.bind.annotation.GetMapping;

@Controller
public class IndexController {
    @GetMapping(path = "index")
    public String auth(Model model, HttpServletRequest request) {
        var requestUrl= request.getRequestURL().toString();
    }
}
```



```

    var websocketAddress = requestUrl.replace("http", "ws").replace("index",
    "echoHandler");
    model.addAttribute("websocket", websocketAddress);
    return "index";
}
}

```

The implementation is quite simple, but to keep the WebSocket handler URL dynamic and relative to the context path of the application, a little artifice is implemented that takes the URL of the initial request, which is `http://localhost:8080/ch19/index`, and uses it to produce the `ws://localhost:8080/ch19/echoHandler` value, which is added as the `websocket` attribute to the `index` model.

That's pretty much all that is needed on the back end. Given that `EchoHandler` is a typical Spring bean, you can do anything you would in a normal Spring application, such as inject services, to carry out any functions this handler may need to do.

The `index.html` page is a very simple Thymeleaf view representing a simple front-end client where we can interact with the back-end WebSocket service. The front end is a simple HTML page with a bit of JavaScript that uses the browser's API to make the WebSocket connection; it also contains some jQuery<sup>3</sup> to handle button-click events and data display. jQuery is quite simple, but introducing a more complex JavaScript framework would be overkill for purposes of this chapter. The front-end application will have the ability to connect, disconnect, send a message, and display status updates to the screen. Listing 19-4 shows the code for the front-end client page (`views/index.html`).

*Listing 19-4.* The `views/index.html` View

```

<html>

<head th:fragment=~{templates/layout :: pageTitle}>
  <title> WebSocket Tester </title>
  <script type="text/javascript" th:src="@{/js/jquery-3.6.4.min.js}"></script>
  <script type="text/javascript">
    let ping;
    let websocket;
    let supportsWebSockets = 'WebSocket' in window || 'MozWebSocket' in window;

    jQuery(function ($) {
      $("#connect").attr("disabled", true);
      if (supportsWebSockets) {
        console.log(">> websocket protocol supported.");
        $("#connect").attr("disabled", false);
      }

      function writePing(message) {
        $('#pingOutput').append(message + '\n');
      }

      function writeMessage(message) {
        $('#messageOutput').append(message + '\n')
      }
    });
  </script>

```

---

<sup>3</sup><https://jquery.com>



```

$('#connect')
    .click(function doConnect() {
        websocket = new WebSocket($("#target").val());

        websocket.onopen = function (evt) {
            let badge= $("#badgeStatus");
            badge.text("Connected");
            badge.attr('class','badge bg-success');

            setInterval(function () {
                if (websocket !== "undefined") {
                    websocket.send("ping");
                }
            }, 3000);
        };

        websocket.onclose = function (evt) {
            let badge= $("#badgeStatus");
            badge.text("Disconnected");
            badge.attr('class','badge bg-light');
        };

        websocket.onmessage = function (evt) {
            if (evt.data === "ping") {
                writePing(evt.data);
            } else {
                writeMessage('ECHO: ' + evt.data);
            }
        };

        websocket.onerror = function (evt) {
            onError(writeStatus('ERROR:' + evt.data))
        };
    });

$('#disconnect')
    .click(function () {
        if (typeof websocket != 'undefined') {
            websocket.close();
            websocket = undefined;
        } else {
            alert("Not connected.");
        }
    });

$('#send')
    .click(function () {
        if (typeof websocket != 'undefined') {
            websocket.send($('#message').val());
        } else {
            alert("Not connected.");
        }
    });

```

```

    });
  });
</script>
</head>

<body>
<div class="container">
  <header th:replace=~{templates/layout :: pageHeader}" ></header>

  <header th:replace=~{templates/layout :: pageMenu}" ></header>

  <section th:fragment=~{templates/layout :: pageContent}">
    <div class="card border-success mb-3" style="max-width: 40rem;">
      <div class="card-header">WebSocket Tester</div>
      <div class="row mb-1 m-sm-1">
        <label for="target" th:text="Target" class="col-sm-4 form-label">FN:</label>
        <div class="col-sm-8">
          <input type="text" id="target" size="40" th:value="{webSocket}"
            class="form-control"/>
        </div>
      </div>
      <div class="row mb-1 m-sm-1">
        <div class="col-sm-2"><input type="submit" id="connect" class="btn btn-
          success" value="Connect"/></div>
        <div class="col-sm-2"><input type="submit" id="disconnect" class="btn btn-
          danger" value="Disconnect"/></div>
        <div class="col-sm-2"><span id="badgeStatus"></span></div>
      </div>
      <div class="row mb-1 m-sm-1">
        <label for="message" th:text="Message" class="col-sm-4 form-
          label">FN:</label>
        <div class="col-sm-8">
          <input type="text" id="message" value="" class="form-control"/>
        </div>
      </div>
      <div class="row mb-1 m-sm-1">
        <div class="col-sm-2"><input type="submit" id="send" value="Send"
          class="btn btn-dark"/></div>
      </div>
      <div class="row mb-1 m-sm-1">
        <label for="messageOutput" th:text="Echo" class="col-sm-4 form-
          label">FN:</label>
        <div class="col-sm-7">
          <pre><textarea id="messageOutput" rows="5" cols="25" class="form-
            control"></textarea></pre>
        </div>
      </div>
      <div class="row mb-1 m-sm-1">
        <label for="pingOutput" th:text="Ping" class="col-sm-4 form-
          label">FN:</label>
        <div class="col-sm-7">
          <pre><textarea id="pingOutput" rows="5" cols="25" class="form-
            control"></textarea></pre>
        </div>
      </div>
    </section>
  </div>
</body>

```

```

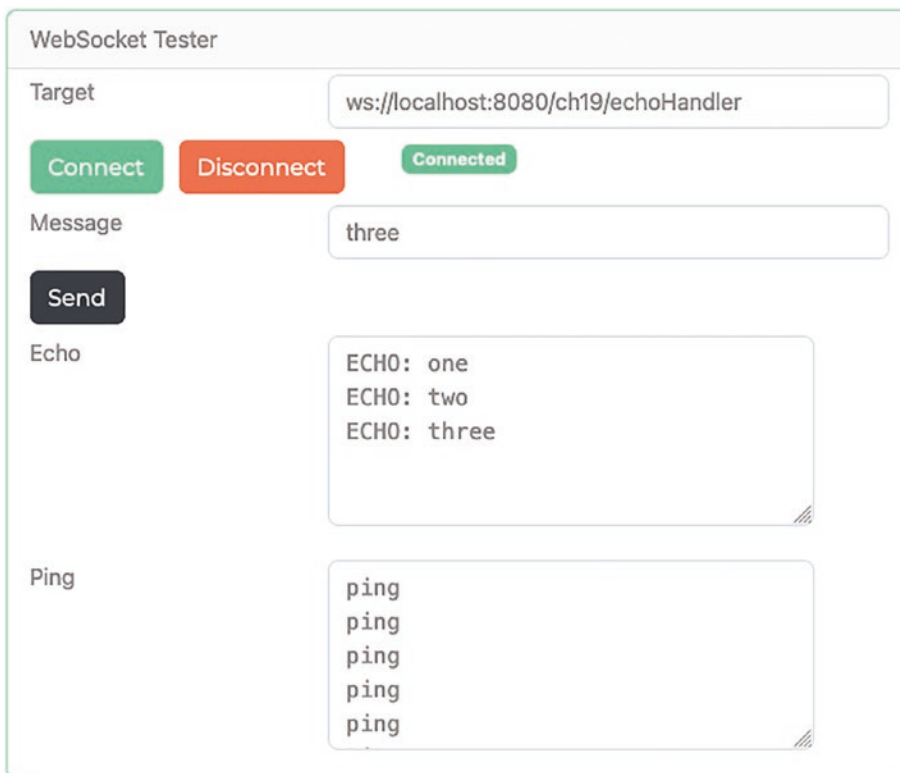
        </div>
    </div>
</div>
</section>

<footer th:replace=~{templates/layout :: pageFooter}" ></footer>
</div>
</body>
</html>

```

The code snippet in Listing 19-4 models a UI that allows us to call back into the WebSocket API and watch real-time results appear on the screen.

Build the project and deploy it into your web container using an IntelliJ IDEA launcher as instructed in **Chapter 14**. Then navigate to `http://localhost:8080/ch19/index` to bring up the UI. Click the Connect button, and you will notice a Connected green badge next to the Connect and Disconnect buttons, as shown in Figure 19-3, and every three seconds a ping message will display in the Ping text area. Go ahead and type a message in the Message text box and then click the Send button. This message will be sent to the back-end WebSocket service and displayed in the Echo box. When you have finished sending messages, click the Disconnect button, and you will notice that the green badge is replaced by a gray badge labeled Disconnected. You will not be able to send any further messages or disconnect again until you reconnect to the WebSocket service.



**Figure 19-3.** WebSocket client page

While this example utilizes the Spring abstraction on top of the low-level WebSocket API, you can clearly see the exciting possibilities this technology can bring to your applications. Now let's take a look at how to handle this functionality when the browser does not support WebSocket and a fallback option is required. The code in Listing 19-4 tests if WebSocket is not supported in the browser using the `supportsWebSockets` variable and disables the Connect button if it is not.

## Using SockJS

Because not all browsers support WebSocket (e.g., this might be the case for browsers on mobile devices) and applications still need to function correctly for end users, the Spring Framework provides a fallback option utilizing SockJS<sup>4</sup>. Using SockJS provides WebSocket-like behavior as close as possible during runtime without the need for changes to application-side code. The SockJS protocol is used on the client side via JavaScript libraries. The Spring Framework's `spring-websocket` library contains the relevant SockJS server-side components. When using SockJS to provide a seamless fallback option, the client will first send a GET request to the server by using a path of `/info` to obtain transport information from the server. SockJS will first try to use WebSocket, then HTTP streaming, and finally HTTP long polling as a last resort.

There is a simple modification to be made to support WebSocket communication using SockJS. First, we need to support asynchronous messaging, which is enabled in the configuration in Listing 19-5 using the `@EnableAsync` annotation.

*Listing 19-5.* Spring MVC Configuration for SockJS Asynchronous Configuration

```
package com.apress.prospring6.nineteen;

import org.springframework.scheduling.annotation.EnableAsync;
// other import statements omitted

@EnableAsync
@Configuration
@EnableWebMvc
@ComponentScan
public class WebConfig implements WebMvcConfigurer, ApplicationContextAware {
// other configuration omitted
}
```

The official Spring Javadoc states that the `@EnableAsync` annotation enables Spring's asynchronous method execution capability, thus enabling annotation-driven async processing for an entire Spring application context<sup>5</sup>.

The second change must be done in `WebSocketConfig` to enable SockJS support for our handler, as shown in Listing 19-6.

<sup>4</sup><https://github.com/sockjs>

<sup>5</sup><https://docs.spring.io/spring-framework/docs/current/javadoc-api/org/springframework/scheduling/annotation/EnableAsync.html>

*Listing 19-6.* Spring WebSocket for SockJS Configuration

```

package com.apress.prospring6.nineteen;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.web.socket.config.annotation.EnableWebSocket;
import org.springframework.web.socket.config.annotation.WebSocketConfigurer;
import org.springframework.web.socket.config.annotation.WebSocketHandlerRegistry;

@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {
    @Override
    public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
        registry.addHandler(echoHandler(), "/echoHandler");
        registry.addHandler(echoHandler2(), "/sockjs/echoHandler").withSockJS();
    }

    @Bean
    public EchoHandler echoHandler() {
        return new EchoHandler();
    }

    @Bean
    public EchoHandler echoHandler2() {
        return new EchoHandler();
    }
}

```

Notice that another `EchoHandler` bean is declared and mapped to `/sockjs/echoHandler`.

Next we will need to create an HTML page as we did in the `WebSocket` API sample, but this time utilizing `SockJS` to take care of the transport negotiation. The most notable differences are that we use the `SockJS` library rather than `WebSocket` directly and utilize a typical `http://` scheme rather than `ws://` to connect to the endpoint. To use `SockJS`, we need to add the corresponding JavaScript library to the HTML page, and instead of using a `WebSocket` for communication, we use a `SockJS` object. The HTML code is almost identical to the code in `views/index2.html`, the only difference being the JavaScript code to handle the `SockJS` communication, and is shown in [Listing 19-7](#).

*Listing 19-7.* The JavaScript Code in `views/index2.html` View

```

// <script type="text/javascript" th:src="@{/js/sockjs-1.6.1.min.js}"></script>
// <script type="text/javascript" th:src="@{/js/jquery-3.6.4.min.js}"></script>
let ping;
let websocket;

jQuery(function ($) {
    function writePing(message) {
        $('#pingOutput').append(message + '\n');
    }
}

```

```

function writeMessage(message) {
    $('#messageOutput').append(message + '\n')
}

$('#connect')
    .click(function doConnect() {
        sockjs = new SockJS($("#target").val());

        sockjs.onopen = function (evt) {
            let badge= $("#badgeStatus");
            badge.text("Connected");
            badge.attr('class','badge bg-success');

            setInterval(function () {
                if (sockjs !== "undefined") {
                    sockjs.send("ping");
                }
            }, 3000);
        };

        sockjs.onclose = function (evt) {
            let badge= $("#badgeStatus");
            badge.text("Disconnected");
            badge.attr('class','badge bg-light');
        };

        sockjs.onmessage = function (evt) {
            if (evt.data === "ping") {
                writePing(evt.data);
            } else {
                writeMessage('ECHO: ' + evt.data);
            }
        };
    });

$('#disconnect')
    .click(function () {
        if (typeof sockjs !== 'undefined') {
            sockjs.close();
            sockjs = undefined;
        } else {
            alert("Not connected.");
        }
    });

$('#send')
    .click(function () {
        if (typeof sockjs !== 'undefined') {
            sockjs.send($('#message').val());
        } else {
            alert("Not connected.");
        }
    });

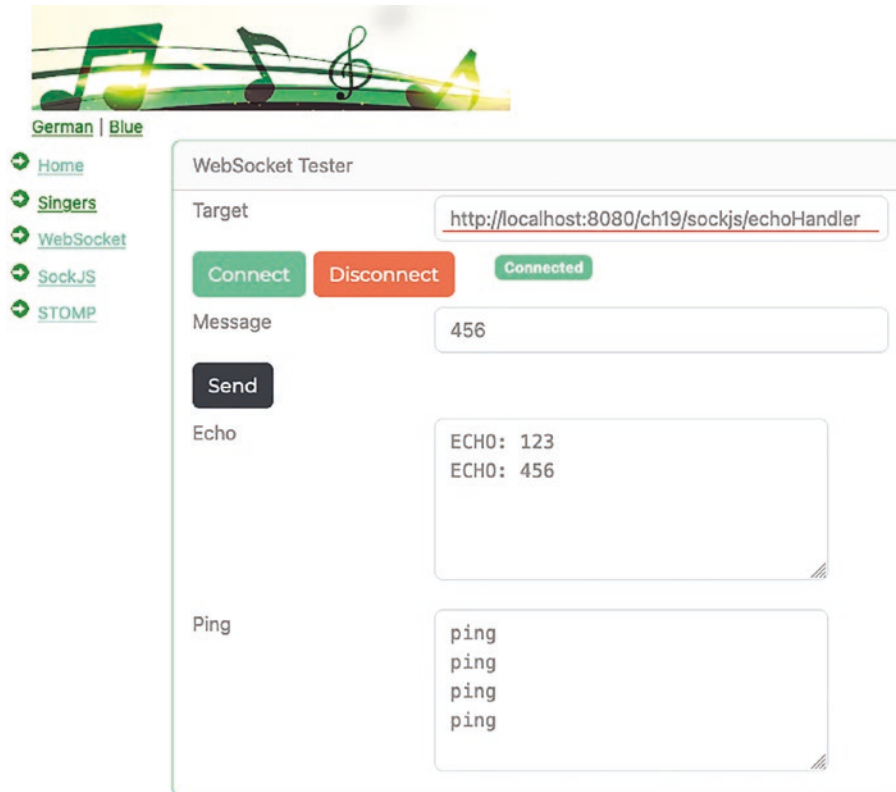
```

```

    });
}
});

```

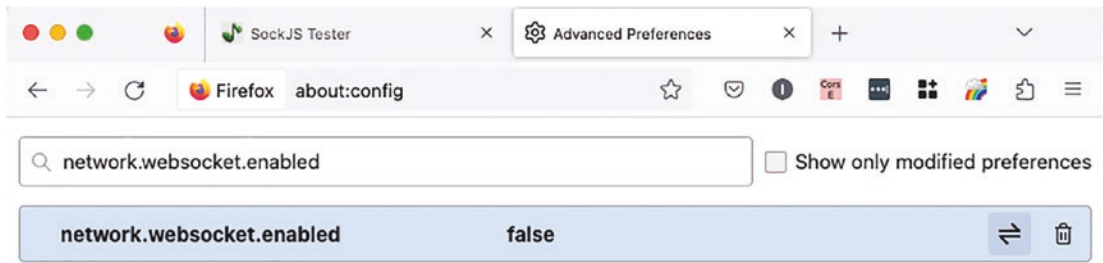
With the new SockJS code implemented, build and deploy the project to the container and navigate to the UI located at `http://localhost:8080/ch19/index2`, which has all the same features and functionality of the WebSocket example, as shown in Figure 19-4.



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**Figure 19-4.** SocketJS application page, after establishing a connection

To test the SockJS fallback functionality, try disabling WebSocket support in your browser. In Firefox, for example, navigate to the `about:config` page and then search for `network.websocket.enabled`. Toggle this setting to false, as shown in Figure 19-5, reload the sample UI, and reconnect.



**Figure 19-5.** Firefox `about:config` page

Utilizing a tool such as Live HTTP Headers will allow you to inspect the traffic going from browser to server for verification purposes. After verifying the behavior, toggle the Firefox setting `network.websocket.enabled` back to true, reload the page, and reconnect. Watching the traffic via Live HTTP Headers will now show you the WebSocket handshake. In the simple example, everything should work just as with the WebSocket API.

## Sending Messages with STOMP

When working with WebSocket, typically a subprotocol such as STOMP will be used as a common format between the client and server so that both ends know what to expect and are able to react accordingly. STOMP is supported out of the box by the Spring Framework, and we will use this protocol in the sample.

STOMP, a simple, frame-based messaging protocol modeled on HTTP, can be used over any reliable bidirectional streaming network protocol such as WebSocket. STOMP has a standard protocol format; JavaScript client-side support exists for sending and receiving messages in a browser and, optionally, for plugging into traditional message brokers that support STOMP, such as RabbitMQ and ActiveMQ. Out of the box, the Spring Framework supports a simple broker that handles subscription requests and message broadcasting to connected clients in memory. In the STOMP example presented in this section, we will utilize the simple broker and leave the full-featured broker setup as an exercise for you<sup>6</sup>.



For a full description of the STOMP protocol, see official the website<sup>7</sup>.

We will create a simple stock-ticker application that displays a few predefined stock symbols, their current price, and the timestamp upon price change. New stock symbols and starting prices can also be added through the UI. Any connecting clients (that is, other browsers in tabs or totally new clients on other networks) will see the same data as they are subscribed to the message broadcasts. Every second, each stock price will be updated to a new random amount and the timestamp will be updated.

To ensure that clients will be able to use the stock-ticker application even if their browser does not support WebSocket, we will utilize SockJS again to transparently handle any transport switching. Before diving into the code, it is worth noticing that STOMP messages support is provided by the `spring-messaging` library.

<sup>6</sup><https://docs.spring.io/spring-framework/docs/current/reference/html/web.html#websocket-stomp>

<sup>7</sup><https://stomp.github.io/stomp-specification-1.2.html>



Let's first create the Stock domain object, which holds information about the stock such as its code and price, as shown in Listing 19-8.

*Listing 19-8.* The Stock Domain Object

```
package com.apress.prospring6.nineteen.stomp;

import java.io.Serializable;
import java.time.LocalDateTime;
import java.time.format.DateTimeFormatter;

public class Stock implements Serializable {
    private static final long serialVersionUID = 1L;

    private static final String DATE_FORMAT = "MMM dd yyyy HH:mm:ss";

    private String code;
    private double price;

    private LocalDateTime date;

    public Stock() { }

    public Stock(String code, double price) {
        this.code = code;
        this.price = price;
    }

    // getters and setters omitted

    public String getDateFormatted() {
        var formatter = DateTimeFormatter.ofPattern(DATE_FORMAT);
        return formatter.format(date);
    }
}
```

To handle requests for stock updates, a controller is needed. Listing 19-9 shows the StockController class.

*Listing 19-9.* The StockController Class

```
package com.apress.prospring6.nineteen.stomp;

import org.springframework.messaging.handler.annotation.MessageMapping;
import org.springframework.messaging.simp.SimpMessagingTemplate;
import org.springframework.scheduling.TaskScheduler;
// other import statements omitted

@Controller
public class StockController {
    private final TaskScheduler taskScheduler;
    private final SimpMessagingTemplate simpMessagingTemplate;
```

```

private List<Stock> stocks = new ArrayList<>();
private Random random = new Random(System.currentTimeMillis());

public StockController(TaskScheduler taskScheduler, SimpMessagingTemplate
simpMessagingTemplate) {
    this.taskScheduler = taskScheduler;
    this.simpMessagingTemplate = simpMessagingTemplate;
}

@MessageMapping("/addStock")
public void addStock(Stock stock) throws Exception {
    stocks.add(stock);
    broadcastUpdatedPrices();
}

private void broadcastUpdatedPrices() {
    for(Stock stock : stocks) {
        stock.setPrice(stock.getPrice() + (getUpdatedStockPrice() * stock.getPrice()));
        stock.setDate(LocalDate.now());
    }
    simpMessagingTemplate.convertAndSend("/topic/price", stocks);
}

private double getUpdatedStockPrice() {
    double priceChange = random.nextDouble() * 5.0;
    if (random.nextInt(2) == 1) {
        priceChange = -priceChange;
    }
    return priceChange / 100.0;
}

@PostConstruct
private void broadcastTimePeriodically() {
    stocks.add(new Stock("VMW", 1.00d));
    stocks.add(new Stock("EMC", 1.00d));
    stocks.add(new Stock("GOOG", 1.00d));
    stocks.add(new Stock("IBM", 1.00d));

    taskScheduler.scheduleAtFixedRate(this::broadcastUpdatedPrices, Duration.
ofSeconds(2));
}
}

```

The code in Listing 19-9 can be explained as follows:

- The controller needs a task scheduler (**Chapter 12**) and a `SimpMessagingTemplate` instance to send Stock prices updates every 2 seconds. `SimpMessagingTemplate` is an implementation of `org.springframework.messaging.core.MessageSendingOperations<D>` that provides support for Simple Messaging Protocols like STOMP.
- The controller is initialized with a few predefined stock entries and their starting prices for demonstration purposes.

- The `/addStock` handler method allows the user to submit a `Stock` instance, which is added to the list of stocks, and then broadcasts the stocks to all subscribers.
- When broadcasting the stock information, the list of `Stock` instances is traversed, the price for each is updated, and then the information is sent to all subscribers of `/topic/price` by using the wired `SimpMessagingTemplate` instance. The `TaskExecutor` instance broadcasts the updated list of stock prices to all subscribed clients by invoking the `broadcastUpdatedPrices(..)` method every 2 seconds.

With the controller in place, we now need an HTML UI to display stock information to clients. To make things easier, the `views/index3.html` view is written in Thymeleaf and inherits theme elements from the `views/templates/layout.html` template used in **Chapters 14** and **17**.

The HTML JavaScript code in the `views/index3.html` view are shown in Listing 19-10.

**Listing 19-10.** The `index3.html` view template

```
<html>
<head th:fragment="~{templates/layout :: pageTitle}">
  <!-- some head elements missing -->
  <script type="text/javascript" th:src="@{/js/sockjs-1.6.1.min.js}"></script>
  <script type="text/javascript" th:src="@{/js/stomp-1.7.1.min.js}"></script>
  <script type="text/javascript" th:src="@{/js/jquery-3.6.4.min.js}"></script>
  <script type="text/javascript">
    let stomp;

    function displayStockPrice(frame) {
      let stocks = JSON.parse(frame.body);

      $('#stock').empty();

      for (let i in stocks) {
        let stock = stocks[i];

        $('#stock').append(
          $('<tr>').append(
            $('<td>').html(stock.code),
            $('<td>').html(stock.price.toFixed(2)),
            $('<td>').html(stock.dateFormatted)
          )
        );
      }
    }

    let connectCallback = function () {
      stomp.subscribe('/topic/price', displayStockPrice);
    };

    let errorCallback = function (error) {
      alert(error);
    };

    jQuery(function ($) {
      $("#addStockButton").attr("disabled", true);
```

```

$('#connect')
  .click(function doConnect() {
    stomp = Stomp.over(new SockJS($("#target").val()));
    stomp.connect("guest", "guest", connectCallback, errorCallback);
    let badge= $("#badgeStatus");
    badge.text("Connected");
    badge.attr('class','badge bg-success');
    $("#addStockButton").attr('disabled', false);
  });

$('#disconnect')
  .click(function () {
    if (typeof stomp != 'undefined') {
      stomp.disconnect();
      stomp = undefined;
      let badge= $("#badgeStatus");
      badge.text("Disconnected");
      badge.attr('class','badge bg-light');
      $("#addStockButton").attr('disabled', true);
    } else {
      alert("Not connected.");
    }
  });

$('.addStockButton').click(function (e) {
  e.preventDefault();
  const stockStr = JSON.stringify({
    'code': $('.addStock .code').val(),
    'price': Number($('.addStock .price').val())
  });
  stomp.send('/app/addStock', {}, stockStr);
  return false;
});
});
</script>
</head>

<section th:fragment=~{templates/layout :: pageContent}>
  <div class="card border-success mb-3" style="max-width: 40rem; left:30px;">
    <div class="card-header">STOMP Tester</div>
    <div class="row mb-1 m-sm-1">
      <label for="target" th:text="Endpoint" class="col-sm-4 form-label">FN:</label>
      <div class="col-sm-8">
        <input type="text" id="target" size="40" th:value="{endpoint}" class="form-control"/>
      </div>
    </div>
    <div class="row mb-1 m-sm-1">
      <div class="col-sm-2"> <input type="submit" id="connect" class="btn btn-success" value="Connect"/></div>
      <div class="col-sm-3"> <input type="submit" id="disconnect" class="btn btn-danger" value="Disconnect"/></div>
    </div>
  </div>

```

```

    <div class="col-sm-2"><span id="badgeStatus"></span></div>
</div>
<div class="row mb-1 m-sm-1">
  <div class="card border-warning mb-3" style="max-width: 35rem;">
    <div class="card-header">Stock Details</div>
    <div class="card-body">
      <table class="table table-hover table-bordered">
        <thead>
          <tr>
            <th scope="col">Code</th>
            <th scope="col">Price</th>
            <th scope="col">Time</th>
          </tr>
        </thead>
        <tbody id="stock"></tbody>
      </table>
    </div>
  </div>
</div>

<div class="row mb-1 m-sm-1 addStock">
  <label for="code" th:text="Code" class="col-sm-4 form-label">FN:</label>
  <div class="col-sm-8">
    <input type="text" id="code" value="" class="form-control code"/>
  </div>
</div>
<div class="row mb-1 m-sm-1 addStock">
  <label for="price2" th:text="Price" class="col-sm-4 form-label">FN:</label>
  <div class="col-sm-8">
    <input type="text" id="price2" value="" class="form-control price"/>
  </div>
</div>
<div class="row mb-1 m-sm-1 addStock">
  <div class="col-sm-2"><input type="submit" id="addStockButton" class="btn btn-
danger addStockButton" value="Add Stock"/></div>
</div>
</div>
</section>

```

Similar to previous examples in this chapter, we have some HTML mixed in with JavaScript to update the display. The reason we combine HTML with JavaScript, although it is not respecting commonsense programming rules, is to keep the Spring MVC configuration as simple as possible; it also helps to make the page and the functions of its components easy to understand. We utilize jQuery to update HTML data, SockJS to provide transport selection, and the STOMP JavaScript library `stomp.min.js` for communication with the server. Data sent via STOMP messages is encoded in JSON format, which we extract on events. Upon a STOMP connection, we subscribe to `/topic/price` to receive stock-price updates.

The Java configuration for STOMP communication is represented by the `StompConfig` class shown in Listing 19-11.

*Listing 19-11.* The StompConfig Configuration Class

```

package com.apress.prospring6.nineteen;

import org.springframework.context.annotation.Configuration;
import org.springframework.scheduling.annotation.EnableAsync;
import org.springframework.messaging.simp.config.MessageBrokerRegistry;
import org.springframework.web.socket.config.annotation.EnableWebSocketMessageBroker;
import org.springframework.web.socket.config.annotation.StompEndpointRegistry;
import org.springframework.web.socket.config.annotation.WebSocketMessageBrokerConfigurer;

@Configuration
@EnableAsync
@EnableWebSocketMessageBroker
public class StompConfig implements WebSocketMessageBrokerConfigurer {
    @Override
    public void registerStompEndpoints(StompEndpointRegistry registry) {
        registry.addEndpoint("/ws").withSockJS();
    }

    @Override
    public void configureMessageBroker(MessageBrokerRegistry config) {
        config.setApplicationDestinationPrefixes("/app");
        config.enableSimpleBroker("/topic");
    }

    @Bean
    TaskExecutor taskExecutor() {
        return new SimpleAsyncTaskExecutor();
    }
}

```

To enable Spring asynchronous calls and task execution, the configuration class must be annotated with `@EnableAsync`, and a bean of type `org.springframework.core.task.TaskExecutor` is needed to repeatedly broadcast stock information.

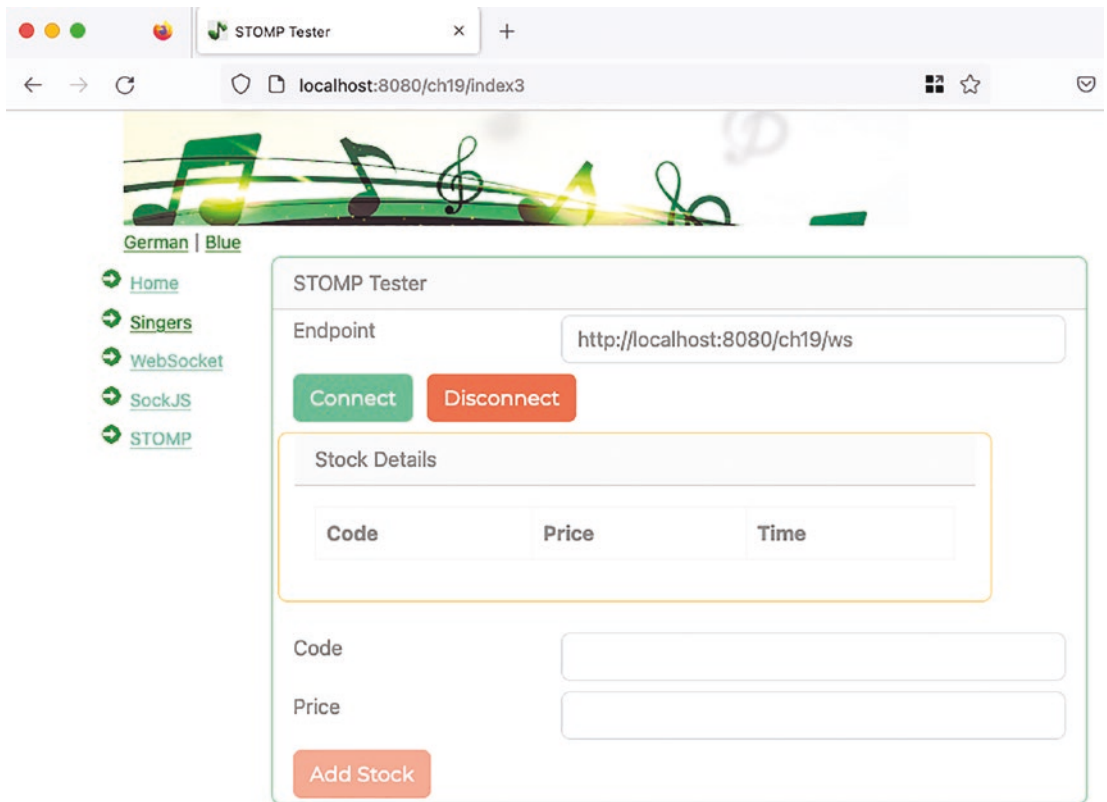
The `@EnableWebSocketMessageBroker` annotation enables broker-backed messaging over `WebSocket` using a higher-level messaging subprotocol. Notice the class implements the `WebSocketMessageBrokerConfigurer` interface which defines methods for configuring message handling with simple messaging protocols (e.g., STOMP) for `WebSocket` clients. The `registerStompEndpoints(..)` method is implemented to register the `/ws` STOMP endpoints mapping. The `http://localhost:8080/ch19/ws` is used to initialize a `SocketJS` instance that provides the support for STOMP communication.

The `configureMessageBroker` is implemented to configure message broker options. The `applicationDestinationPrefixes` property helps filter destinations targeting application annotated methods; this configuration sets the `/app` filter. This filter needs to prefix the URL path of the stock handler method, which is why in Listing 19-10 you see the following:

```
stomp.send('/app/addStock', {}, stockStr)
```

The `enableSimpleBroker("/topic")` enables a simple message broker and configures one or more prefixes to filter destinations targeting the broker. In the `StockController` you see in the `broadcastUpdatedPrices()` method that stock data is published to the topic `/topic/price` as the destination, while in the `index3.html` the STOMP instance is subscribing to this topic so that stock data can be retrieved.

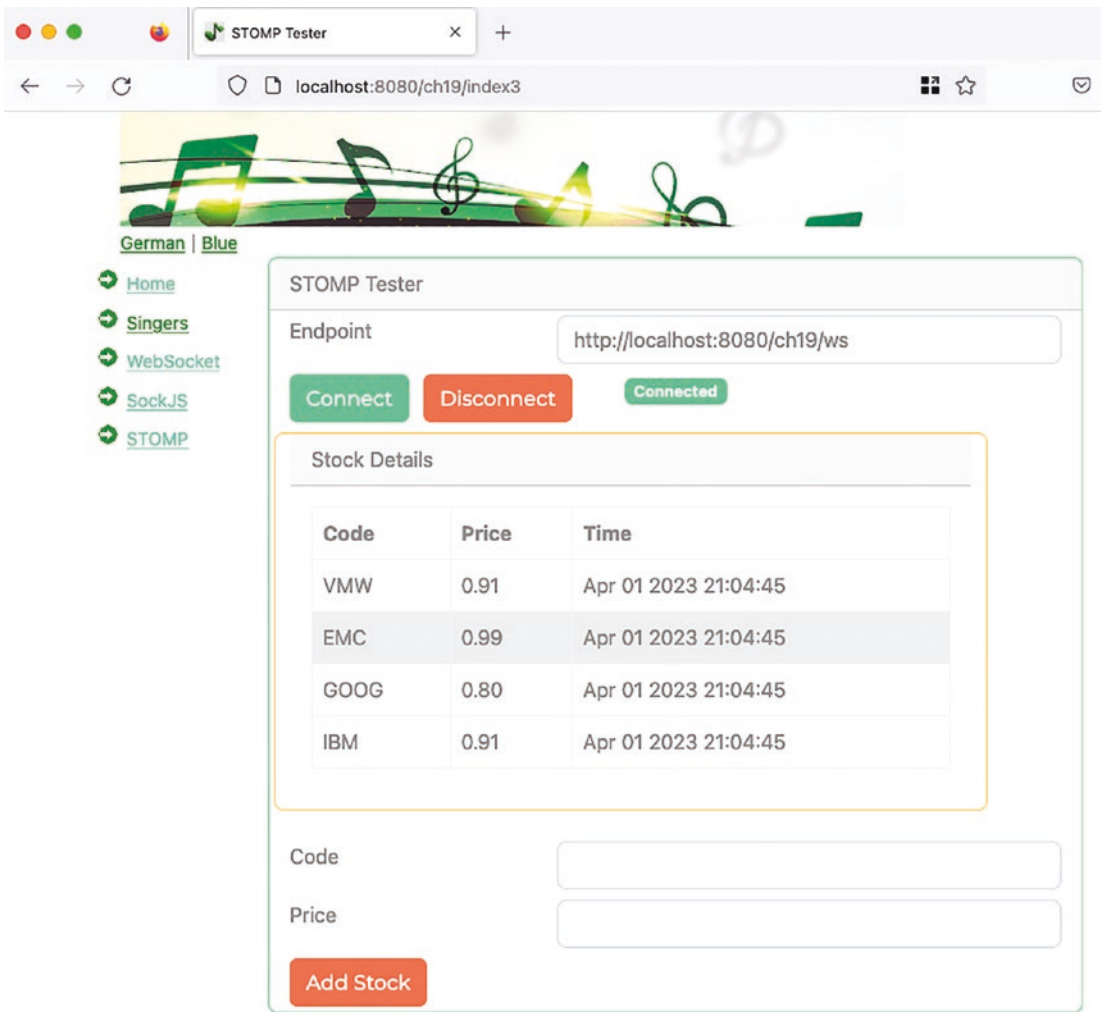
When first accessing the page, there is no STOMP connection, thus the stock table is empty and the Add Stock button is disabled, as shown in Figure 19-6.



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**Figure 19-6.** STOMP application page, before establishing a connection

After clicking the Connect button, the familiar green Connected badge appears, stock data is loaded in the table and refreshed every 2 seconds, and the Add Stock button is now enabled, which allows you to add your own stocks, as shown in Figure 19-7.



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**Figure 19-7.** STOMP application page, after establishing a connection

Under the covers, a connection is established, and in the browser console we can see the browser subscribing to the topic/price queue and then information being received every 2 seconds. A snippet of the browser console log is shown in Listing 19-12.

**Listing 19-12.** Browser Console Log Snippet for STOMP Communication

```
Opening Web Socket... stomp-1.7.1.min.js:8:1895
Web Socket Opened... stomp-1.7.1.min.js:8:1895
>>> CONNECT
login:guest
passcode:guest
```



```

accept-version:1.1,1.0
heart-beat:10000,10000

<<< CONNECTED          stomp-1.7.1.min.js:8:1895
version:1.1
heart-beat:0,0

connected to server undefined stomp-1.7.1.min.js:8:1895
>>> SUBSCRIBE          stomp-1.7.1.min.js:8:1895
id:sub-0
destination:/topic/price

# this bit repeats every 2 seconds
<<< MESSAGE            stomp-1.7.1.min.js:8:1895
destination:/topic/price
content-type:application/json
subscription:sub-0
message-id:v41nbtcg-1338
content-length:593

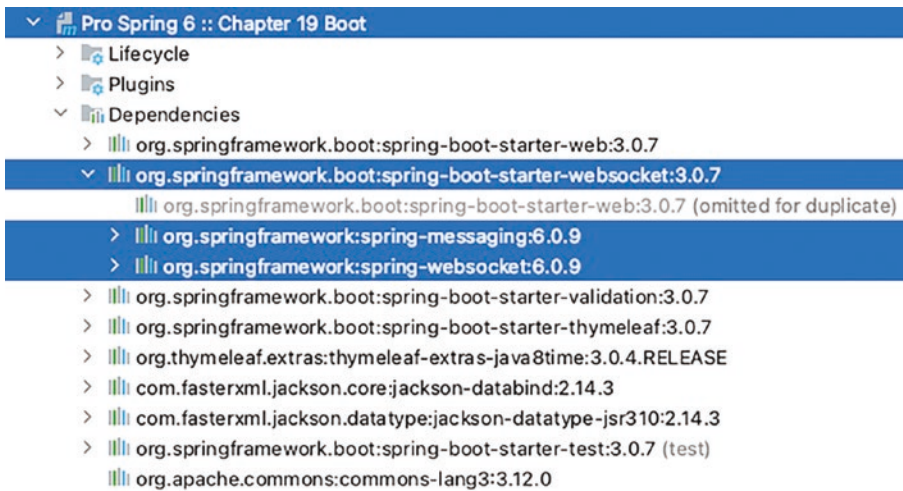
[{"code":"VMW","price":0.8412643922671524,"date":[2023,4,1,22,34,0,818886000],"dateFormatted":
"Apr 01 2023 22:34:00"},{"code":"EMC","price":0.3389473652730331,"date":[2023,4,1,22,34,0
,818888000],"dateFormatted":"Apr 01 2023 22:34:00"},{"code":"GOOG","price":0.86116531147
55639,"date":[2023,4,1,22,34,0,818889000],"dateFormatted":"Apr 01 2023 22:34:00"},{"code":"
IBM","price":0.6431663274824831,"date":[2023,4,1,22,34,0,818889000],"dateFormatted":"Apr 01
2023 22:34:00"},{"code":"TSL001","price":1.1764953118520888E-4,"date":[2023,4,1,22,34,0,8188
90000],"dateFormatted":"Apr 01 2023 22:34:00"}]
...

>>> DISCONNECT        stomp-1.7.1.min.js:8:1895

```

## Spring Boot Equivalent Application

Converting the preceding application to a Spring Boot application is fairly easy because there is a `spring-boot-starter-websocket` library. The dependencies for the `chapter19-boot` project are shown in [Figure 19-8](#).



**Figure 19-8.** Project *chapter19-boot* dependencies

Because the user can choose to either use communication directly over WebSocket or use high-level protocols such as STOMP, configuration classes for the two situations, together with the `@EnableWebSocket` or `@EnableWebSocketMessageBroker` annotations are required. So, aside from a simplification in build configurations and the lack of a server to run the application, Spring Boot does not reduce developers' work too much. For this reason, this chapter will not cover how to write a Spring Boot application for communication using WebSocket, since all the details have already been covered in **Chapter 14**, the web chapter, and in this chapter, for everything related to WebSocket. However, the *chapter19-boot* project is part of the source code for the book, so feel free to check it out.

## Summary

In this chapter, we covered the general concepts of WebSocket. We discussed the Spring Framework's support for the low-level WebSocket API and then moved on to using SockJS as a fallback option to select the appropriate transport, depending on the client browser. Finally, we introduced STOMP as a WebSocket subprotocol for passing messages between the client and server. For all examples, Java configuration classes were shown and explained.

In the next chapter, we will discuss how to build a Spring Reactive application and how WebSocket can be used for reactive communication.

## CHAPTER 20



# Reactive Spring

In previous chapters, typical Java web applications were built and run on an instance of Apache Tomcat server that was external for Spring classic configuration, or embedded in the application for Spring Boot Web applications. Whatever the case, the Spring `DispatcherServlet` was responsible for directing incoming HTTP requests to all the handlers declared in the application. However, there are a few things to consider. Can an application like the ones we developed thus far be used in a real production environment? How many HTTP requests can `DispatcherServlet` handle at the same time? Can that number be increased? `DispatcherServlet` does not truly have a say in the number of requests it can handle. The servlet container defines that, in our case, the Apache Tomcat server.

Apache Tomcat is a popular choice for building and maintaining dynamic websites and applications based on the Java software platform. The Java Servlet API enables a web server to handle dynamic Java-based web content using the HTTP protocol. This is known as **the request-response model**: the client makes a request; the server prepares a response and sends it back to the client. It is unidirectional and controlled by the client, and the server does not care if the client can handle the response. For example, when you enter a Facebook chat window in your browser, if the server would send all conversations you've had with that friend, the page would not only take a long time to load, but it might crash the browser.

Over the years, there were many improvements made to the software and application development style, that allowed a more efficient client-server interaction, but the one that is the focus of this chapter is **reactive communication**.



If you want a more detailed explanation on how client-server communication evolved from the initial

request-response to the reactive model, check out the *Pro Spring MVC with WebFlux* book<sup>1</sup>, published by Apress in 2021; start with chapter 9.

Efficient reactive communication can only occur between a reactive client and a reactive server, ergo between reactive applications. Compared to a classic request-response style, where the client and server exchange data in disconnected blobs of information, reactive communication implies continuous data flow between client and server.

---

<sup>1</sup><https://link.springer.com/book/10.1007/978-1-4842-5666-4>

Reactive applications are the solution when it comes to handling large amounts of data. Reactive applications are applications designed with resilience, responsiveness, and scalability as a priority. The Reactive Manifesto<sup>2</sup> describes the characteristics of reactive applications. The Reactive Streams API specification<sup>3</sup> provides a minimum set of interfaces that application components should implement so that applications can be considered reactive. Thus, the Reactive Streams API is an interoperability specification that ensures that reactive components integrate flawlessly and keep the operations non-blocking and asynchronous.

There are four key terms that describe reactive applications.

- **Responsive:** fast and consistent response times are expected.
- **Resilient:** failures are expected, and applications are designed to handle them and self-heal.
- **Elastic:** the application should be able to deal with high loads by scaling up its capabilities automatically and scaling down when no longer needed.
- **Message-driven:** reactive communication should be asynchronous, and it is implied that components are loosely coupled and communicate using messages. Additionally, backpressure is applied to prevent producers of messages from overwhelming consumers.

Reactive applications are supposed to be more flexible, loosely coupled, non-blocking, and scalable, but at the same time easier to develop, more malleable to change and more tolerant of failure. Building reactive applications requires following the principles of the reactive programming paradigm.

After reading thus far, you might think that reactive applications are pinnacle of software design evolution, and that every application in the world should be redesigned to be a reactive one. That is not always true, reactive applications don't always run faster than classic ones, and they come with their own sets of problems. As you will see in this chapter, reactive programming is quite different from imperative programming and requires a little bit of a mind shift. The main benefits of reactive applications are that they are non-blocking, and they are able to scale an application with a small, fixed number of threads and lesser memory requirements while at the same time making the best use of the available processing power.

In this chapter, you will learn about reactive programming and how you can build fully reactive applications using Spring WebFlux.

## Introduction to Reactive Programming in Spring

Reactive programming is a declarative programming paradigm that is based on the idea of asynchronous event processing and data streams. Reactive Streams is an initiative to provide a standard for asynchronous stream processing with non-blocking back pressure. They are extremely useful for solving problems that require complex coordination across thread boundaries.

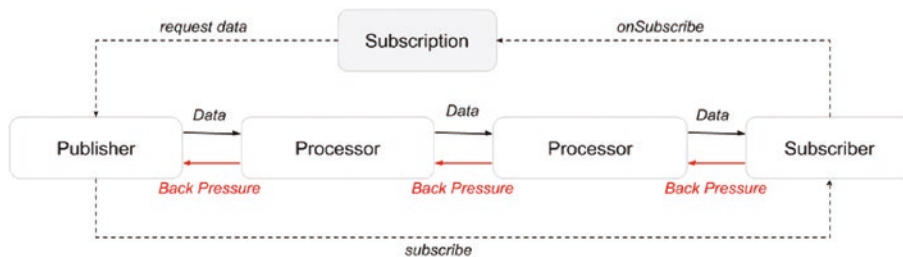
---

<sup>2</sup><https://www.reactivemanifesto.org/>

<sup>3</sup><https://www.reactive-streams.org/>

Java introduced the Streams API in version 8 and Lambda expressions, which was the first step toward reactive programming because reactive programming can also be defined as *functional programming with reactive streams*. Reactive streams were not available in the JDK until version 9. Unable to wait for JDK 9, which was released with a six-month delay, the Pivotal<sup>4</sup> open source team, the same one that created Spring, built the Spring WebFlux<sup>5</sup> using Project Reactor<sup>6</sup>, its own reactive library.

Reactive Streams provide a common API for reactive programming in Java. It is composed of four simple interfaces that provide a standard for asynchronous stream processing with non-blocking back pressure. If you want to write a component that can integrate with other reactive components, you need to implement one of these. On an abstract level, the components and the relationships between them, as described in the Reactive Streams specification, looks like what is shown in Figure 20-1.



**Figure 20-1.** Reactive Streams specification abstract representation

If you think it looks a lot like the publisher/subscriber model with the bonus of back-pressure, you are not wrong, that's pretty much what it is. Data *flows* between components, each component processes it and passes it forward, and each component regulates the speed via back pressure. The most appropriate model in the real world is a factory conveyor belt. Let's go through the components in Figure 20-1.

- A **publisher** is a potentially infinite producer of data. In Java, a producer of data must implement `org.reactivestreams.Publisher<T>`. A publisher prepares and transfers the data to subscribers as individual messages. The publisher emits values on demand from the subscriber.
- A **subscriber** registers with the publisher to consume data. In Java, a data consumer must implement `org.reactivestreams.Subscriber<T>`. A subscriber receives messages from the publisher and processes them. It is a terminal operation in the Streams API.
- Upon subscribing, a **subscription** object is created to represent the one-to-one relationship between the publisher and the subscriber. This object requests data from the publisher and cancels the demand for data. In Java, a subscription class must implement `org.reactivestreams.Subscription` and an object of this type can only be used once by a subscriber.

<sup>4</sup><https://tanzu.vmware.com/open-source>

<sup>5</sup><https://docs.spring.io/spring-framework/docs/current/reference/html/web-reactive.html>

<sup>6</sup><https://projectreactor.io>

- A **processor** is a special component that has the same properties as a publisher and subscriber. In Java, a processor type must implement `org.reactivestreams.Processor<T,R>`. Processors can be chained to form a stream processing pipeline. A processor consumes data from the publisher/processor in front of it in the chain and emits data for the processor/subscriber after it in the chain to consume. The subscriber/processor applies back pressure to slow down the producer/processor when emitting data if it cannot consume it fast enough.

You can check out the code for these interfaces in your IDE or on [GitHub](#)<sup>7</sup>.



Most reactive implementations for the JVM were developed in parallel, and so today we have: [RxJava](#)<sup>8</sup>, [Akka Streams](#)<sup>9</sup>, [Ratpack](#)<sup>10</sup>, [Vert.x](#)<sup>11</sup> and [Project Reactor](#).

---

Code written with Reactive Streams looks similar to code written with non-Reactive Streams, but what happens under the hood is different. Reactive streams are **asynchronous**, but you do not have to write the logic for dealing with that. You only need to declare what must happen when some value is emitted on a stream. The code you are writing is invoked when the stream emits an item asynchronously, independent of the main program flow. If there is more than one processor involved, each is executed on its own thread. Since your code runs asynchronously, you must be careful with the functions you are providing as arguments to your processor(also referred to as *transformer*) methods. You must make sure they are **pure functions**. Pure functions should only interact with the program through their arguments and return values, they return the same result for the same argument values, and they should never modify an object that requires synchronization, as this will probably cause unpredictable delay of the entire flow.

Project Reactor implements the Reactive Streams API providing a non-blocking stable foundation with efficient demand management for reactive applications. It declares two main publisher implementations:

- `reactor.core.publisher.Mono<T>` is a reactive stream publisher representing zero or one element.
- `reactor.core.publisher.Flux<T>` is a reactive stream publisher representing an asynchronous sequence of zero to infinity elements.

`Mono<T>` and `Flux<T>` are similar to `java.util.concurrent.Future<V>`. They represent the result of an asynchronous computation. The difference between them is that `Future<V>`, blocks the current thread until the computation completes when you try to get the result by invoking the `get()` method. `Mono<T>` and `Flux<T>` both provide a family of `block*()` methods used to retrieve the value of an asynchronous computation that does not block the current thread.

To make it obvious how reactive programming looks different syntactically from imperative programming, let's consider the following scenario: given a list of singers, we want to find all with an age greater than 50, and we want to sum their ages. If the code is written in imperative style, it might look like the snippet in [Listing 20-1](#).

---

<sup>7</sup><https://github.com/reactive-streams/reactive-streams-jvm/tree/master/api/src/main/java/org/reactivestreams>

<sup>8</sup><https://github.com/ReactiveX/RxJava>

<sup>9</sup><https://doc.akka.io/docs/akka/current/stream/index.html>

<sup>10</sup><https://ratpack.io>

<sup>11</sup><https://vertx.io>

**Listing 20-1.** Imperative style code to process a list of singers

```
package com.apress.prospring6.twenty.boot;
//import statements omitted

public class SimpleProgrammingTest {
    List<Singer> singers = List.of(
        Singer.builder().firstName("John").lastName("Mayer").birthDate(LocalDate.
            of(1977, 10, 16)).build(),
        Singer.builder().firstName("B.B.").lastName("King").birthDate(LocalDate.of(1929,
            9, 16)).build(),
        Singer.builder().firstName("Peggy").lastName("Lee").birthDate(LocalDate.of(1920,
            5, 26)).build(),
        Singer.builder().firstName("Ella").lastName("Fitzgerald").birthDate(LocalDate.
            of(1917, 4, 25)).build()
    );

    Function<Singer, Pair<Singer, Integer>> computeAge = singer -> Pair.of(singer,Period.
        between(singer.getBirthDate(), LocalDate.now()).getYears());
    Predicate<Pair<Singer, Integer>> checkAge = pair -> pair.getRight() > 50;

    @Test
    void imperativePlay(){
        int agesum = 0;
        for (var s : singers) {
            var p = computeAge.apply(s);
            if (checkAge.test(p)) {
                agesum += p.getRight();
            }
        }
        assertEquals(300, agesum);
    }
}
```

Not pretty, right? Well, this is the type of code all Java developers used to write in Java before the Stream API was introduced in Java 8. A set of instructions were listed one after the other for the JVM to execute. Additionally, using a `Function<T,R>` and a `Predicate<T>` is a little bit of a cheat, considering those types did not exist before Java 8 either. The decision to use them was made for simplicity and reusability reasons.

Using the Stream API, in combination with `Function<T,R>` and a `Predicate<T>` instances, the same code can be written more declarative and more functional, as shown in Listing 20-2.

**Listing 20-2.** Declarative(functional) style code using Java 8 Stream API to process a list of singers

```
package com.apress.prospring6.twenty.boot;
//import statements omitted

import static org.junit.jupiter.api.Assertions.assertEquals;

public class SimpleProgrammingTest {
    // list, function and predicate same as Listing 20-1
    @Test
    void streamsPlay() {
```

```

    var agesum = singers.stream() // Stream<Singer>
        .map(computeAge) // Stream<Pair<Singer, Integer>>
        .filter(checkAge)// Stream<Pair<Singer, Integer>>
        .map(Pair::getRight) // Stream<Integer>
        .reduce(Integer:: sum) // Optional<Integer>
        .orElseThrow(() -> new RuntimeException("Something went terribly wrong!"));

    assertEquals(300, agesum);
}
}

```

Declarative programming is more of a process of constantly defining what things are, as pointed out by the comments in Listing 20-2 showing the types of objects the resulting stream emits. Declarative programming focuses on **what** the program should achieve, while imperative programming focuses on **how** the program should achieve the result.

Transforming the code in Listing 20-2 into reactive code does not require much effort: we just replace `Stream<T>` with `Flux<T>`, and we make sure to declare a subscriber that does something with the result of the last processor in the chain: the `reduce(..)` function. The code is depicted in Listing 20-3.

**Listing 20-3.** Functional style code using Reactive Streams to process a list of singers

```
package com.apress.prospring6.twenty.boot;
```

```
import reactor.core.publisher.BaseSubscriber;
```

```
import reactor.core.publisher.Flux;
```

```
//other import statements omitted
```

```
public class SimpleProgrammingTest {
```

```
    // list, function and predicate same as Listing 20-1
```

```
    @Test
```

```
    void reactivePlay() {
```

```
        Flux.fromIterable(singers) // Flux<Singer>
```

```
            .map(computeAge) // Flux <Pair<Singer, Integer>>
```

```
            .filter(checkAge) // Flux <Pair<Singer, Integer>>
```

```
            .map(Pair::getRight) // Flux <Integer>
```

```
            .reduce(0, Integer::sum) // Mono<Integer>
```

```
            .subscribe(new BaseSubscriber<>() {
```

```
                @Override
```

```
                protected void hookOnNext(Integer agesum) {
```

```
                    assertEquals(300, agesum); // depending when you are running this
```

```
                    test it might fail, now in April 2023 it passes ;)
```

```
                }
```

```
            });
```

```
        }
```

```
    }
```

The `BaseSubscriber<T>` abstract class is a simple base class for a `Subscriber<T>` implementation that lets the user perform a `request(long)` and `cancel()` on it directly. The `hookOnNext(..)` method is useful to attach behavior to the emitted value; in our case, this is the perfect place to check our assumption.

Now that you've been introduced to reactive programming with Project Reactor, let's switch gears and see how we can write reactive applications using Spring WebFlux.



## Introducing Spring WebFlux

Spring Web MVC is designed around the `DispatcherServlet`, which is the gateway that maps HTTP requests to handlers and is set up with theme configurations, internationalization, file upload and view resolution. Spring MVC was built for the Servlet API and Servlet containers. This means that it mostly uses blocking I/O and one thread per HTTP request. Supporting asynchronous processing of requests is possible but requires a larger thread pool, which in turn requires more resources and is difficult to scale.

Spring WebFlux is a reactive stack web framework that was added in Spring 5, and it is Spring's response to the rising issue of blocking I/O architecture. It can run on Servlet 3.1+ containers, but it can adapt to other native server APIs. The Spring team's preferred server of choice is Netty<sup>12</sup>, which is well established in the async, non-blocking space. Spring WebFlux is built with functional reactive programming in mind and allows for code to be written in declarative style. Spring MVC and WebFlux have a few elements in common and can even be used together. There is no reason for a handler method to not be able to return `Flux<T>` or `Mono<T>`, as it will be shown soon in this chapter.



One thing to keep in mind: when writing a reactive application, every component of the application must be reactive, otherwise the application will not truly be reactive. The non-reactive component might become a bottleneck and break down the entire flow. For example, a three-tier application with the typical tiers: presentation, service, database will only be reactive if all three are reactive. Therefore, a reactive Spring WebFlux application must have reactive views, reactive controllers, reactive services, reactive repositories and a reactive database (any SQL database that comes with a reactive driver, or a reactive NoSQL database like MongoDB, RethingDB etc). In addition, the client making calls to the application must be reactive too.

---

Before converting the singers application to a reactive one, let's review how Spring WebFlux works under the bonnet.

Reactive applications can be deployed on Servlet 3.1+ containers, such as Tomcat, Jetty or Undertow. The trick here is to not use the `DispatcherServlet` bean. The `DispatcherServlet` bean is the central dispatcher for HTTP request handlers/controllers, and no matter how powerful it is, it is still a blocking component. This is where the new and improved Spring web components come to the rescue by introducing the `org.springframework.http.server.reactive.HttpHandler`<sup>13</sup>. This interface represents the lowest level contract for reactive HTTP request handling, and Spring provides server adapters based on it for each supported server. Its code is shown in Listing 20-4.

---

<sup>12</sup> <https://netty.io>

<sup>13</sup> <https://github.com/spring-projects/spring-framework/blob/main/spring-web/src/main/java/org/springframework/http/server/reactive/HttpHandler.java>

**Listing 20-4.** Spring’s `Handler` interface

```
package org.springframework.http.server.reactive;

import reactor.core.publisher.Mono;
// other comments omitted
public interface Handler {

    /**
     * Handle the given request and write to the response.
     * @param request current request
     * @param response current response
     * @return indicates completion of request handling
     */
    Mono<Void> handle(ServerHttpRequest request, ServerHttpResponse response);
}

```

Table 20-1 lists the servers supported by Spring WebFlux and the name of the adapter classes that represent the core of the non-blocking I/O to Reactive Streams bridge for each server.

**Table 20-1.** HTTP servers supported by Spring WebFlux

Server Name	Spring Adapter	Servlet API used
Netty <sup>14</sup>	ReactorHandlerAdapter	Netty API using the Reactor Netty library
Undertow <sup>15</sup>	UndertowHandlerAdapter	spring-web Undertow to Reactive Streams bridge
Tomcat <sup>16</sup>	TomcatHandlerAdapter	spring-web: Servlet 3.1 non-blocking I/O to Reactive Streams bridge
Jetty <sup>17</sup>	JettyHandlerAdapter	spring-web: Servlet 3.1 non-blocking I/O to Reactive Streams bridge

On top of `Handler`, Spring provides the `org.springframework.web.server.WebHandler`<sup>18</sup> interface, which is a slightly higher level contract describing all general purpose server APIs with filter chain style processing and exception handling. This interface is shown in Listing 20-5, and it is pretty similar to `Handler`.

**Listing 20-5.** `WebHandler` interface

```
package org.springframework.web.server;

import reactor.core.publisher.Mono;

import org.springframework.web.server.adapter.HttpWebHandlerAdapter;

```

<sup>14</sup> <https://netty.io>

<sup>15</sup> <https://undertow.io>

<sup>16</sup> <https://tomcat.apache.org>

<sup>17</sup> <https://www.eclipse.org/jetty>

```

import org.springframework.web.server.adapter.WebHttpHandlerBuilder;

public interface WebHandler {
    /**
     * Handle the web server exchange.
     * @param exchange the current server exchange
     * @return {@code Mono<Void>} to indicate when request handling is complete
     */
    Mono<Void> handle(ServerWebExchange exchange);
}

```

Instead of using `ServletRequest` and `ServletResponse` objects in its `handle(..)` method, `WebHandler` uses an object of type `ServerWebExchange`, a specialized interface representing a contract for an HTTP request-response interaction that also exposes additional server-side processing-related properties and features such as request attributes. Therefore, what does this mean for a Spring WebFlux configuration compared to a Spring Web MVC application?

A Spring Web MVC application has an `org.springframework.web.servlet.DispatcherServlet` bean as the front controller intercepting all requests and matching them to handler methods. A Spring WebFlux application has an `org.springframework.web.reactive.DispatcherHandler` bean as a dispatcher for HTTP request handlers/controllers. `DispatcherHandler` is an implementation of `WebHandler` and `ApplicationContextAware` interfaces that gives it access to all the beans in the application configuration. It is the central `WebHandler` implementation and provides an algorithm for request processing performed by configurable components. It delegates to special beans for processing requests and rendering appropriate responses, and their implementations are, as expected, non-blocking. Similar to the Spring MVC ecosystem, there is a `HandlerMapping` bean to map a request to a handler, a `HandlerAdapter` bean to invoke a handler, and an `org.springframework.web.server.WebExceptionHandler` bean to handle exceptions, and a `HandlerResultHandler` bean to get the result from the handler and finalize the response all declared into the `org.springframework.web.reactive` package.

In the Spring typical way, for most cases, the configuration of the `DispatcherHandler` does not require code that describes it directly. To configure a Spring WebFlux application that will be run in a Servlet 3.1+ container, you need to do the following:

- declare a Spring WebFlux configuration class and annotate it with `@Configuration` and `@EnableWebFlux`. The `@EnableWebFlux` annotation is part of the `org.springframework.web.reactive.config` package, and it enables the use of annotated controllers and functional endpoints
- extend the `org.springframework.web.server.adapter.AbstractReactiveWebInitializer` class and implement the `getConfigClasses()` method and inject your Spring WebFlux configuration class in it.

In a Spring Boot application, you do not need to do any of this. Just declare your controllers, your handler classes and functional endpoints and that is it. Because in this chapter the end game is to build a fully reactive application, from the database to the presentation layer, the classic Spring configuration for a reactive application will not be shown. (Especially since there is a book that covers that in more detail, that is still quite relevant: *Pro Spring MVC with WebFlux* book, published by Apress in 2021)

---

<sup>18</sup> <https://github.com/spring-projects/spring-framework/blob/main/spring-web/src/main/java/org/springframework/web/server/WebHandler.java>

## Spring Boot Configuration for a Reactive application

Let's start with the configuration. To build a reactive three-tier application, we need all layers to be built with reactive components. This means the following:

- The data access layer must be reactive: this means that the database driver must be reactive and the persistence layer, if used, needs to be reactive too. The classic database JDBC drivers are not reactive, so in a reactive application, they represent a blocking I/O component that affects the behavior of the whole application. Therefore, an SQL reactive driver was needed, so R2DBC<sup>19</sup> was developed. The **Reactive Relational Database Connectivity (R2DBC)** project brings reactive programming APIs to relational databases, and a driver for MariaDB is available. For persistence, there is a Hibernate Reactive library<sup>20</sup>, but currently its capabilities are limited, so we will not use it in this chapter.
- The service layer must be reactive: this is not that complicated; we just need to make sure the service classes only return `Flux<T>` and `Mono<T>` instances.
- The web layer must be reactive: this means controllers and handlers are reactive too, and thus only return `Flux<T>` and `Mono<T>` instances.
- The presentation layer must be reactive: this means that the view templates must be dynamic, so they can render the data as it arrives from the server. A combination of Thymeleaf<sup>21</sup> and jQuery<sup>22</sup> can handle reactive communication with a server well enough, but if you need a more advanced UI, React<sup>23</sup> and Angular<sup>24</sup> are a more appropriate choice.

Figure 20-2 shows the project dependencies.

---

<sup>19</sup><https://r2dbc.io>

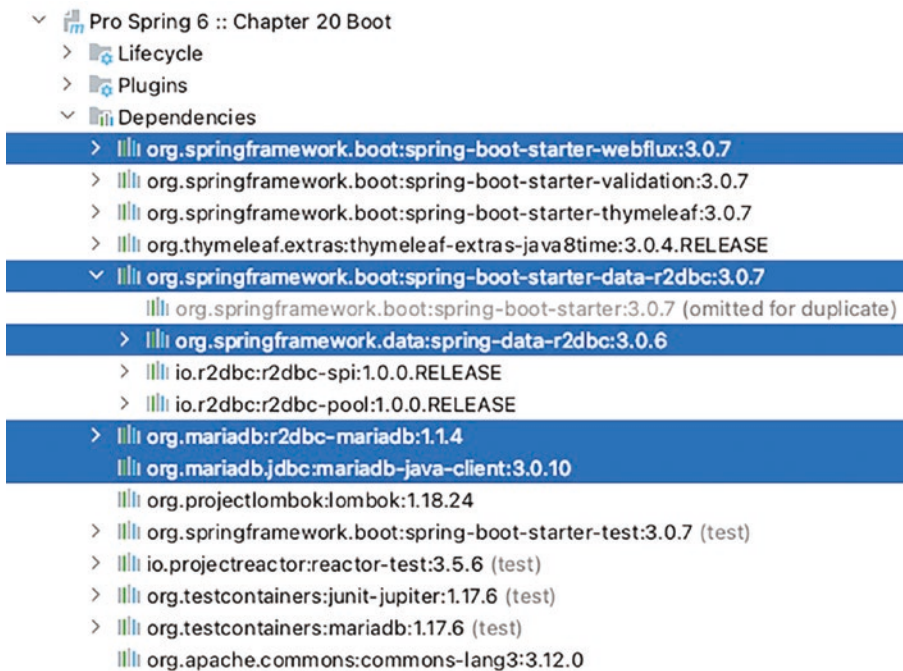
<sup>20</sup><https://hibernate.org/reactive>

<sup>21</sup><https://www.thymeleaf.org>

<sup>22</sup><https://jquery.com>

<sup>23</sup><https://react.dev>

<sup>24</sup><https://angular.io>



**Figure 20-2.** Project `chapter20-boot` dependencies

The main dependency of `spring-boot-starter-data-r2dbc` is `spring-data-r2dbc`<sup>25</sup>, which is part of the Spring Data family, and it makes it easy to implement reactive repositories. Spring Data R2DBC is quite simple: while it does not offer caching, lazy loading, write-behind, or many other features of ORM frameworks, it does offer object mapping, which is just enough to remove some boilerplate code, because converting database objects to Java objects can be a hassle.

The main dependency of `spring-boot-starter-webflux` is `spring-webflux`, which includes all Spring components needed to develop a reactive web application. The reactive-stack web framework, Spring WebFlux, was added to the Spring Framework in version 5, and it is non-blocking, supports Reactive Streams back pressure and runs on such servers as Netty, Undertow, and Servlet containers. The Spring Boot WebFlux default configuration includes the Reactor Netty<sup>26</sup> server, which offers non-blocking and backpressure-ready TCP/HTTP/UDP/QUIC<sup>27</sup> clients and servers based on the Netty<sup>28</sup> framework.

<sup>25</sup> <https://spring.io/projects/spring-data-r2dbc>

<sup>26</sup> <https://github.com/reactor/reactor-netty>

<sup>27</sup> <https://www.chromium.org/quic>

<sup>28</sup> <https://netty.io>

## Reactive Repository and Database

The database of choice for the project linked to this chapter is MariaDB. There is a stable R2DBC driver for MariaDB, so this replaces the blocking JDBC driver. The reactive driver provides non-blocking communication with the database, as expected, and authentication too. Since using the driver is done under the bonnet by Spring Data, the only thing that lets a developer looking at the code know that a reactive driver is used is the configuration. The database connection URL no longer uses the `jdbc:` prefix but the `r2dbc:` prefix.

Listing 20-6 shows the Spring Boot datasource configuration properties in the `application.yaml` configuration file when a reactive driver is used.

**Listing 20-6.** Spring Boot Data Source Configuration with a Reactive Driver

```
spring:
  url: r2dbc:mariadb://localhost:3306/musicdb
  username: prospring6
  password: prospring6
```

Spring Data R2DBC provides a few useful classes, such as `R2dbcEntityTemplate` in the `org.springframework.data.r2dbc.core` package, which is the equivalent of `JdbcTemplate` for a reactive environment. It simplifies the use of Reactive R2DBC by using reactive entity classes to model data and avoiding common errors. To perform database operations, it delegates to a `DatabaseClient` (same package) bean, which can also be used to run statements for mapped entities using the Criteria API. In this project, Spring Data reactive repositories are used, thus none of these are referenced directly. Just know that they exist, and they can be used if needed.

Spring Data reactive repositories are not that different from non-reactive repositories. They are just interfaces that provide a contract for the basic queries for an entity type: create, read, update, and delete. They can be expanded by adding (reactive version) `@Query` annotated methods and custom implementations if needed, as shown in **Chapter 10**.

Listing 20-7 shows the `SingerRepo` interface that extends the `ReactiveCrudRepository<T, ID>` Spring Data repository interface and adds its own reactive methods.

**Listing 20-7.** `SingerRepo` reactive repository interface

```
package com.apress.prospring6.twenty.boot.repo;

import com.apress.prospring6.twenty.boot.model.Singer;
import org.springframework.data.r2dbc.repository.Query;
import org.springframework.data.repository.query.Param;
import org.springframework.data.repository.reactive.ReactiveCrudRepository;
import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;

import java.time.LocalDate;

public interface SingerRepo extends ReactiveCrudRepository<Singer, Long>{

    @Query("select * from singer where first_name=:fn and last_name=:ln")
    Mono<Singer> findByFirstNameAndLastName(@Param("fn") String firstName, @Param("ln")
    String lastName);
```

```

@Query("select * from singer where first_name=:fn")
Flux<Singer> findByFirstName(@Param("fn") String firstName);

@Query("select * from singer where last_name=:ln")
Flux<Singer> findByLastName(@Param("ln") String lastName);

@Query("select * from singer where birth_date=:ln")
Flux<Singer> findByBirthDate(@Param("bd") LocalDate birthDate);
}

```

Note that some Spring Data components, such as the `@Param` annotation, can be used in a reactive context, and only those interacting directly with the data flow need to be reactive. For example, Spring has two `@Query` annotations: a reactive one in the `org.springframework.data.r2dbc.repository` package and a non-reactive one in the `org.springframework.data.jpa.repository` package.

The `ReactiveCrudRepository<T, ID>` interface used in this example is the reactive equivalent of `CrudRepository<T, ID>` introduced in **Chapter 10**, and its main characteristic is that it returns reactive types, so instead of data, we obtain a data reactive stream as a result that will emit the data when requested by a subscriber.

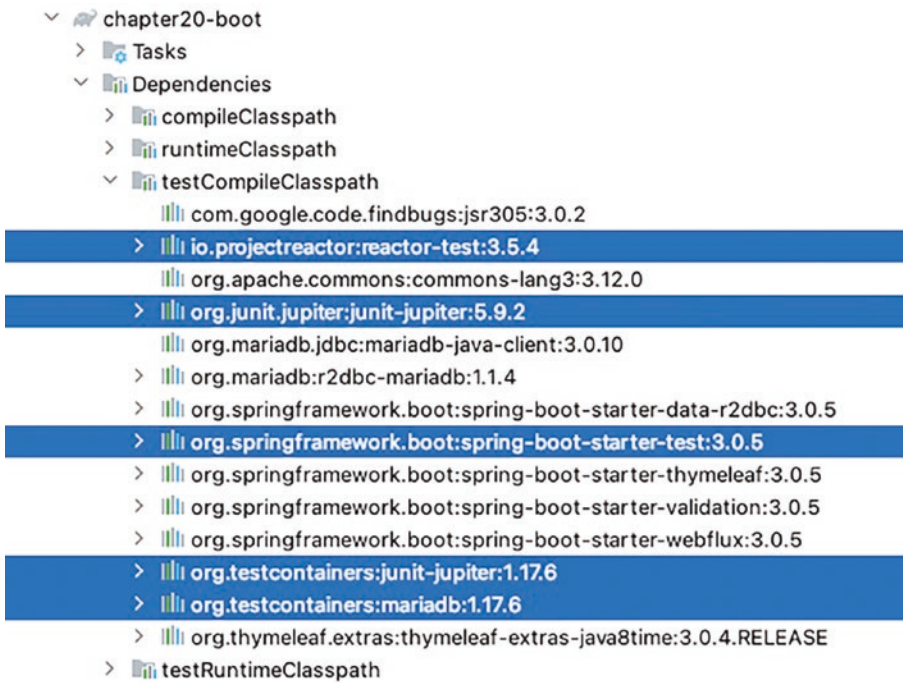


Notice that to keep our repository fully reactive, all additional methods must return `Flux<T>` or `Mono<T>`.

---

When Spring Data reactive repositories are enriched with additional methods, via configuration as shown in Listing 20-7, or by composing custom implementations via custom interfaces as shown in **Chapter 10** you might want to test your repository. This can be easily done by using a combination of `TestContainers`, `JUnit 5`, `Spring Boot` and `Project Reactor` test libraries. (*Yeah, I know, it does not seem so easy when you need 4 libraries to get it done, but it is true!*)

Figure 20-3 shows the test dependencies of the `chapter20-boot` project.



**Figure 20-3.** Project *chapter20-boot* test dependencies

To write the test, you need to do the following:

- You need to set up a MariaDB container and extract its properties and convert the connection URL to a reactive connection URL and inject it into the Spring Boot Test context. This step is necessary so that Spring Boot can configure the R2DBC driver.
- Annotate the test class with `@DataR2dbcTest` to let Spring Boot know that the test context needed is one specific for a Reactive context, and we are only interested in Spring Data components.
- To check assertions on the data being manipulated reactively, we need to use Project Reactor's `StepVerifier`, which provides a declarative way of creating a verifiable script for an async Publisher sequence by expressing expectations about the events that will happen upon subscription.
- To control the order of the test methods being executed (we are keeping the test really simple here), mark methods with their execution step number and check assumptions. We use JUnit 5 annotations and static methods that at this point in the book you should be familiar with.

Listing 20-8 shows the test class that checks the most important methods of the `SingerRepo` interface and uses all the libraries and components mentioned.



**Listing 20-8.** Reactive RepositoryTest test class

```

package com.apress.prospring6.twenty.boot;

// Spring Boot imports
import org.springframework.boot.test.autoconfigure.data.r2dbc.DataR2dbcTest;
import org.springframework.data.r2dbc.core.R2dbcEntityTemplate;

// TestContainers imports
import org.testcontainers.containers.MariaDBContainer;
import org.testcontainers.junit.jupiter.Container;
import org.testcontainers.junit.jupiter.Testcontainers;
import org.testcontainers.utility.MountableFile;

// Project Reactor Test imports
import reactor.test.StepVerifier;

// JUnit 5 import
import static org.junit.jupiter.api.Assertions.assertNotNull;

// other import statements omitted

@Testcontainers
@DataR2dbcTest
@TestMethodOrder(MethodOrderer.OrderAnnotation.class)
public class RepositoryTest {

    @Container
    static MariaDBContainer<?> mariaDB = new MariaDBContainer<>("mariadb:latest")
        .withCopyFileToContainer(MountableFile
            .forClasspathResource("testcontainers/create-schema.sql"), "/docker-
            entrypoint-initdb.d/init.sql");

    @Autowired
    SingerRepo singerRepo;

    @Autowired
    R2dbcEntityTemplate template;

    @Order(1)
    @BeforeEach
    public void testRepoExists() {
        assertNotNull(singerRepo);
    }

    @Order(2)
    @Test
    public void testCount() {
        singerRepo.count()
            .log()
            .as(StepVerifier::create)
            .expectNextMatches(p -> p == 4)

```

```

        .verifyComplete();
    }

    @Order(3)
    @Test
    public void testFindByFistName() {
        singerRepo.findByFistName("John")
            .log()
            .as(StepVerifier:: create)
            .expectNextCount(2)
            .verifyComplete();
    }

    @Order(4)
    @Test
    public void testFindByFistNameAndLastName() {
        singerRepo.findByFistNameAndLastName("John", "Mayer")
            .log()
            .as(StepVerifier:: create)
            .expectNext(Singer.builder()
                .id(1L)
                .firstName("John")
                .lastName("Mayer")
                .birthDate(LocalDate.of(1977, 10, 16))
                .build())
            .verifyComplete();
    }

    @Order(5)
    @Test
    public void testCreateSinger() {
        singerRepo.save(Singer.builder()
            .firstName("Test")
            .lastName("Test")
            .birthDate(LocalDate.now())
            .build())
            .log()
            .as(StepVerifier:: create)
            .assertNext(s -> assertNotNull(s.getId()))
            .verifyComplete();
    }

    @Order(6)
    @Test
    public void testDeleteSinger() {
        singerRepo.deleteById(4L)
            .log()
            .as(StepVerifier:: create)
            .expectNextCount(0)
            .verifyComplete();
    }
}

```

```

@dynamicPropertySource
static void registerDynamicProperties(DynamicPropertyRegistry registry) {
    registry.add("spring.r2dbc.url", () -> "r2dbc: mariadb://"
        + mariaDB.getHost() + ":" + mariaDB.getFirstMappedPort()
        + "/" + mariaDB.getDatabaseName());
    registry.add("spring.r2dbc.username", () -> mariaDB.getUsername());
    registry.add("spring.r2dbc.password", () -> mariaDB.getPassword());
}
}

```

Note that the test methods are written following the functional programming paradigm as well. Each statement declares the operation to be performed on the data when it is emitted. The most important method here is the `verifyComplete()` method that triggers the verification, expecting a completion signal as a terminal event.

The `log()` method was added to observe all reactive streams signals and trace them using a configured logging library, in this case, Logback. When this test class is run, the tests should pass, and the console log might look verbose, but it makes it quite obvious that the `SingerRepo` and the `R2DBC` driver are indeed working together and communicating reactively.

**Listing 20-9.** Reactive repository test class console log

```

INFO 14470 --- [    Test worker] c.a.p.twenty.boot.RepositoryTest      : Starting
RepositoryTest using Java 19.0.2 with PID 14470
INFO 14470 --- [    Test worker] .s.d.r.c.RepositoryConfigurationDelegate : Bootstrapping
Spring Data R2DBC repositories in DEFAULT mode.
INFO 14470 --- [    Test worker] .s.d.r.c.RepositoryConfigurationDelegate : Finished Spring
Data repository scanning in 130 ms. Found 1 R2DBC repository interfaces.
INFO 14470 --- [    Test worker] c.a.p.twenty.boot.RepositoryTest      : Started
RepositoryTest in 1.385 seconds (process running for 10.938)
INFO 14470 --- [    Test worker] reactor.Mono.UsingWhen.1            :
onSubscribe(MonoUsingWhen.MonoUsingWhenSubscriber)
INFO 14470 --- [    Test worker] reactor.Mono.UsingWhen.1            :
request(unbounded)
INFO 14470 --- [actor-tcp-nio-2] reactor.Mono.UsingWhen.1            : onNext(4)
INFO 14470 --- [actor-tcp-nio-2] reactor.Mono.UsingWhen.1            : onComplete()

INFO 14470 --- [    Test worker] reactor.Flux.UsingWhen.2            :
onSubscribe(FluxUsingWhen.UsingWhenSubscriber)
INFO 14470 --- [    Test worker] reactor.Flux.UsingWhen.2            :
request(unbounded)
INFO 14470 --- [actor-tcp-nio-2] reactor.Flux.UsingWhen.2            :
onNext(Singer(id=3, firstName=John, lastName=Butler, birthDate=1975-04-01))
INFO 14470 --- [actor-tcp-nio-2] reactor.Flux.UsingWhen.2            :
onNext(Singer(id=1, firstName=John, lastName=Mayer, birthDate=1977-10-16))
INFO 14470 --- [actor-tcp-nio-2] reactor.Flux.UsingWhen.2            : onComplete()

INFO 14470 --- [    Test worker] reactor.Mono.Next.3                 :
onSubscribe(MonoNext.NextSubscriber)
INFO 14470 --- [    Test worker] reactor.Mono.Next.3                 :
request(unbounded)
INFO 14470 --- [actor-tcp-nio-2] reactor.Mono.Next.3                 :
onNext(Singer(id=1, firstName=John, lastName=Mayer, birthDate=1977-10-16))

```

```

INFO 14470 --- [actor-tcp-nio-2] reactor.Mono.Next.3           : onComplete()
INFO 14470 --- [   Test worker] reactor.Mono.UsingWhen.4     :
onSubscribe(MonoUsingWhen.MonoUsingWhenSubscriber)
INFO 14470 --- [   Test worker] reactor.Mono.UsingWhen.4     :
request(unbounded)
INFO 14470 --- [actor-tcp-nio-2] reactor.Mono.UsingWhen.4     :
onNext(Singer(id=5, firstName=Test, lastName=Test, birthDate=2023-04-15))
INFO 14470 --- [actor-tcp-nio-2] reactor.Mono.UsingWhen.4     : onComplete()

INFO 14470 --- [   Test worker] reactor.Mono.UsingWhen.5     :
onSubscribe(MonoUsingWhen.MonoUsingWhenSubscriber)
INFO 14470 --- [   Test worker] reactor.Mono.UsingWhen.5     :
request(unbounded)
INFO 14470 --- [actor-tcp-nio-2] reactor.Mono.UsingWhen.5     : onComplete()

```

This console log shows the thread identifiers and makes it quite obvious that repository operations are executed on a different thread, as expected for a reactive component.

All that is well and good, but can we check erroneous behavior? How can we check that a `Singer` without a `lastName` cannot be saved in the table. Technically, this should never happen because we expect Spring validation to prevent such an object from being passed as an argument to the repository bean, but just as an example, let's do it! `StepVerifier` provides a few methods for that: the `verifyError*()` method family allows a developer to check if an operation completed with an error and what the characteristics of that error are. For example, in Listing 20-10, we check that trying to save a `Singer` object without a `lastName` fails and a `TransientDataAccessResourceException` is thrown.

**Listing 20-10.** Reactive repository test method modeling a negative test scenario

```

import org.springframework.dao.TransientDataAccessResourceException;
...

@Test // negative test, lastName is null which is not allowed
public void testFailedCreateSinger() {
    singerRepo.save(Singer.builder()
        .firstName("Prince")
        .birthDate(LocalDate.now())
        .build())
        .log()
        .as(StepVerifier::create)
        .verifyError(TransientDataAccessResourceException.class);
}

```

Now that we have a reactive data repository, we can use it to build a reactive service.

## Reactive Services

A reactive service class is nothing special in this scenario; it just forwards returned objects from a reactive repository and replaces lower-level data processing exceptions with service-level scoped exceptions. In a real implementation, a service method might apply more transformations to the data returned by the repository methods by adding its own processor functions, as shown in the beginning of this chapter.

Listing 20-11 shows the `SingerService` interface, the template for our reactive service.

**Listing 20-11.** `SingerService` interface describing the template for a reactive service class

```
package com.apress.prospring6.twenty.boot.service;
// import statements omitted

public interface SingerService {

    Flux<Singer> findAll();

    Mono<Singer> findById(Long id);

    Mono<Singer> findByFirstNameAndLastName(String firstName, String lastName);
    Flux<Singer> findByFirstName(String firstName);

    Mono<Singer> save(Singer singer);

    Mono<Singer> update(Long id, Singer actorMono);

    Mono<Void> delete(Long id);

}
```

Note that all the methods return reactive types, which is what makes it truly a reactive service capable of interacting with a reactive repository and a reactive controller without hindering the data flow.

The `SingerServiceImpl` class, implementing this interface, is shown in Listing 20-12.

**Listing 20-12.** `SingerServiceImpl` reactive service class and bean definition

```
package com.apress.prospring6.twenty.boot.service;
// import statements omitted

import java.time.LocalDate;
import java.time.format.DateTimeFormatter;

@RequiredArgsConstructor
@Transactional
@Service
public class SingerServiceImpl implements SingerService {
    private final SingerRepo singerRepo;

    @Override
    public Flux<Singer> findAll() {
        return singerRepo.findAll();
    }

    @Override
    public Mono<Singer> findByFirstNameAndLastName(String firstName, String lastName) {
        return singerRepo.findByFirstNameAndLastName(firstName, lastName);
    }
}
```

```

@Override
public Mono<Singer> findById(Long id) {
    return singerRepo.findById(id);
}

@Override
public Flux<Singer> findByFirstName(String firstName) {
    return singerRepo.findByFirstName(firstName);
}

@Override
public Mono<Singer> save(Singer singer) {
    return singerRepo.save(singer)
        .onErrorMap(error -> new SaveException("Could Not Save Singer " + singer,
            error));
}

@Override
public Mono<Singer> update(Long id, Singer updateData) {
    return singerRepo.findById(id)
        .flatMap( original -> {
            original.setFirstName(updateData.getFirstName());
            original.setLastName(updateData.getLastName());
            original.setBirthDate(updateData.getBirthDate());
            return singerRepo.save(original)
                .onErrorMap(error -> new SaveException("Could Not Update Singer " +
                    updateData, error));
        });
}

@Override
public Mono<Void> delete(Long id) {
    return singerRepo.deleteById(id);
}
}

```

The class is pretty simple, has little logic of its own, mostly surrounding the search function and the Singer object update.

The `SaveException` is just a simple class extending `RuntimeException` that wraps around the Spring Data exceptions to provide more information about the context in which the exception was produced.

The other thing to note here is that this service is transactional. Therefore, how do transactions work in a reactive application? They work pretty much the same as in a non-reactive application, but the functionality is based on different components.

Transactions in a reactive application have the same purpose as in an non-reactive application: to group multiple database operations in a single multistep operation that succeeds only if all the steps do; otherwise, any successful steps prior to the failed step get rolled back. In Spring applications, imperative and reactive transaction management is enabled by a `PlatformTransactionManager` bean that manages transactions for transactional resources, and resources are marked as transactional by annotating them with Spring's `@Transactional` annotation from package `org.springframework.transaction.annotation`. At a lower level although, things are a little bit different.

Transaction management needs to associate its transactional state with an execution. In imperative programming, this is typically a `java.lang.ThreadLocal` storage object, so the transactional state is bound

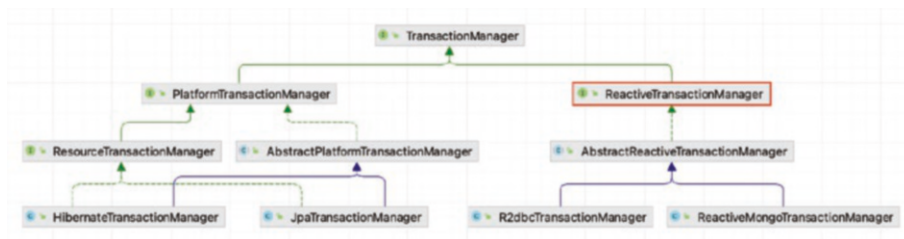
to a Thread object, in which the Spring container started to execute the code. In a reactive application, this does not apply, because reactive execution requires multiple threads. The solution was to introduce a reactive alternative to the ThreadLocal storage class and this is Reactor's reactor.util.context.Context interface. Contexts allow binding contextual data to a particular execution, and for reactive programming, this is a Subscription object. The Reactor's Context object lets Spring bind the transaction state, along with all resources and synchronizations, to a particular Subscription object. All reactive code that uses Project Reactor can now participate in reactive transactions.

Starting with Spring Framework 5.2 M2, Spring supports reactive transaction management through the ReactiveTransactionManager SPI. The org.springframework.transaction.ReactiveTransactionManager interface is a transaction management abstraction for reactive and non-blocking integrations that uses transactional resources. It is a foundation for reactive transactional methods that return Publisher<T> types and for programmatic transaction management that uses TransactionalOperator. Spring Data R2DBC provides the R2dbcTransactionManager class in the org.springframework.r2dbc.connection package that implements ReactiveTransactionManager.

In Figure 20-4 shows the imperative and reactive hierarchies of interfaces and classes of org.springframework.transaction.TransactionManager.



In Figure 20-4, ReactiveMongoTransactionManager is included as well because the pro-spring-6 project has spring-data-mongodb in the classpath. This class is the reactive transaction manager for MongoDB and manages transactions so that code executed within a managed transaction participates in multi-document transactions.



**Figure 20-4.** TransactionManger imperative and reactive hierarchy, side by side

The R2dbcTransactionManager wraps around a reactive connection to the database to perform its job, and this connection is provided by the R2DBC driver. In a Spring Boot application, the configuration is fairly simple, as shown in Listing 20-13.

**Listing 20-13.** Configuring an R2dbcTransactionManager

```
package com.apress.prospring6.twenty.boot;
```

```
import io.r2dbc.spi.ConnectionFactory;
import org.springframework.r2dbc.connection.R2dbcTransactionManager;
import org.springframework.transaction.ReactiveTransactionManager;
import org.springframework.transaction.annotation.EnableTransactionManagement;
// other import statements omitted
```

```

@EnableTransactionManagement
@SpringBootApplication
public class Chapter20Application {
    final static Logger LOGGER = LoggerFactory.getLogger(Chapter20Application.class);

    public static void main(String... args) {
        System.setProperty(AbstractEnvironment.ACTIVE_PROFILES_PROPERTY_NAME, "dev");
        SpringApplication.run(Chapter20Application.class, args);
    }

    @Bean
    ReactiveTransactionManager transactionManager(ConnectionFactory connectionFactory) {
        return new R2dbcTransactionManager(connectionFactory);
    }
}

```

Two things need to be clarified about the sample in Listing 2-13:

- The `@EnableTransactionManagement` annotation is needed to enable Spring's annotation-driven transaction management capability, meaning support for `@Transactional` annotations.
- The `ConnectionFactory` bean is not declared explicitly. Spring Boot creates this bean from the configuration in the `application.yaml` (or the equivalent `application.properties`) and injects it wherever needed, in this case in our reactive transaction management bean. (The Spring Boot configuration file was already depicted in Listing 20-6.)

Although slightly repetitive, we can also write some tests for `SingerServiceImpl`. All we have to do is to add this bean to the test context. Listing 20-14 shows a few test methods for `SingerServiceImpl`.

**Listing 20-14.** Testing the `SingerServiceImpl` reactive service class

```

package com.apress.prospring6.twenty.boot.service;
// import statements omitted

@DataR2dbcTest
@TestMethodOrder(MethodOrderer.OrderAnnotation.class)
@Import(SingerServiceImpl.class)
public class SingerServiceTest {

    @Autowired
    SingerService singerService;

    // some test methods and container setup omitted

    @Order(2)
    @Test
    void testFindAll() {
        singerService.findAll()
            .log()
            .as(StepVerifier::create)

```



```

        .expectNextCount(4)
        .verifyComplete();
    }

    @Order(3)
    @Test
    void testFindById() {
        singerService.findById(1L)
            .log()
            .as(StepVerifier::create)
            .expectNextMatches(s -> "John".equals(s.getFirstName()) && "Mayer".equals(s.
                getLastName()))
            .verifyComplete();
    }

    // some test methods omitted

    @Order(8)
    @Test // duplicate firstName and lastName
    public void testNoCreateSinger() {
        singerService.save(Singer.builder()
            .firstName("John")
            .lastName("Mayer")
            .birthDate(LocalDate.now())
            .build())
            .log()
            .as(StepVerifier::create)
            .verifyError(SaveException.class); // repo throws org.springframework.dao.
                DuplicateKeyException
    }

    @Order(9)
    @Test
    public void testUpdateSinger() {
        singerService.update(4L, Singer.builder()
            .firstName("Erik Patrick")
            .lastName("Clapton")
            .birthDate(LocalDate.now())
            .build())
            .log()
            .as(StepVerifier::create)
            .expectNext(Singer.builder()
                .id(4L)
                .firstName("Erik Patrick")
                .lastName("Clapton")
                .birthDate(LocalDate.now())
                .build())
            .verifyComplete();
    }

    @Order(10)
    @Test
    public void testUpdateSingerWithDuplicateData() {

```

```

    singerService.update(4L, Singer.builder()
        .firstName("John")
        .lastName("Mayer")
        .birthDate(LocalDate.now())
        .build())
    .log()
    .as(StepVerifier::create)
    .verifyError(SaveException.class); // repo throws org.springframework.dao.
    DuplicateKeyException
}

@Order(11)
@Test // negative test, lastName is null which is not allowed
public void testFailedCreateSinger() {
    singerService.update(4L, Singer.builder()
        .firstName("Test")
        .birthDate(LocalDate.now())
        .build())
    .log()
    .as(StepVerifier::create)
    .verifyError(SaveException.class); // repo throws org.springframework.dao.
    DataIntegrityViolationException
}

@Order(12)
@Test
public void testDeleteSinger() {
    singerService.delete(4L)
        .log()
        .as(StepVerifier::create)
        .expectNextCount(0)
        .verifyComplete();
}
}

```

The lines in bold show the tests that check service level exceptions being thrown instead of the Spring Data exceptions. The type of underlying exception is shown in the comments.

For all these situations, the choice was made to use `onErrorMap(..)` to transform the exception into something more useful. However, the Project reactor provides six methods to handle errors on its reactive types (`Mono<T>`, `Flux<T>`), which are listed and explained below:

- `onErrorReturn(..)`: declares a default value to be emitted in case an exception is thrown in the processor. This method does not hinder the data flow in any way; when processing a troublesome element, the default value is emitted, and the rest of the elements in the flow will be processed normally. There are three versions of this method:
  - one that takes as a parameter the value to be returned.
  - one that takes as parameters the value to be returned and the type of exception for which the default value should be returned.
  - one that takes as parameters the value to be returned and a predicate for the exception to match for the default value to be returned.

- `onErrorResume()`: declares a default function to use to choose a fallback `Publisher<T>` in case an exception is thrown in the processor. It also comes with the same three flavors. For troublesome elements, the chosen `Publisher<T>` is used to emit a value, and the rest of the elements in the flow will be processed normally.
- `onErrorContinue(..)`: declares a consumer to be used in case an exception is thrown in the processor. This method also comes in three flavors, the same as described for `onErrorReturn(..)`, but instead of returning a value the consumer is executed. It processes the troublesome elements using the declared consumer and leaves the downstream chain as it is for good elements.
- `doOnError(..)`: consumes error and stops execution for further elements in the stream. It also comes in the same three flavors, but after the consumer is executed, the error is propagated downstream.
- `onErrorMap(..)`: cast one error into another and stop execution for further elements in the stream.

Since the test context does not have a transaction manager, tests are not transactional. Having a few service tests passing is proof that the reactive service layer works as well, so we can now continue the implementation by adding reactive controllers.

## Reactive Controllers

It was mentioned previously that a reactive controller is nothing other than a controller that contains handler methods that return `Flux<T>` and `Mono<T>`. This makes sense for REST controllers because for a controller handler method returning a logical view name, reactivity makes no sense, since it does not add any benefits. This being said, take a look at Listing 20-15, which shows a REST controller for managing Singer instances.

*Listing 20-15.* The `ReactiveSingerController` class

```
package com.apress.prospring6.twenty.boot.controller;
```

```
import org.springframework.http.HttpStatus;
import org.springframework.http.ResponseEntity;
import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;
// other import statements omitted
```

```
@Slf4j
@RequiredArgsConstructor
@RestController
@RequestMapping(path = "/reactive/singer")
public class ReactiveSingerController {
    private final SingerService singerService;
```

```
    /* 1 */
    @GetMapping(path = {"", "/"})
    public Flux<Singer> list() {
        return singerService.findAll();
    }
```

```
    /* 3 */
```

```

@GetMapping(path =("/{id}")
public Mono<ResponseEntity<Singer>> findById(@PathVariable Long id) {
    return singerService.findById(id)
        .map(s -> ResponseEntity.ok().body(s))
        .defaultIfEmpty(ResponseEntity.notFound().build());
}

/* 4 */
@PostMapping
@ResponseStatus(HttpStatus.CREATED)
public Mono<Singer> create (@RequestBody Singer singer) {
    return singerService.save(singer);
}

/* 5 */
@PutMapping("/{id}")
public Mono<ResponseEntity<Singer>> updateById(@PathVariable Long id, @RequestBody
Singer singer){
    return singerService.update(id,singer)
        .map(s -> ResponseEntity.ok().body(s))
        .defaultIfEmpty(ResponseEntity.badRequest().build());
}

/* 2 */
@DeleteMapping("/{id}")
public Mono<ResponseEntity<Void>> deleteById(@PathVariable Long id){
    return singerService.delete(id)
        .then(Mono.fromCallable(() -> ResponseEntity.noContent().<Void>build()))
        .defaultIfEmpty(ResponseEntity.notFound().build());
}

/* 6 */
@GetMapping(params = {"name"})
public Flux<Singer> searchSingers(@RequestParam("name") String name) {
    if (StringUtils.isBlank(name)) {
        throw new IllegalArgumentException("Missing request parameter 'name'");
    }
    return singerService.findByFirstName(name);
}

/* 7 */
@GetMapping(params = {"fn", "ln"})
public Mono<Singer> searchSinger(@RequestParam("fn") String fn, @RequestParam("ln")
String ln) {
    if ((StringUtils.isBlank(fn) || StringUtils.isBlank(ln))) {
        throw new IllegalArgumentException("Missing request parameter, one of {'fn',
'ln'}");
    }
    return singerService.findByFirstNameAndLastName(fn, ln);
}
}

```

Except for the returned types, which are necessary because the reactive `SingerService` is used, there is nothing special about this controller. When you start the application and test the `reactive/singer` endpoints using a client such as `curl`, Postman or HTTPie or a browser (for the GET endpoints), you will notice that this controller does not behave in any way different from a non-reactive controller. This is because neither of these is a reactive client, but this academic example is too small and simple to actually notice anything.



You can try to generate random data (a lot of it) to fill the `singer` table and then try to access

the `/reactive/singer` endpoint to notice the data flow.

---

Therefore, there is not much that we can use this controller for right now. The reason this controller was introduced first is because the intention is to rewrite it using handler functions, one of the fancy things introduced by Spring WebFlux. You probably noticed the comment with a number attached to each method. Those are there to make it easy to look up the equivalent handler function.

## Handler Classes and Functional Endpoints

A handler class is just a logical way of grouping handler functions. A handler function must implement the `HandlerFunction`<sup>29</sup> functional interface and provide an implementation for its `handle(..)` method that takes an `org.springframework.web.reactive.function.server.ServerRequest` object as argument and returns a `Mono<org.springframework.web.reactive.function.server.ServerResponse>` object.

Listing 20-16 shows its code.

**Listing 20-16.** Spring's reactive `HandlerFunction` functional interface

```
package org.springframework.web.reactive.function.server;

import reactor.core.publisher.Mono;

@FunctionalInterface
public interface HandlerFunction<T extends ServerResponse> {

    Mono<T> handle(ServerRequest request);

}
```

An implementation of `HandlerFunction<T>` represents a function that handles a request, and it can be mapped to the request path via a `RouterFunction`.

---

<sup>29</sup> <https://github.com/spring-projects/spring-framework/blob/main/spring-webflux/src/main/java/org/springframework/web/reactive/function/server/HandlerFunction.java>



The version shown in Listing 20-16 is the reactive version, introduced as part of Spring WebFlux in version 5.0. The same goes for RouterFunction. In Spring MVC version 5.2 non-reactive versions were added in package `org.springframework.web.servlet.function` as a functional alternative to classic controllers. The syntax is more declarative, and the request mapping centralized in a single bean making the configuration easier to read.

Let's make use of this new declarative syntax and write some code that declares handler functions instead of handler methods for requests. Listing 20-17 shows the `SingerHandler` class that groups all the handler functions analogous to the ones in the `ReactiveSingerController` introduced in the previous section.

*Listing 20-17.* The `SingerHandler` class

```
package com.apress.prospring6.twenty.boot.handler;

import org.springframework.http.MediaType;
import org.springframework.web.reactive.function.server.HandlerFunction;
import org.springframework.web.reactive.function.server.ServerRequest;
import org.springframework.web.reactive.function.server.ServerResponse;
import java.net.URI;
import static org.springframework.web.reactive.function.server.ServerResponse.*;
// other import statements omitted

@Component
public class SingerHandler {
    private final SingerService singerService;

    public HandlerFunction<ServerResponse> list;
    public HandlerFunction<ServerResponse> deleteById;

    public SingerHandler(SingerService singerService) {
        this.singerService = singerService;

        /* 1 */
        list = serverRequest -> ok()
            .contentType(MediaType.APPLICATION_JSON).body(singerService.findAll(),
                Singer.class);

        /* 2 */
        deleteById = serverRequest -> noContent()
            .build(singerService.delete(Long.parseLong(serverRequest.
                pathVariable("id"))));
    }

    /* 3 */
    public Mono<ServerResponse> findById(ServerRequest serverRequest) {
        var id = Long.parseLong(serverRequest.pathVariable("id"));
        return singerService.findById(id)
    }
}
```

```

        .flatMap(singer -> ok()).contentType(MediaType.APPLICATION_JSON).
        bodyValue(singer)
        .switchIfEmpty(notFound().build());
    }

    /* 4 */
    public Mono<ServerResponse> create(ServerRequest serverRequest) {
        Mono<Singer> singerMono = serverRequest.bodyToMono(Singer.class);
        return singerMono
            .flatMap(singerService::save)
            .log()
            .flatMap(s -> created(URI.create("/singer/" + s.getId())))
            .contentType(MediaType.APPLICATION_JSON).bodyValue(s);
    }

    /* 5 */
    public Mono<ServerResponse> updateById(ServerRequest serverRequest) {
        var id = Long.parseLong(serverRequest.pathVariable("id"));
        return singerService.findById(id)
            .flatMap(fromDb -> serverRequest.bodyToMono(Singer.class)
                .flatMap(s -> ok()
                    .contentType(MediaType.APPLICATION_JSON)
                    .body(singerService.update(id, s), Singer.class)
                )
            ).switchIfEmpty(badRequest().bodyValue("Failure to update user!"));
    }

    /* 6 */
    public Mono<ServerResponse> searchSingers(ServerRequest serverRequest) {
        var name = serverRequest.queryParam("name").orElse(null);
        if (StringUtils.isBlank(name) ) {
            return badRequest().bodyValue("Missing request parameter 'name'");
        }
        return ok()
            .contentType(MediaType.APPLICATION_JSON).body(singerService.
                findByFirstName(name), Singer.class);
    }

    /* 7 */
    public Mono<ServerResponse> searchSinger(ServerRequest serverRequest) {
        var fn = serverRequest.queryParam("fn").orElse(null);
        var ln = serverRequest.queryParam("ln").orElse(null);

        if ((StringUtils.isBlank(fn) || StringUtils.isBlank(ln))) {
            return badRequest().bodyValue("Missing request parameter, one of {fn, ln}");
        }

        return singerService.findByFirstNameAndLastName(fn, ln)
            .flatMap(singer -> ok()).contentType(MediaType.APPLICATION_JSON).bodyValue(singer);
    }
}

```

A `SingerHandler` bean is declared and is part of the Spring WebFlux application configuration, and its methods are used as handler functions for requests managing `Singer` instances.

The numbers that mark the functions make it easy to identify the equivalent handler method in the `ReactiveSingerController` class, but also make it easy to use them as pointers when trying to explain the particularities of each function.

1. `list` is a simple handler function that returns all the `Singer` instances retrieved by invoking `singerService.findAll()`. It is declared as a field of type `HandlerFunction<ServerResponse>` and it is a member of the `SingerHandler` class. It cannot be declared and initialized in the same line because of its dependency on `singerService`. To initialize this field, the `singerService` field must be initialized first. Since it is initialized in the constructor, the initialization of the `list` field is also part of the constructor. The initial `ServerResponse.ok()` sets the HTTP response status to 200 (OK), and it returns a reference to the internal `BodyBuilder` that allows for other methods to be chained to describe the request. The chain must end with one of the `body*(..)` methods that returns a `Mono<ServerResponse>`.
2. `deleteById` is a simple handler function that deletes a `Singer` instance with the ID matching the path variable. The path variable is extracted by calling `serverRequest.pathVariable("id")`. The ID argument represents the name of the path variable. The `singerService.delete()` method returns `Mono<Void>`, so `Mono<ServerResponse>` actually emits a response with an empty body and 204 (no content) status code set by `ServerResponse.noContent()`.
3. `findById` is a handler function that returns a single `Singer` instance identified by the `id` path variable. The instance is retrieved by calling `singerService.findById(..)` that returns a `Mono<Singer>`. If this stream emits a value, this means a singer was found matching the path variable, and a response is created with the 200 (OK) status code and a body represented by the `Singer` instance as JSON. To access the `Singer` instance, emitted by the stream without blocking, the `flatMap(..)` function is used. If the stream does not emit a value, this means a singer with the expected ID was not found, so an empty response is created with the status 404 (Not Found) by calling `switchIfEmpty(ServerResponse.notFound().build())`.
4. `create` is a handler function for creating a new `Singer` instance. The `Singer` instance is extracted from the request body. The request body is read as a `Mono<Singer>` by calling `serverRequest.bodyToMono(String.class)`. The `flatMap(singerService::save)` stream emits a value when a successful save is executed, and the response is populated with a location header pointing to the URL where the created resource can be accessed and the 201 (Created) response status. If the stream does not emit a value, this means the save operation failed, and there is an option to configure the desired response status by adding a `switchIfEmpty(status(HttpStatus.INTERNAL_SERVER_ERROR).build())` function to this processing chain. However, we declared our `SingerService` to throw a `SavingException` when saving a `Singer` instance fails, and thus, this does not apply anymore because the error handler will take care of it.



5. `updateById` is a handler function for updating a `Singer` instance. It is mentioned here just to point out that the `switchIfEmpty(..)` function can build a response with a custom body as well, not just a response status and this method shows an example where the response body is set to the "Failure to update singer!" text. The body can be any type of object, including the exception object being emitted by the `singerService.update(..)` method.
6. `searchSingers` is a handler function that handles a request with a parameter named `name`. Its value is extracted by calling `serverRequest.queryParam("name")`.

Now that we have our handler functions, the next step is to map them to requests. This is done via a `RouterFunction` bean. This bean can be declared in any configuration class. `org.springframework.web.reactive.function.server.RouterFunction<T>`<sup>30</sup> is a simple functional interface describing a function that routes incoming requests to `HandlerFunction<T>` instances. Its code is shown in Listing 20-18.

**Listing 20-18.** Spring's reactive `RouterFunction` functional interface

```
package org.springframework.web.reactive.function.server;
// import statements omitted

@FunctionalInterface
public interface RouterFunction<T extends ServerResponse> {

    Mono<HandlerFunction<T>> route(ServerRequest request);

    // default methods omitted
}
```

The `route(..)` method returns the handler function matching the request provided as an argument. If a handler function is not found, it returns an empty `Mono<Void>`. The `RouterFunction<T>` has a similar purpose as the `@RequestMapping` annotation (and its specialized versions) in controller classes.

Composing a `RouterFunction<T>` for a Spring application is made easy by using the builder methods in the `org.springframework.web.reactive.function.server.RouterFunctions` class. This class provides static methods for building simple and nested routing functions and can even transform a `RouterFunction<T>` into a `HttpHandler` instance, which makes the application run in a Servlet 3.1+ container. Before discussing routing functions any further, let's first see the router function for handler functions declared in `SingerHandler`. The router function is shown in Listing 20-19.

**Listing 20-19.** The `RoutesConfig` class declaring the routing configuration bean for the handler functions in `SingerHandler`

```
package com.apress.prospring6.twenty.boot;

import org.springframework.web.reactive.function.server.RequestPredicates;
import org.springframework.web.reactive.function.server.RouterFunction;
import org.springframework.web.reactive.function.server.ServerResponse;
```

<sup>30</sup> <https://github.com/spring-projects/spring-framework/blob/main/spring-webflux/src/main/java/org/springframework/web/reactive/function/server/RouterFunction.java>

```

import static org.springframework.web.reactive.function.server.RequestPredicates.queryParam;
import static org.springframework.web.reactive.function.server.RouterFunctions.route;

@Slf4j
@Configuration
public class RoutesConfig {
    final static Logger LOGGER = LoggerFactory.getLogger(RoutesConfig.class);

    @Bean
    public RouterFunction<ServerResponse> singerRoutes(SingerHandler singerHandler) {
        return route()
            .GET("/handler/singer", queryParam("name", t -> true),
                singerHandler::searchSingers) /* 6 */
            .GET("/handler/singer", RequestPredicates.all()
                .and(queryParam("fn", t -> true))
                .and(queryParam("ln", t -> true)),
                singerHandler::searchSinger) /* 7 */
            // requests with parameters always come first
            .GET("/handler/singer", singerHandler.list) /* 1 */
            .POST("/handler/singer", singerHandler.create) /* 4 */
            .GET("/handler/singer/{id}", singerHandler.findById) /* 3 */
            .PUT("/handler/singer/{id}", singerHandler.updateById) /* 5 */
            .DELETE("/handler/singer/{id}", singerHandler.deleteById) /* 2 */
            .filter((request, next) -> {
                LOGGER.info("Before handler invocation: {}", request.path());
                return next.handle(request);
            })
            .build();
    }
}

```

The `singerRoutes` bean is a router function used to route incoming requests to the handler functions declared in the `SingerHandler` bean introduced previously.

In Listing 20-19, each handler function is marked with a number that matches the handler function in `SingerHandler`. The `route()` method returns a `RouterFunctionBuilder` instance that is further used to add router mappings via methods specific to HTTP methods, paths and request parameters.

The following list discusses the content of each line, and the bullet number matches the function number.

1. `GET("/handler/singer", singerHandler.list)` - `GET(..)` is a static method from the abstract utility class `org.springframework.web.reactive.function.server.RequestPredicates` used here to create a route that maps GET requests to the `/handler/singer` URL with the `singerHandler.list` function.
2. `DELETE("/handler/singer/{id}", singerHandler.deleteById)` - `DELETE(..)` is a static method from the utility class `RequestPredicates` that creates a route that maps DELETE requests to the `/handler/singer/{id}` URL, where `id` is the name of the path variable to the `singerHandler.deleteById` function.
3. `GET("/handler/singer/{id}", singerHandler.findById)` - maps GET requests to `/handler/singer/{id}` to `singerHandler.findById`

4. `POST("/handler/singer", singerHandler::create)` - `POST(..)` is a static method from the utility class `RequestPredicates` that creates a route that maps POST requests to the `/handler/singer` URL to the `singerHandler.create` function.
5. `PUT("/handler/singer/{id}", singerHandler::updateById)` - `PUT(..)` is a static method from the utility class `RequestPredicates` that creates a route that maps PUT requests to the `/handler/singer/{id}` URL to the `singerHandler.updateById` function.
6. `GET("/handler/singer", queryParams("name", t → true), singerHandler::searchSingers)` - maps GET methods to the `/handler/singer?name=${val}` URL to the `singerHandler.searchSingers` function. The parameters are declared via the `RequestPredicates.queryParam(..)` utility method, which basically returns a `RequestPredicate` that returns true if the parameter is part of the URL
7. This statement does the same thing as the method at point 6, but uses the `RequestPredicates.all()` builder method to check for the presence of two parameters.

The `filter(..)` statement declares a function that filters all requests. The statement in this example just prints a simple log, but it can be used to inspect any kind of cross-cutting concerns, such as logging, security, etc.

The `build()` method is called to construct the `RouterFunction<ServerResponse>` bean.

With this configuration in place, now we have a singer API available under `/handler/singer` URL. When you start the application and test the `/handler/singer` endpoints using a client like `curl`, Postman, or a browser (for the GET endpoints) you'll notice that all works well and the behavior is the same as the one implemented by the `ReactiveSingerController`.



Routes for requests that have parameters need to be specified first in the builder, or at least before the

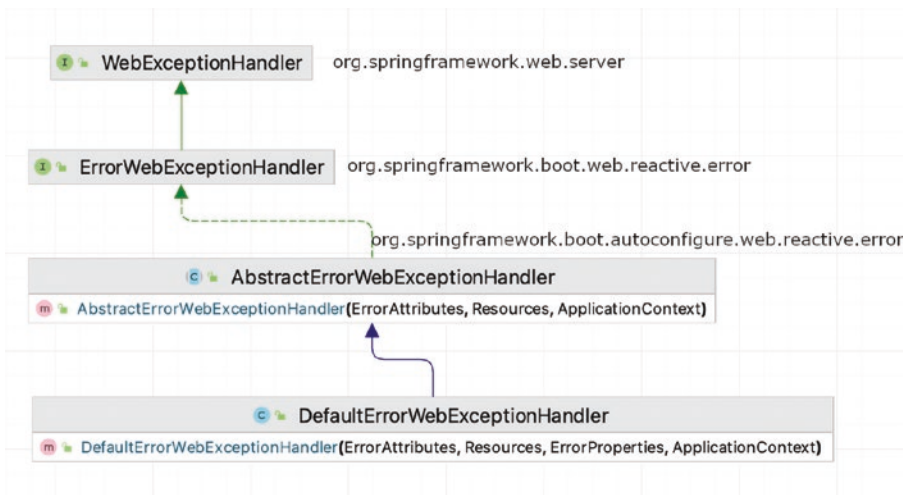
routes based on the same path, but with no parameters. The request is checked against the existing routes of the router function in the order they were declared. Thus, a request to URL `/handler/singers?name=John` matches the first mapping to the `/handler/singers` found in the list. This is because, the existence of the parameters is checked only after a route is found, since request parameters are optional and not part of the route. Therefore, a GET request to `/handler/singers` will first be matched against the first GET `/handler/singers` route, then the existence of the name parameter is checked and if not found the conclusion is that this is not a match, and so, the next GET `/handler/singers` in the list is found to be a match, but neither `fn` and `ln` parameters are found, thus this is not a match either, and so the next one in the list is identified, and this route has no parameters, so the `singerHandler.list` gets finally invoked.

---

## Reactive Error Handling

In the **Reactive Services** section, the `save(..)` and `update(..)` methods were modified to emit messages of type `SavingException`. When a handler function or reactive handler method invokes one of these methods and the unexpected happens, the exception has to be handled. This allows developers to log the exception and save the context in which it was thrown and decide the HTTP status code. For reactive controllers, a class annotated with `@RestControllerAdvice` gets the job done, but for handler functions, we need something else, something more functional. We need a `WebExceptionHandler` bean. This bean works for reactive controllers too.

Spring Boot autoconfigures a default `WebExceptionHandler` of type `DefaultErrorWebExceptionHandler`. Figure 20-5 depicts the `WebExceptionHandler` hierarchy.



**Figure 20-5.** *WebExceptionHandler hierarchy*

The response returned by this bean is a generic JSON representation object that contains the 400 (Bad Request) HTTP status code, the URI path and an alpha numeric request identifier. If we want to customize the behavior, we need to declare our own `WebExceptionHandler` bean.

Listing 20-20 depicts a very simple version of the custom `WebExceptionHandler` bean that is added to the `RoutingConfig` class.

**Listing 20-20.** Custom `WebExceptionHandler` bean

```

package com.apress.prospring6.twenty.boot;

import org.springframework.web.server.WebExceptionHandler;
//other import statements omitted

@Slf4j
@Configuration
public class RoutesConfig {
    final static Logger LOGGER = LoggerFactory.getLogger(RoutesConfig.class);

    // other beans omitted

    @Bean
    
```

```

@Order(-2)
public WebExceptionHandler exceptionHandler() {
    return (ServerWebExchange exchange, Throwable ex) -> {
        if (ex instanceof SaveException se) {
            log.debug("RouterConfig:: handling exception :: ", se);
            exchange.getResponse().setStatusCode(HttpStatus.BAD_REQUEST);
            return exchange.getResponse().setComplete();
        } else if (ex instanceof IllegalArgumentException iae) {
            log.debug("RouterConfig:: handling exception :: ", iae);
            exchange.getResponse().setStatusCode(HttpStatus.BAD_REQUEST);
            return exchange.getResponse().setComplete();
        }
        return Mono.error(ex);
    };
}
}

```

Note that to ensure that our exception handler is used, we need to give it the highest priority by annotating it with `@Order(-2)`; otherwise, Spring Boot will still use the default handler.

## Testing Reactive Endpoints with WebTestClient

To test a reactive endpoint using an actual reactive client, we can use an instance of `WebTestClient`.

The `WebClient` API was introduced in Spring 5 to replace the existing `RestTemplate` class. In Spring 6, you can still use both to submit requests to a Spring application, with the `WebClient` being preferred for reactive applications since it is part of the `spring-webflux` package. `WebClient` can be used for synchronous or asynchronous HTTP requests with a functional fluent API that can integrate directly into your existing Spring configuration and the `WebFlux` reactive framework.

`WebClient` can only be used on top of an existing asynchronous HTTP client library. In the `chapter20-boot` project this is `Reactor Netty`, but `Jetty Reactive` or `Apache Reactive HTTP` clients are just as good. `WebClient` can be used to make requests to other reactive services written in any language.

For testing reactive web applications, `WebTestClient` was introduced as well, as a counterpart for the `WebClient` used in production. `WebTestClient` uses `WebClient` internally to perform requests while also providing a fluent API to verify responses.

In this section we'll use a `WebTestClient` to submit some requests to the APIs built in the previous sections.

Let's start by testing the endpoints backed up by the `ReactiveSingerController`. Listing 20-21 shows the creation of a `WebTestClient` pointing at the root URL `http://localhost:8081/reactive/singer` and a test that checks that the expected number of records are returned.

*Listing 20-21.* Test class using `WebTestClient`

```

package com.apress.prospring6.twenty.boot.webclient;

import org.springframework.test.web.reactive.server.WebTestClient;
// other import statements omitted

public class ReactiveSingerControllerTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(SingerHandlerTest.class);

```

```

private final WebClient controllerClient = WebClient
    .bindToServer()
    .baseUrl("http://localhost:8081/reactive/singer")
    .build();

@Test
void shouldReturnAFew(){
    controllerClient.get()
        .uri(uriBuilder -> uriBuilder.queryParam("name", "John").build())
        .accept(MediaType.APPLICATION_JSON)
        .exchange()
        .expectStatus().isOk()
        .expectHeader().contentType(MediaType.APPLICATION_JSON)
        .expectBody()
        .jsonPath("$.length()").isEqualTo(2);
}
}

```

There are a few things happening here:

- We create a `WebClient` instance by using the builder returned by `WebClient.bindToServer()`, and we set the base URL for this client to `http://localhost:8081/reactive/singer`. Obviously, this means that the application must be running for this test to work as intended.
- a GET request is sent to the configured base URL with the name parameter set to "John"
- to send the request we use the `exchange()` function
- To check the result, we use the assertion methods available: `expect*(..)` to check statuses and headers and `jsonPath(..)*` to check assumptions on the request body, assuming the body is represented as JSON.

However, what is interesting to test, is a negative scenario For example, the test method in Listing 20-22 checks the application behaviour when we try to create another 'John Mayer'.

*Listing 20-22.* Test method for a negative scenario using `WebClient`

```

package com.apress.prospring6.twenty.boot.webclient;

import org.springframework.test.web.reactive.server.WebClient;
// other import statements omitted

public class ReactiveSingerControllerTest {

    private static final Logger LOGGER = LoggerFactory.getLogger(SingerHandlerTest.class);

    private final WebClient controllerClient = WebClient
        .bindToServer()
        .baseUrl("http://localhost:8081/reactive/singer")
        .build();

```

```

@Test
void shouldFailToCreateJohnMayer(){
    controllerClient.post()
        .accept(MediaType.APPLICATION_JSON)
        .bodyValue(Singer.builder()
            .firstName("John")
            .lastName("Mayer")
            .birthDate(LocalDate.of(1977, 10, 16))
            .build())
        .exchange()
        .expectStatus().is4xxClientError()
        .expectBody()
        .consumeWith(body -> LOGGER.debug("body: {}", body));
}
}

```

The `shouldFailToCreateJohnMayer()` test method will pass, and no `Singer` instance will be created since there is already a singer with those names. The response HTTP code is 400, as proven by the response details printed in the console, which you can see in Listing 20-23. The response details include the submitted data.

**Listing 20-23.** Console log for the `shouldFailToCreateJohnMayer()` test execution

```

DEBUG c.a.p.t.b.w.SingerHandlerTest -- body:
> POST http://localhost:8081/reactive/singer
> accept-encoding: [gzip]
> user-agent: [ReactorNetty/1.1.5]
> host: [localhost:8081]
> WebTestClient-Request-Id: [1]
> Accept: [application/json]
> Content-Type: [application/json]
> Content-Length: [74]

{
  "id":null,
  "firstName":"John",
  "lastName":"Mayer",
  "birthDate":"1977-10-16"
}

< 400 BAD_REQUEST Bad Request
< content-length: [0]

```

The `WebTestClient` does not care what type of backend component generates the response to the request it is sending, which means the tests written in this section pass if the base URL is replaced with `http://localhost:8081/handler/singer`, and the requests are handled by functions in the `SingerHandler` class. The tests pass also when the URL points to an application written in a language other than Java, as long as the application is reactive and the response has the expected format.

## Reactive Web Layer

Migrating the web layer requires quite a few changes because rendering a view is quite difficult when you do not know how much data is sent to be rendered. In the past, Asynchronous JavaScript and XML (also known as AJAX) was used to resolve this problem, but AJAX enables us to update pages only in response to user action on the page. It does not solve the problem of updates coming from the server. Since reactive communication involves data flowing in both directions, new web libraries were needed. There is more than one way to do so, but in this section, we cover the most common way to do so: by using **server-sent events**.

Let's create a page in the singer application to display the list of beans in the application context. In previous chapters, `HomeController` contained a single handler method that returned a simple `String`. We will modify this method to return all the names of the beans in the application context as a `Flux<String>`.

Thymeleaf supports reactive views, and there is more than one way to populate the model with reactive data. To keep things quick and simple, we use a JavaScript piece of code to slowly populate the view with data coming as a flow. However, before that, we have to configure Thymeleaf for reactive support. Listing 20-24 shows this configuration class. Most properties are set with the default values set by Spring Boot, but the class is written like this to make it obvious what is customizable from a development point of view.

*Listing 20-24.* The reactive Thymeleaf configuration class

```
package com.apress.prospring6.twenty.boot;

import org.springframework.boot.autoconfigure.thymeleaf.ThymeleafProperties;
import org.springframework.boot.context.properties.EnableConfigurationProperties;
import org.springframework.web.reactive.config.ViewResolverRegistry;
import org.springframework.web.reactive.config.WebFluxConfigurer;
import org.thymeleaf.spring6.ISpringWebFluxTemplateEngine;
import org.thymeleaf.spring6.view.reactive.ThymeleafReactiveViewResolver;
// other import statements omitted

@Configuration
@EnableConfigurationProperties(ThymeleafProperties.class)
public class ReactiveThymeleafWebConfig implements WebFluxConfigurer {

    private final ISpringWebFluxTemplateEngine thymeleafTemplateEngine;

    public ReactiveThymeleafWebConfig(ISpringWebFluxTemplateEngine templateEngine) {
        this.thymeleafTemplateEngine = templateEngine;
    }

    /*
    @Bean
    public ITemplateResolver thymeleafTemplateResolver() {
        var resolver = new SpringResourceTemplateResolver();
        resolver.setApplicationContext(this.context);
        resolver.setPrefix("classpath:templates/");
        resolver.setSuffix(".html");
        resolver.setTemplateMode(TemplateMode.HTML);
        resolver.setCacheable(false);
        resolver.setCheckExistence(false);
    }
    */
}
```



```

        return resolver;
    } */

@Bean
public ThymeleafReactiveViewResolver thymeleafReactiveViewResolver() {
    var viewResolver = new ThymeleafReactiveViewResolver();
    viewResolver.setTemplateEngine(thymeleafTemplateEngine);
    viewResolver.setOrder(1);
    return viewResolver;
}

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

```

The template resolver bean that is responsible for resolving templates does not need to be reactive. Since the template resolver bean contains data from the application configuration, when using Spring Boot, it can be dropped all together and replaced by annotating the configuration class with `@EnableConfigurationProperties(ThymeleafProperties.class)`. This is the reason why in Listing 20-24, the bean declaration is commented.

The template engine that uses the template resolver is reactive and is an implementation of the `ISpringWebFluxTemplateEngine` interface. Therefore, the `SpringTemplateEngine` class designed for integration with the Spring MVC type, must be replaced with `SpringWebFluxTemplateEngine`, an implementation of the `ISpringWebFluxTemplateEngine` interface, designed for integration with Spring WebFlux and execution of templates in a reactive-friendly way. Since the template engine requires a template resolver and nothing else, this bean declaration is skipped, Spring Boot is allowed to configure it, and we just inject it in our configuration using the configuration class constructor constructor.

The `@EnableConfigurationProperties(ThymeleafProperties.class)` annotation enables support for Thymeleaf configuration properties. The `ThymeleafProperties` class is annotated with `@ConfigurationProperties(prefix = "spring.thymeleaf")`, which makes it a configuration bean for Thymeleaf properties. This means you can use a `application.yaml` or `application.properties` file to configure Thymeleaf. The properties are prefixed with `spring.thymeleaf` and allow you to configure the template resolver bean without writing additional code. The Spring Boot Thymeleaf configuration properties are depicted in Listing 20-25.

**Listing 20-25.** Spring Boot Thymeleaf configuration

```

spring:
  thymeleaf:
    prefix: classpath:templates/
    suffix: .html
    mode: HTML
    cache: false
    check-template: false
    reactive:
      max-chunk-size: 8192

```

The `ThymeleafReactiveViewResolver` is an implementation of the `org.springframework.web.reactive.result.view.ViewResolver` interface, the Spring WebFlux view resolver interface. The `responseMaxChunkSizeBytes` is the one you should be interested in, because it defines the maximum size for the output `org.springframework.core.io.buffer.DataBuffer` instances produced by the Thymeleaf engine

and passed to the server as output. This is important because if you have a lot of data being sent through a `Flux<T>`, you might want to render the view in chunks, bit by bit, instead of keeping a web page in a loading state, until the response is complete. Especially since this one of the main ideas of reactive communication.

Now, let's talk about our controller. Since `HomeController` needs to be annotated with `@RestController`, because its handler method returns a reactive stream of data, we need another way to return the logical view name. We can use a handler function and a router function for this, but first, let's look at `HomeController`, depicted in Listing 20-26.

**Listing 20-26.** The reactive `HomeController` class

```
package com.apress.prospring6.twenty.boot.controller;
// import statements omitted

@RestController
public class HomeController implements ApplicationContextAware {
    private ApplicationContext ctx;

    @Override
    public void setApplicationContext(ApplicationContext applicationContext) throws
    BeansException {
        ctx = applicationContext;
    }

    // The response payload for this request will be rendered in JSON
    @RequestMapping(value = "/beans", produces = MediaType.TEXT_EVENT_STREAM_VALUE)
    public Flux<String> getBeanNames() {
        List<String> beans = Arrays.stream(ctx.getBeanDefinitionNames()).sorted().
        collect(Collectors.toList());
        return Flux.fromIterable(beans).delayElements(Duration.ofMillis(200));
    }
}
```

Notice the `MediaType.TEXT_EVENT_STREAM_VALUE`, which is a constant with the text/event-stream value. This is the MIME type specific to a simple stream of text data that the server sends to the client when a GET request is sent to this URL: `http://localhost:8081/beans`

Messages in the event stream are separated by a pair of newline characters. A colon as the first character of a line is a comment and is ignored.

When the application is started, you can test whether the method returns a flux of bean names by running a simple `curl` command. The command and a few events from on the stream are shown in Listing 20-27.

**Listing 20-27.** Data stream returned by GET request to `http://localhost:8081/beans`

```
> curl -H "Accept:text/event-stream" http://localhost:8081/beans
data:applicationAvailability

data:applicationTaskExecutor

data:chapter20Application

data:clientConnectorCustomizer

data:connectionFactory
```

```
data:data-r2dbc.repository-aot-processor#0
// the rest of the stream events omitted
```

Thymeleaf generates three types of SSEs:

- **Header** - the data is prefixed by head: or `{prefix_}head`. Used for a single event during the communication containing all the markup previous to the iterated data (if any). Example: *When you are reading a Facebook thread, the moment you open the page, all the comments that exist in the database, previous to the timestamp when you opened that page, should already be rendered in the page. There is no point to render them one by one. Thymeleaf supports this type of initializing event.*
- **Data Message** - the data is prefixed by message: or `{prefix_}message`. Used for a series of events, one for each value produced by the data driver. Example: *When you are reading a Facebook thread, comments from other users that are being posted while you are viewing the page just appear in the comment section, one by one. Data from the comment would be sent to the client through an SSE of type message.*
- **Tail** - the data is prefixed by tail: or `{prefix_}tail`. Used for a single event during the communication containing all the markup following the iterated data (if any). Example: *Assuming Facebook had an option though which the user could choose to stop seeing new comments, an event of this type could be used to send all the comments exiting in the database with a timestamp value between the last displayed comment and the timestamp when the user chose to stop seeing new comments.*



The prefix value can be set via the `org.thymeleaf.spring6.context.webflux.`

`ReactiveDataDriverContextVariable` constructor when a reactive stream is wrapped in it, and the variable is added as an attribute to a Thymeleaf reactive view. The prefix is really useful when more than one SSE source is used on the same Web page, because it helps separate the server events in categories, so the data can be displayed in different parts of the page. This however, is a complex scenario that we won't cover in this chapter.

---

The `/beans` URL is used as a source for a stream of SSEs. An `EventSource` instance is created using the URL, and it opens a persistent connection through which the server sends events in `text/event-stream` format. The connection remains open until closed by calling `EventSource.close()`. The events are marked as message events by Spring WebFlux, and an `EventListener` instance is set on the `EventSource` instance to intercept those events, extract the data and add it to the HTML page.

The bean names stream was intentionally slowed down by calling the `delayElements(Duration.ofMillis(200))` on the resulting `Flux<String>` to show the continuous communication. If you use Chrome or Firefox, when loading the page, you can see the events being sent by the server in the developer console. Just remove the comment from the `console.log(event)` statement from the body of the `EventListener` instance shown in the `home.html` template snippet (HTML and JavaScript) depicted in Listing 20-28.

**Listing 20-28.** Thymeleaf template snippet used to display the bean names received as server-sent events (snippet from the `home.html` file)

```
<section th:fragment="~{templates/layout :: pageContent}">
  <script type="text/javascript" th:inline="javascript">
    /*<![CDATA[*]
```

```

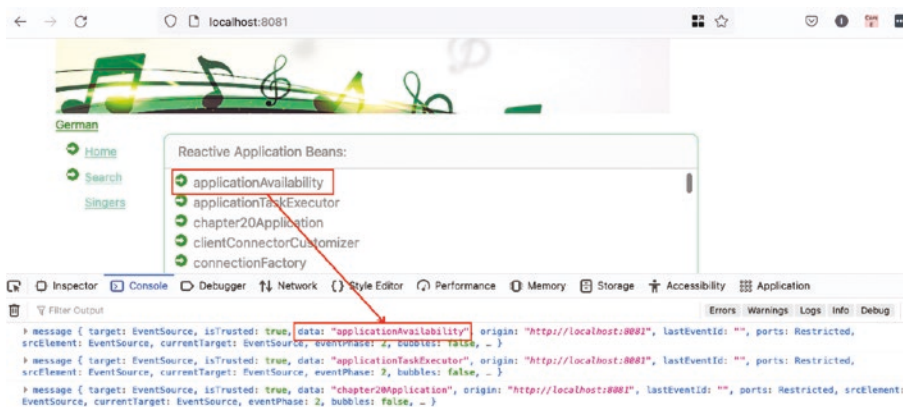
$(window).on( "load", function() {
    renderBeans.start();
});
$(window).on( "onbeforeunload", function() {
    renderBeans.stop();
});
let renderBeans = {
    source: new EventSource(/*[[@{/beans|}]]*/),
    start: function () {
        this.source.addEventListener("message", function (event) {
            //console.log(event);
            $("#beans").append('<li>'+ event.data + '</li>')
        });
        this.source.onerror = function () {
            this.source.close();
        };
    },
    stop: function() {
        this.source.close();
    }
};
/*]]>*/
</script>
<div class="card border-success mb-3" style="max-width: 40rem; left:30px;">
  <div class="card-header"> Reactive Application Beans: </div>
  <div class="row mb-1 m-sm-1">
    <div class="scrollable">
      <ul id="beans">
      </ul>
    </div>
  </div>
</div>
</section>

```

The `/*[[@{/beans|}]]*/` is a Thymeleaf link expression used to generate a URL relative to the application context. Looks weird, I know, but all those symbols make sure is not interpreted like something else, and it results in a valid piece of JavaScript code.

In Listing 20-28, the jQuery library was used to write the JavaScript code required to handle server-sent events. The server-sent events (SSEs) are a server push technology enabling a client to receive automatic updates from a server via an HTTP connection. This means that the page is rendered, but the connection is kept open, so the server can send more data to the client. The server-sent events EventSource API is standardized as part of HTML5, and except Internet Explorer, all other browsers support it.

In Figure 20-6, the main page of the Singers application is opened in Firefox, and you can see the stream of data being sent from the server in the developer console.



**Figure 20-6.** Server-sent events displayed in Firefox's developer console

There is one piece left that is missing: the mapping between the `/home` URL path and the `home.html` view. It was mentioned at the beginning of this section that this can be done by using a handler function and a routing function.

Listing 20-29 shows the handler function for rendering the view template with the 'home' name.

**Listing 20-29.** Handler function for mapping requests to a view, returning a logical view name

```
package com.apress.prospring6.twenty.boot.handler;
```

```
import org.springframework.http.MediaType;
import org.springframework.stereotype.Component;
import org.springframework.web.reactive.function.server.ServerRequest;
import org.springframework.web.reactive.function.server.ServerResponse;
import reactor.core.publisher.Mono;
```

```
@Component
public class HomeHandler {
    public Mono<ServerResponse> view(ServerRequest request) {
        return ServerResponse
            .ok()
            .contentType(MediaType.TEXT_HTML)
            .render("home");
    }
}
```

The `render(..)` method has two versions, the one used in Listing 20-29 that just takes the logical view name as an argument, is declared with var-args for the model attributes, in case there are any: `render(String name, Object... modelAttributes)`. There is another version, where the second argument is a `Map<String, ?>` representing the model used to render the template that can be used for rendering an error page

To add this handler function to the application routing configuration, we just need to inject the `HomeHandler` in the routing function bean configured in this chapter and add a `GET(..)` routing function, as shown in Listing 20-30.

**Listing 20-30.** Router function including the `HomeController::view` handler function

```

package com.apress.prospring6.twenty.boot;
// import statements omitted
@Slf4j
@Configuration
public class RoutesConfig {
    final static Logger LOGGER = LoggerFactory.getLogger(RoutesConfig.class);

    @Bean
    public RouterFunction<ServerResponse> singerRoutes(HomeController homeHandler,
        SingerHandler singerHandler) {
        return route()
            .GET("/", homeHandler::view)
            .GET("/home", homeHandler::view)
            // singer routes omitted
            .filter((request, next) -> {
                LOGGER.info("Before handler invocation: {}", request.path());
                return next.handle(request);
            })
            .build();
    }
}

```

Another thing that might be interesting to know, when writing Spring reactive web applications, you might want to isolate the routing configuration for the static resources in a different routing function created with the `RouterFunctions.resources(...)` method. This method routes requests that match the given pattern to resources relative to the given root location, which is useful to skip the static resources from additional filtering that applies only to dynamic resources.

An example of `RouterFunction<ServerResponse>` bean for static resources is shown in Listing 20-31.

**Listing 20-31.** `RouterFunction<ServerResponse>` for static resources

```

package com.apress.prospring6.twenty.boot;
import org.springframework.web.reactive.function.server.RouterFunction;
import static org.springframework.web.reactive.function.server.RouterFunctions.resources;
// other import statements omitted

@Slf4j
@Configuration
public class RoutesConfig {
    public RouterFunction<ServerResponse> staticRouter() {
        return resources("/images/**", new ClassPathResource("static/images/"))
            .and(resources("/styles/**", new ClassPathResource("static/styles/")))
            .and(resources("/js/**", new ClassPathResource("static/js/")));
    }

    // other configurations omitted
}

```

Note that `RouterFunction<ServerResponse>` can be composed using the `and(..)` method. The resulting router function is a composed routing function that first invokes the first function and then invokes the other function if this route has no result, and so on.

## Handler Functions Validation

A functional endpoint can use Spring's validation components to apply validation to the request body. To explain how validation works, we'll add a criteria object that allows the user to specify the filter for a database query. This criteria object is used in the service to decide which query repo to execute.

The `CriteriaDto` class is added to the `SingerService` interface because it is only used in the context of this service and thus is very strongly related to it. Since we are working with data provided by the user, a validator class is needed as well. These two classes and the method skeleton for the service method using the `CriteriaDto` as an argument are shown in Listing 20-32.

**Listing 20-32.** `CriteriaDto` object and `CriteriaValidator` classes

```
package com.apress.prospring6.twenty.boot.service;

import org.springframework.validation.Errors;
import org.springframework.validation.ValidationUtils;
import org.springframework.validation.Validator;
// other import statements omitted

public interface SingerService {
    // other service methods omitted
    Flux<Singer> findByCriteriaDto(CriteriaDto criteria);

    @Getter
    @Setter
    @NoArgsConstructor
    class CriteriaDto {
        private String fieldName;
        private String fieldValue;
    }

    class CriteriaValidator implements Validator {

        @Override
        public boolean supports(Class<?> clazz) {
            return (CriteriaDto.class).isAssignableFrom(clazz);
        }

        @Override
        public void validate(Object target, Errors errors) {
            ValidationUtils.rejectIfEmpty(errors, "fieldName", "required", new Object[] {
                "fieldName" }, "Field Name is required!");
            ValidationUtils.rejectIfEmpty(errors, "fieldValue", "required", new Object[] {
                "fieldValue" }, "Field Value is required!");
        }
    }
}
```

```

enum FieldGroup {
    FIRSTNAME,
    LASTNAME,
    BIRTHDATE;

    public static FieldGroup getField(String field){
        return FieldGroup.valueOf(field.toUpperCase());
    }
}

```

CriteriaDto instances are used to hold search criteria for a form object. For these instances to be valid, both fields must be present.

The FieldGroup enum is added to easily select the column based on which the filtering is done. Listing 20-33 shows the implementation of the `findByCriteriaDto(..)` method.

**Listing 20-33.** `SingerServiceImpl#findByCriteriaDto(..)` implementation

```

package com.apress.prospring6.twenty.boot.service;
// import statements omitted

@RequiredArgsConstructor
@Transactional
@Service
public class SingerServiceImpl implements SingerService {
    @Override
    public Flux<Singer> findByCriteriaDto(CriteriaDto criteria) {
        var fieldName = FieldGroup.getField(criteria.getFieldName().toUpperCase());
        if ("*".equals(criteria.getFieldValue())) {
            return singerRepo.findAll();
        }
        return switch (fieldName) {
            case FIRSTNAME -> "*".equals(criteria.getFieldValue())
                ? singerRepo.findAll()
                : singerRepo.findByFirstName(criteria.getFieldValue());
            case LASTNAME -> "*".equals(criteria.getFieldValue())
                ? singerRepo.findAll()
                : singerRepo.findByLastName(criteria.getFieldValue());
            case BIRTHDATE -> "*".equals(criteria.getFieldValue())
                ? singerRepo.findAll()
                : singerRepo.findByBirthDate(LocalDate.parse(criteria.getFieldValue()),
                    DateTimeFormatter.ofPattern("yyyy-MM-dd"));
        };
    }
}

```

Just for fun, the possibility to select all the entries when a field value is equal to `*` was coded in. This method is invoked by a handler function in class `SingerHandler`, which is shown in Listing 20-34.



**Listing 20-34.** Handler function that invokes the `findByCriteriaDto(..)` service method

```

package com.apress.prospring6.twenty.boot.handler;

import org.springframework.validation.BeanPropertyBindingResult;
// import statements omitted

@Component
public class SingerHandler {
    // other handler functions omitted

    public Mono<ServerResponse> search(ServerRequest serverRequest) {
        var criteriaMono = serverRequest.bodyToMono(SingerService.CriteriaDto.class);
        return criteriaMono.log()
            .flatMap(this::validate)
            .flatMap(criteria -> ok().contentType(MediaType.APPLICATION_JSON)
                .body(singerService.findByCriteriaDto(criteria), Singer.class));
    }

    private Mono<SingerService.CriteriaDto> validate(SingerService.CriteriaDto criteria) {
        var validator = new SingerService.CriteriaValidator();
        var errors = new BeanPropertyBindingResult(criteria, "criteria");
        validator.validate(criteria, errors);
        if (errors.hasErrors()) {
            // throw new ServerWebInputException(errors.toString());
            throw MissingValueException.of(errors.getAllErrors());
        }
        return Mono.just(criteria);
    }
}

```

Notice the `validate(..)` method. This method is used as a processor in a reactive chain. For this simple example, the `CriteriaValidator` is instantiated in this method. In bigger applications where a validator is used in multiple handler functions, you might want to declare it as a bean. If the `validator.validate(criteria, errors)` populates the `errors` object, a `MissingValueException` is created with the name of the fields that are missing and the error messages. The `MissingValueException` is a custom exception type, with a simple builder that allows converting the validation errors in representations that can be shown in the interface.

Listing 20-35 shows this custom exception type.

**Listing 20-35.** The `MissingValueException` custom exception type

```

package com.apress.prospring6.twenty.boot.problem;

import org.springframework.validation.FieldError;
import org.springframework.validation.ObjectError;
// some import statements omitted

@SuppressWarnings("serial")
public class MissingValueException extends RuntimeException {
    private Map<String,String> fieldNames;
}

```

```

public MissingValueException(String message, Map<String,String> fieldNames) {
    super(message);
    this.fieldNames = fieldNames;
}

public MissingValueException(String message, Throwable cause, Map<String,String>
fieldNames) {
    super(message, cause);
    this.fieldNames = fieldNames;
}

public Map<String,String> getFieldNames() {
    return fieldNames;
}

public static MissingValueException of(List<ObjectError> errors) {
    final List<String> fields = new ArrayList<>();
    var fieldNames = new HashMap<String,String>();
    errors.forEach(err -> fieldNames.put( ((FieldError)err).getField() , err.
getDefaultMessage()));
    return new MissingValueException("Some values are missing!", fieldNames);
}
}

```

The next step is to also add a method in `SingerHandler` to render the search view. The method is shown in Listing 20-36.

**Listing 20-36.** The `SingerHandler.searchView()` handler function to render the Thymeleaf search view

```

package com.apress.prospring6.twenty.boot.handler;
// import statements omitted

@Component
public class SingerHandler {
    // other handler function omitted

    public Mono<ServerResponse> searchView(ServerRequest request) {
        return ServerResponse
            .ok()
            .contentType(MediaType.TEXT_HTML)
            .render("singers/search", new SingerService.CriteriaDto());
    }
}

```

Now that we have all these, before designing the view template, we need to add the routing for the two new handler functions to the `singerRoutes` routing function introduced in Listing 20-19.

We also need to add a new section in the `WebExceptionHandler` to handle the `MissingValueException`.

Listing 20-37 shows the minimal configuration of the `singerRoutes` routing function showing the two mappings and the new `WebExceptionHandler` bean that includes a block for handling the `MissingValueException`.

**Listing 20-37.** The updated routing function and exception handler that includes code for handling **`MissingValueException` instances**

```
package com.apress.prospring6.twenty.boot;
// import statements omitted

@Slf4j
@Configuration
public class RoutesConfig {
    final static Logger LOGGER = LoggerFactory.getLogger(RoutesConfig.class);

    @Bean
    public RouterFunction<ServerResponse> singerRoutes(HomeHandler homeHandler,
        SingerHandler singerHandler) {
        return route()
            // returns home view template
            .GET("/", homeHandler::view)
            .GET("/home", homeHandler::view)
            .GET("/singers/search", singerHandler::searchView)
            .POST("/singers/go", singerHandler::search)
            // other mapping omitted
            .filter((request, next) -> {
                LOGGER.info("Before handler invocation: {}" , request.path());
                return next.handle(request);
            })
            .build();
    }

    @Bean
    @Order(-2)
    public WebExceptionHandler exceptionHandler() {
        return (ServerWebExchange exchange, Throwable ex) -> {
            if (ex instanceof SaveException se) {
                log.debug("RouterConfig:: handling exception :: " , se);
                exchange.getResponse().setStatusCode(HttpStatus.BAD_REQUEST);

                // marks the response as complete and forbids writing to it
                return exchange.getResponse().setComplete();
            } else if (ex instanceof IllegalArgumentException iae) {
                log.debug("RouterConfig:: handling exception :: " , iae);
                exchange.getResponse().setStatusCode(HttpStatus.BAD_REQUEST);

                // marks the response as complete and forbids writing to it
                return exchange.getResponse().setComplete();
            } else if (ex instanceof MissingValueException mve) {
                exchange.getResponse().setStatusCode(HttpStatus.BAD_REQUEST);
                exchange.getResponse().getHeaders().add("Content-Type", "application/json");
            }
        };
    }
}
```

```

        final String message;
        try {
            message = new ObjectMapper().writeValueAsString(mve.getFieldNames());
            var buffer = exchange.getResponse().bufferFactory().wrap(message).
                getBytes();
            return exchange.getResponse().writeWith(Flux.just(buffer));
        } catch (JsonProcessingException e) {
        }
    }
}
return Mono.error(ex);
};
}
}
}

```

Now we have everything we need but the view. The `singers/search.html` view needs to have a dynamic section where a table is built with the results of the search, a dynamic section that is displayed only when there are errors and the JavaScript code that populates these elements.

The main section of the `search.html` view template is shown in Listing 20-38.

**Listing 20-38.** The main section of the `singers/search.html` view

```

<section th:fragment=~{templates/layout :: pageContent}">
  <div class="content"> <!-- content -->
    <h4 th:text="{command.search} + ' ' + {singer.title}">SEARCH</h4>

    <div class="container col-lg-12">
      <form action="#" th:action="@{/singers/go}" name="search"
        th:object="{criteriaDto}" method="post" class="col p-4" id="singerSearchForm">

        <div class="row mb-1">
          <label for="fieldName" th:text="{label.Criteria.fieldname} + ':'"
            class="col-sm-4 form-label">FN</label>
          <div class="col-sm-8">
            <select th:field="{fieldName}" class="form-select">
              <option th:value="firstName" th:text="{label.Singer.
                firstname}">FN</option>
              <option th:value="lastName" th:text="{label.Singer.
                lastname}">LN</option>
              <option th:value="birthDate" th:text="{label.Singer.
                birthDate}">BD</option>
            </select>
          </div>
        </div>

        <div class="row mb-1">
          <label for="fieldValue" th:text="{label.Criteria.fieldvalue} + ':'"
            class="col-sm-4 form-label"></label>
          <div class="col-sm-8">
            <div>
              <input type="text" th:field="{fieldValue}" class="form-control"/>
              <small th:text="{label.dateFormat.accepted}" class="text-
                muted">ACC</small></div>

```

```

        </div>
    </div>

    <div class="bs-component mb-1">
        <input type="submit" th:value="#{command.search}" id="searchButton"
            class="btn btn-dark"/>
        <div class="col-sm-8">
            <small id="errMessage"></small>
        </div>
    </div>
</form>
<script th:inline="javascript">
    /**/
    $( window ).on( "load", function() {
        $('#errMessage').hide();
        $('#singerSearchResults').hide();
    });
    function renderSearchResults(singers) {
        $('#errMessage').empty()
        $('#errMessage').hide();
        let content = '';
        let baseDetailUrl = /*[[@{/singers/}]]*/ '/singers';
        for (let i = 0; i &lt; singers.length; i++) {
            content += '&lt;tr&gt;';
            content += '&lt;td&gt;&lt;a href="'+ baseDetailUrl + singers[i].id+'"'&gt;'
                +singers[i].id+'&lt;/a&gt;&lt;/td&gt;';
            content += '&lt;td&gt;'+singers[i].firstName+'&lt;/td&gt;';
            content += '&lt;td&gt;'+singers[i].lastName+'&lt;/td&gt;';
        }
        $('#singerSearchResults tbody').html(content);
        if(content !== '') {
            $('#singerSearchResults').show();
        } else {
            $('#singerSearchResults').hide();
        }
    }

    $('#singerSearchForm').submit(function(evt){
        evt.preventDefault();
        let fieldName = $('#fieldName').val();
        let fieldValue = $('#fieldValue').val();
        let json = { "fieldName" : fieldName, "fieldValue" : fieldValue};

        $.ajax({
            url: $('#singerSearchForm')[0].action,
            type: 'POST',
            dataType: 'json',
            contentType: 'application/json',
</pre>
</div>
<div data-bbox="891 909 930 926" data-label="Page-Footer">897</div>
```

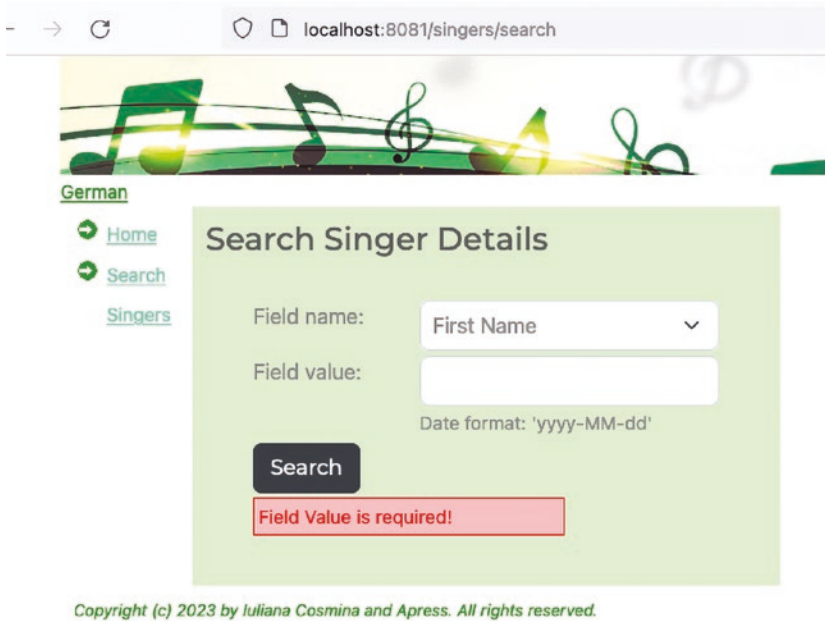
```

    data: JSON.stringify(json),
    success: function(responseData) { renderSearchResults(responseData);},
    error: function(e) {
        let jsonData = e.responseJSON;
        for(let i in jsonData) {
            let key = i;
            let val = jsonData[i];
            $('#errorMessage').append("<p class='error'>" + val + "</p>");
        }
        $('#errorMessage').show();
    }
    });
})
/*]]>*/
</script>
<table id="singerSearchResults" class="table table-hover">
  <thead>
    <tr>
      <th th:text="#{label.Singer.count}" class="table-success">COUNT</th>
      <th th:text="#{label.Singer.firstname}" class="table-success">FIRSTNAME</th>
      <th th:text="#{label.Singer.lastname}" class="table-success">LASTNAME</th>
    </tr>
  </thead>
  <tbody>
    <th:block th:each="singer : ${singers}">
      <td><a th:href="@{/singer/} + ${singer.id}" th:text="${singer.id}">ID</a></td>
      <td th:text="${singer.firstName}">...</td>
      <td th:text="${singer.lastName}">...</td>
    </th:block>
  </tbody>
</table>
</div>
</div> <!-- content -->
</section>

```

The JavaScript code looks a lot like the one written to display the bean names, with the exception that this time column rows are being written and there is also an error section for the \$.ajax(..) invocation that is responsible for showing the validations error messages received from the server.

Figure 20-7 shows the Search Singer page with a validation error message being displayed after a request was sent without providing a value for the search.



**Figure 20-7.** Search Singer page with a validation error message

Building Spring reactive applications is a vast subject and I know this section does not give it justice. If you are interested in building Spring Reactive applications you might want to take a look at the other resources referenced in this chapter, including *Josh Long's Reactive Spring*, published by on LeanPub and last updated in September 2022<sup>31</sup>.

## Summary

This chapter gave you an insight into what is important when building a reactive Spring WebFlux application. A few details of migrating multi-layered applications were covered to underline the fact that a reactive application is fully reactive, only if all its components are reactive. To help you make the change from Spring Web MVC to WebFlux comparisons between configurations for the two technologies were made.

We looked into using reactive controllers and handler functions.

We looked into testing reactive repositories and services and consuming reactive services using `WebTestClient`.

There are a few things to take away from this chapter. Spring WebFlux has a few advantages: the code is cleaner and more concise. Spring Boot provides so many components out of the box that it allows for more time to be dedicated to development and less to configuration. Error handling is easier to implement, and code is easier to read. However, not all components (or application for that matter) must be reactive. For example: when all you want to build is a simple page to render to the user, there is no need to render it using a reactive component.

<sup>31</sup> <https://leanpub.com/reactive-spring>

# Appendix A

## Setting Up Your Development

This appendix helps you set up the development environment that you will use to write, compile, and execute the Spring applications discussed in this book.

### Introducing project `pro-spring-6`

Project `pro-spring-6` is a two-level Gradle/Maven project. `pro-spring-6` is the root project and is the parent of the projects named `chapter02` through `chapter20`. Each module is named as the chapter where its contents are referenced. Each chapter has two or more modules associated with it, depending on the context and topics covered. The ones with names that end in `-boot` are Spring Boot projects. The ones that don't are just Java projects using Spring, because yes, you can use Spring without using Spring Boot. I call these *classic Spring projects* because this is how Spring applications were developed before Spring Boot was around. This project depends on many libraries that will be automatically downloaded when your project is opened in an editor for the first time.

This project is configured with both Gradle and Maven and you can build it and import it in IntelliJ IDEA using whichever you prefer.

### Understanding the Gradle Configuration

The `pro-spring-6` project defines a set of libraries available for the child modules to use, and it has the Gradle configuration in a file typically named `build.gradle`. All the modules on the second level (in other words, the `chapter**` projects) have a Gradle configuration file named `[module_name].gradle` (for example, `chapter02.gradle`). This was a development choice; the configuration file of a chapter module is more visible in an editor this way. Plus, if you want to modify the configuration file for a chapter module, you can easily find the file in IntelliJ IDEA using a unique name.

Additionally, there is a closure element in `pro-spring-6/settings.gradle` that verifies at build time that all chapter modules have their configuration file present.

```
// pro-spring-6/settings.gradle
rootProject.name = 'pro-spring-6'

include 'chapter02'
include 'chapter02-boot'
include 'chapter03'
// other module names omitted
```



```
rootProject.children.each { project ->
    project.buildFileName = "${project.name}.gradle"
    assert project.projectDir.isDirectory()
    assert project.buildFile.exists()
    assert project.buildFile.isFile()
}
```

This file also contains the names of all modules; if some module gives you trouble, you can comment on it here, and the project will build without it.



For example, the `chapter07-jooq` and `chapter07-jooq-boot` modules are commented, because these projects require a started MariaDB Docker container to generate the JOOQ sources. When studying **Chapter 7**, build the image and start the Docker container as instructed, and then you can remove the comments, so you can build these modules as part of the project.

If a Gradle build file is not named the same as the module, then when executing any Gradle task, an error is thrown. The error is similar to the one depicted in the following configuration snippet, where the `chapter02.gradle` file was renamed to `chapter02_2.gradle`:

```
$ gradle
FAILURE: Build failed with an exception.

* Where:
Settings file '/workspace/pro-spring-6/settings.gradle' line: 67

* What went wrong:
A problem occurred evaluating settings 'pro-spring-6'.
> assert project.buildFile.exists()
    |           |           |
    |           |           false
    |           /workspace/pro-spring-6/chapter02/chapter02.gradle
    |           :chapter02

* Try:
> Run with --stacktrace option to get the stack trace.
> Run with --info or --debug option to get more log output.
> Run with --scan to get full insights.

* Get more help at https://help.gradle.org

BUILD FAILED in 669ms
```

Another approach for a multimodular project would have been to have in the main `build.gradle` file specific closures to customize the configuration for each module. However, in the spirit of good development practices, I decided to keep the configurations for the modules as decoupled as possible and in the same location as the module contents.

The `pro-spring-6/build.gradle` configuration file contains a variable for each software version being used. The `pro-spring-6` was configured to use Spring Boot dependency management even for classic projects, but there are some dependencies that the Spring Boot dependency management plugin does not manage, so we have to put their versions in a common place to ensure that different modules that do not end up using different versions and causing dependency conflicts. It also makes it really practical to upgrade them. The versions are declared as global variables and grouped under the `ext` closure.

```
ext {
    lombokVersion = "1.18.24"
    lang3Version = "3.12.0"
    mockitoVersion = "2.0.2-beta"
    testcontainersVersion = "1.17.6"
    jakartaAnnotationVersion = "2.1.1"
    jakartaInjectApiVersion = "2.0.1"
    jacksonVersion = "2.14.1"
    dbcp2Version = "2.9.0"
    // other version omitted
}
```

Additionally, here, the `bootProjects` variable is declared and initialized with the Spring Boot module names. This variable is used to configure the Spring Boot plugin only for these modules.

```
ext {
    bootProjects = subprojects.findAll { ( it.name.endsWith('-boot')) }
}

configure(bootProjects) { project ->
    apply plugin: 'org.springframework.boot'
}
```

There are other configurations that are required for all modules that are declared in this file, most of them related to plugins being applied, common dependencies, compiling options, java version used, etc.

This file also contains the declarations for all plugins used in the project. Since they are referenced in the modules only by their ID, having them here declared together with their versions also makes the plugins easier to upgrade.

In the projects on the second level of the hierarchy (in other words, the `chapterXX` projects), you'll find the `chapterXX.gradle` configuration files. Dependencies are referred to by their group, artifact name and version when Spring Boot dependency management plugin is used for managing them. Here you can see the `chapter09.gradle` file:

```
import org.springframework.boot.gradle.plugin.SpringBootPlugin
```

```
description 'Chapter 09: Spring Transaction Management!'
```

```
// we are using Spring Boot dependency management, but we configure Spring MVC in the classic manner - explicitly, with no Spring Boot "magic". This is to avoid confusing IntelliJ IDEA by accidentally ending up with different versions of Spring and its dependencies in the project classpath.
```

```
dependencyManagement {
    imports {
        mavenBom SpringBootPlugin.BOM_COORDINATES
    }
}
```

```
dependencies {
    implementation 'org.springframework:spring-orm' // managed by Spring Boot Dependency
                                                Management
    implementation 'org.springframework:spring-context'

    implementation "ch.qos.logback:logback-classic:$logbackVersion" // not managed by
                                                                    Spring Boot Dependency
                                                                    Management
    implementation "jakarta.annotation:jakarta.annotation-api:$jakartaAnnotationVersion"

    implementation "com.zaxxer:HikariCP:$hikariVersion"
    runtimeOnly "org.mariadb.jdbc:mariadb-java-client"
    implementation "org.hibernate.orm:hibernate-core:$hibernateVersion"

    testImplementation 'org.springframework:spring-test'
    testImplementation 'org.junit.jupiter:junit-jupiter-engine'
    testImplementation "org.testcontainers:mariadb:$testcontainersVersion"
    testImplementation "org.testcontainers:junit-jupiter:$testcontainersVersion"
}

task jar(type: Jar, overwrite: true) {
    duplicatesStrategy = DuplicatesStrategy.INCLUDE
    /* Gradle Fat jars with multiple dependencies are affected by the same bug: https://issues.
    apache.org/jira/browse/MASSEMBLY-360 this statement fixes it */
    manifest {
        attributes(
            "Created-By": "Iuliana Cosmina",
            "Specification-Title": "Pro Spring 6 - Chapter 09",
            "Main-Class": "com.apress.prospring6.nine.Chapter9Demo",
            "Class-Path": configurations.runtimeClasspath.collect { it.getName()
            }.join(' ')
        )
    }
    from {
        configurations.runtimeClasspath.collect { it.isDirectory() ? it : zipTree(it) }
    }
}
```



Notice how the `SpringBootPlugin` class is imported just to access the static variable `BOM_COORDINATES` that will point to the Spring Boot Dependencies BOM file, so the Spring Boot dependency plugin will extract the version for the managed dependencies from there.

For projects where there is a main class, we are building an executable jar with a custom manifest file. Just to show you how it is done, but also because I like having my name everywhere. ;)

For `chapter09-boot.gradle`, the configuration is simpler, dependency management is configured by default, and creating an executable jar is also easy because of the Spring Boot Plugin. Additionally, some dependencies don't have to be specified at all since they are transitive dependencies for Spring Boot Starters dependencies. For a quick comparison, please see the `chapter09-boot.gradle` file:

```

apply plugin: 'java'

dependencies {
    implementation 'org.springframework.boot:spring-boot-starter-jdbc'
    implementation 'org.springframework:spring-orm'

    implementation "jakarta.annotation:jakarta.annotation-api:$jakartaAnnotationVersion"
    implementation "com.zaxxer:HikariCP:$hikariVersion"
    runtimeOnly "org.mariadb.jdbc:mariadb-java-client"
    implementation "org.hibernate.orm:hibernate-core:$hibernateVersion"

    testImplementation 'org.springframework.boot:spring-boot-starter-test'
    testImplementation "org.testcontainers:mariadb:$testcontainersVersion"
    testImplementation "org.testcontainers:junit-jupiter:$testcontainersVersion"
}

bootJar {
    manifest {
        attributes 'Start-Class': 'com.apress.prospring6.nine.boot.Chapter9Application'
    }
}

```

This project is configured with Gradle Wrapper, so if you do not want to install Gradle locally, when building it, just use the `gradlew` or `gradlew.bat` executables.

The default tasks for this project are declared to be clean and build, so you can build it by just running the previously mentioned executables.

What I like about Gradle is that the configuration is readable and more compact, even for applications that need to be packaged as a war. Of course, how readable and compact a Gradle configuration is depends greatly on the developer's skills.

## Understanding the Maven Configuration

In this edition of the book, the `pro-spring-6` project comes with a Maven configuration too, mostly because after 8 years I got tired of people asking for one and I gave in.

The approach I took is similar to the Gradle configuration: all that was common to all modules is part of the `pro-spring-6/pom.xml`. Under the `<properties>` element, all the project common properties, e.g., java version, dependency versions, plugin versions, encoding, etc., are declared.

### **<properties>**

```

<spring-boot.version>3.0.5</spring-boot.version>
<!-- Java version for non-Boot projects -->
<maven.compiler.source>19</maven.compiler.source>
<maven.compiler.target>19</maven.compiler.target>
<!-- Java version for Boot projects-->
<java.version>19</java.version>

<versions-maven-plugin.version>2.12.0</versions-maven-plugin.version>
<maven-compiler-plugin.version>3.10.1</maven-compiler-plugin.version>
<jackson.version>2.14.2</jackson.version>
<lombok.version>1.18.24</lombok.version>

```

```
<commons-lang3.version>3.12.0</commons-lang3.version>
<project.build.sourceEncoding>UTF-8</project.build.sourceEncoding>
<!-- other properties omitted-->
</properties>
```

Under the <modules> element, all the module names are listed.



For example, the chapter07-jooq and chapter07-jooq-boot modules are commented, because these projects require a started MariaDB Docker container to generate the JOOQ sources. When studying **Chapter 7**, build the image and start the Docker container as instructed, and then you can remove the comments, so you can build these modules as part of the project.

Dependencies common to all modules are declared under the <dependencies> element.

All dependencies used by most modules are declared under the <dependencyManagement> element with their version pointing to their respective properties. This allows for simplified usage when declaring them as dependencies for modules because the version is no longer necessary. (Sample A-1)

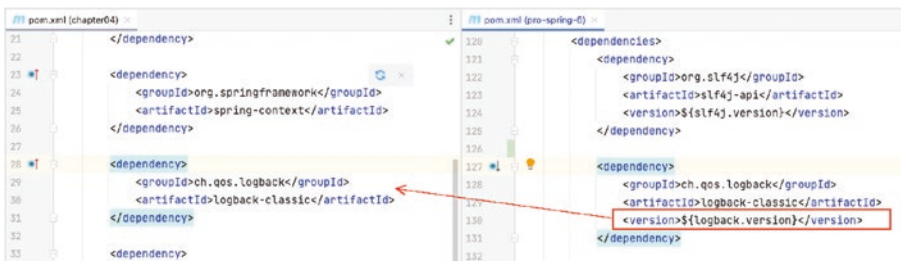


Figure A-1. logback-classic dependency in parent pom.xml and in chapter04/pom.xml.

Under <dependencyManagement> the spring-boot-dependencies is added as well with the <scope>import</scope>, this is what configured dependency management for all modules.

```
<dependencyManagement>
  <dependencies>
    <!-- other dependencies omitted -->
    <dependency>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-dependencies</artifactId>
      <version>${spring-boot.version}</version>
      <type>pom</type>
      <scope>import</scope>
    </dependency>
  </dependencies>
</dependencyManagement>
```

A similar approach has been taken for the plugins as well, and a `<pluginManagement>` element is present under `<build>` to declare common plugins and configurations for all modules. The next snippet shows the `maven-compiler-plugin` being configured here so that this configuration is inherited by all modules, which means that all modules are compiled with ``${maven.compiler.source}``, which is set to 19, as shown previously.

The default goals for this project are declared to be `clean` and `install`, so you can build it by just running the previously mentioned executables.

The `pom.xml` files do not differ that much between a classic project and a Boot project. The only difference is that the Spring Boot project has the `spring-boot-maven-plugin` configured, while the classic project has the `maven-compiler-plugin`.

As an example, let's look at `chapter09/pom.xml`.

```
<?xml version="1.0" encoding="UTF-8"?>
<project> <!-- Xsd schema references omitted-->
  <modelVersion>4.0.0</modelVersion>

  <parent>
    <groupId>com.apress.prospring6</groupId>
    <artifactId>pro-spring-6</artifactId>
    <version>6.0-SNAPSHOT</version>
  </parent>

  <artifactId>chapter09</artifactId>
  <name>Pro Spring 6 :: Chapter 09</name>
  <description>This is a Java project is a collection of simple code samples using
  Spring.</description>

  <dependencies>
    <dependency>
      <groupId>org.springframework</groupId>
      <artifactId>spring-orm</artifactId> <!-- managed by Spring Boot Dependency
      Management -->
    </dependency>

    <!-- logging lib -->
    <dependency>
      <groupId>ch.qos.logback</groupId>
      <artifactId>logback-classic</artifactId> <!-- not managed by Spring Boot
      Dependency Management-->
    </dependency>

    <!-- not used in that many projects, thus not part of root pom.xml
    <dependencyManagement> -->
    <dependency>
      <groupId>com.zaxxer</groupId>
      <artifactId>HikariCP</artifactId>
      <version>${hikari.version}</version>
    </dependency>
    <!-- other dependencies omitted -->
  </dependencies>
```

```

<build>
  <plugins>
    <plugin>
      <!-- no version, configured with <pluginManagement> -->
      <groupId>org.apache.maven.plugins</groupId>
      <artifactId>maven-compiler-plugin</artifactId>
    </plugin>
  </plugins>
</build>
</project>

```

Compare this with chapter09-boot/pom.xml.

```

<?xml version="1.0" encoding="UTF-8"?>
<project> <!-- Xsd schema references omitted-->
  <modelVersion>4.0.0</modelVersion>

  <parent>
    <groupId>com.apress.prospring6</groupId>
    <artifactId>pro-spring-6</artifactId>
    <version>6.0-SNAPSHOT</version>
  </parent>

  <artifactId>chapter09-boot</artifactId>
  <name>Pro Spring 6 :: Chapter 09 Boot (Transactions) </name>
  <description>This is a very simple Spring Boot project.</description>

  <dependencies>
    <!-- almost the same dependencies-->
  </dependencies>

  <build>
    <plugins>
      <plugin>
        <groupId>org.springframework.boot</groupId>
        <artifactId>spring-boot-maven-plugin</artifactId>
        <!-- version needed, cannot be configured with <pluginManagement> -->
        <version>${spring-boot.version}</version>
        <configuration>
          <mainClass>com.apress.prospring6.nine.boot.Chapter9Application</
            mainClass>
        </configuration>
      </plugin>
    </plugins>
  </build>
</project>


```

The Maven configuration becomes slightly complicated for projects that need to be packaged as war since the `maven-assembly` plugin is necessary to assemble the war properly.

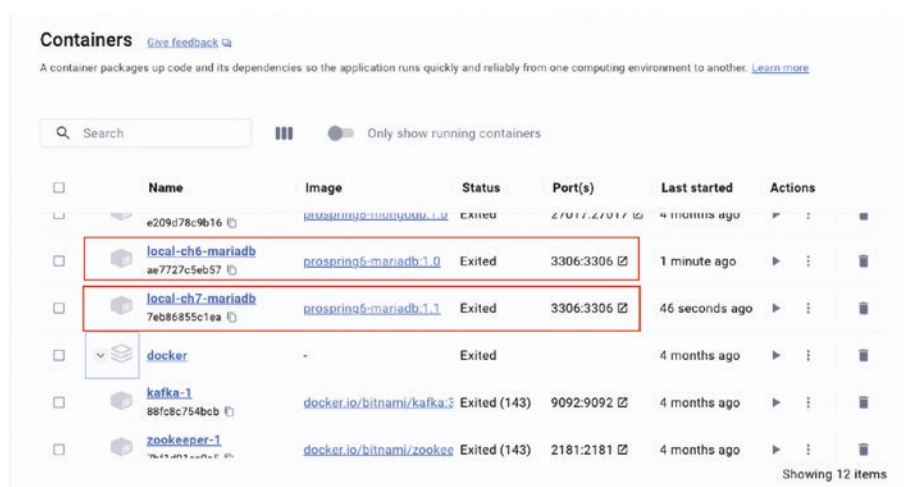
This project is configured with Maven Wrapper, so if you do not want to install Maven locally, when building it, just use the `mvnw` or `mvnw.bat` executables.

# Using Docker

Starting with **Chapter 6**, most projects require a database, for running and testing. For running the application, you need to set up the container as instructed in the chapterXX.adoc readme file. The Docker Image files are located under chapterXX/docker-build directory.

■  Just remember to stop the container when switching to another project, because containers map the MariaDB port 3306, to the 3306 port of your computer to allow your Spring applications to work with the database as if it were installed on your computer. Obviously, you can't have more than one container mapped to the same port.

Your Docker Dashboard should look like mine, shown in Figure A-2.



**Figure A-2.** Docker dashboard showing containers for project chapter06 and chapter07.

For testing, we are using TestContainers<sup>1</sup>, a very practical library that downloads a Docker image and starts the container automatically. All you need, of course, is to have Docker running locally.

Once your container is deployed and started, you can use the Database View in IntelliJ IDEA to check that the database is there and populated as expected.

<sup>1</sup><https://www.testcontainers.org>



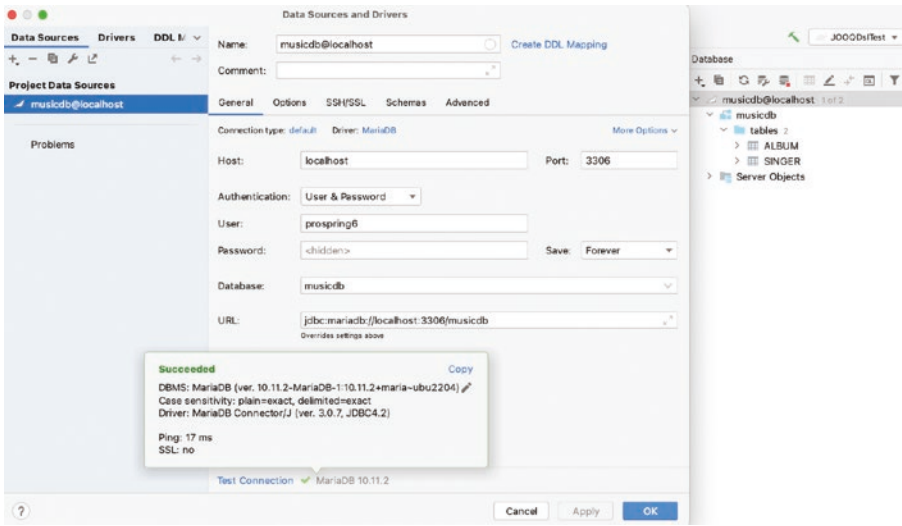


Figure A-3. Using IntelliJ IDEA Database view to check that a MariaDB container is usable.

For Chapter 13, two containers are needed, and they are created and configured using Docker Compose<sup>2</sup>. This is because these containers work together to provide a Kafka service, and the Kafka container needs to be configured with some details of the Zookeeper container that Docker compose injects.

## Building and Troubleshooting

After you clone the source code (or download it), you need to import the project in the IntelliJ IDEA editor. To do this, follow these steps:

- Select from the IntelliJ IDEA menu File ► New ► Project from Existing Sources (as shown in Figure A-4).

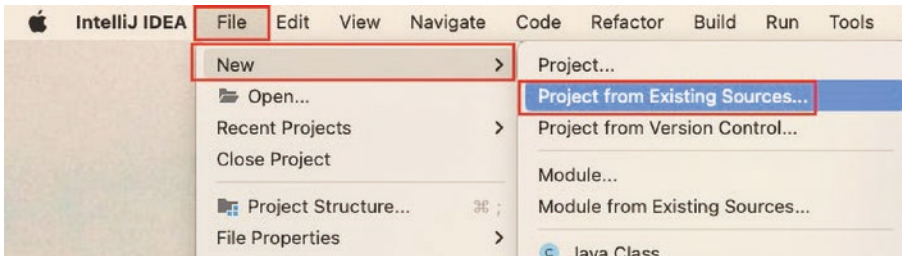


Figure A-4. Project import menu options in IntelliJ IDEA.

After selecting the proper option, a pop-up window will appear requesting the location of the project (as shown in Figure A-5).

<sup>2</sup><https://docs.docker.com/compose/compose-file>

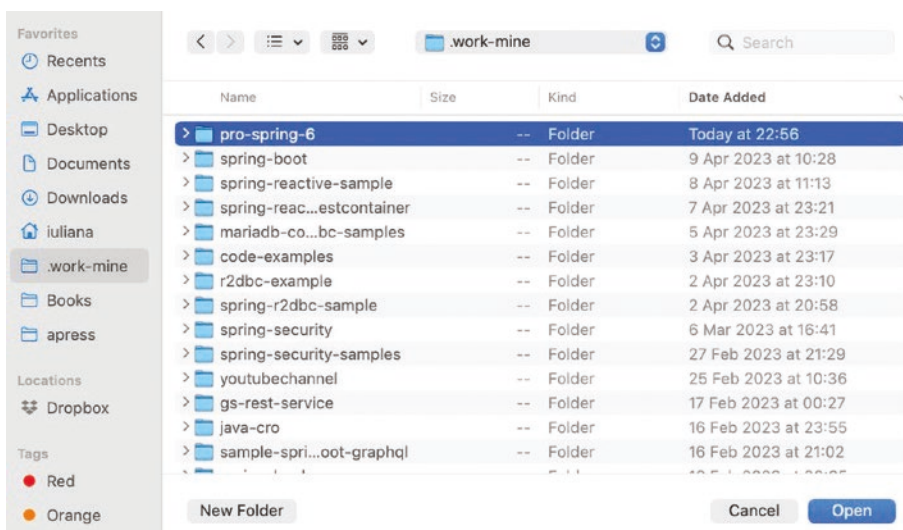


Figure A-5. Selecting the project root directory pop-up in IntelliJ IDEA.

- Select the pro-spring-6 directory. A pop-up will ask for the project type. IntelliJ IDEA can create its own type of project from the selected sources and build it with its internal Java builder, but this option is not useful here because pro-spring-6 is a Gradle project.
- Check the "Import project from external model" radio button and select Gradle or Maven from the menu, as depicted in Figure A-6.

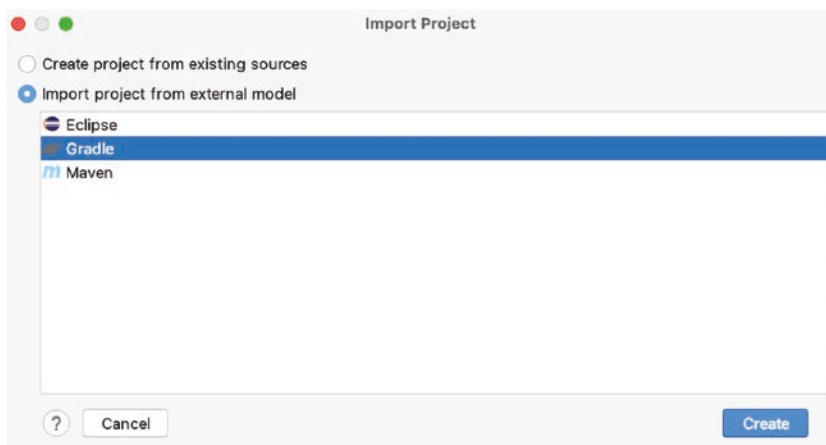
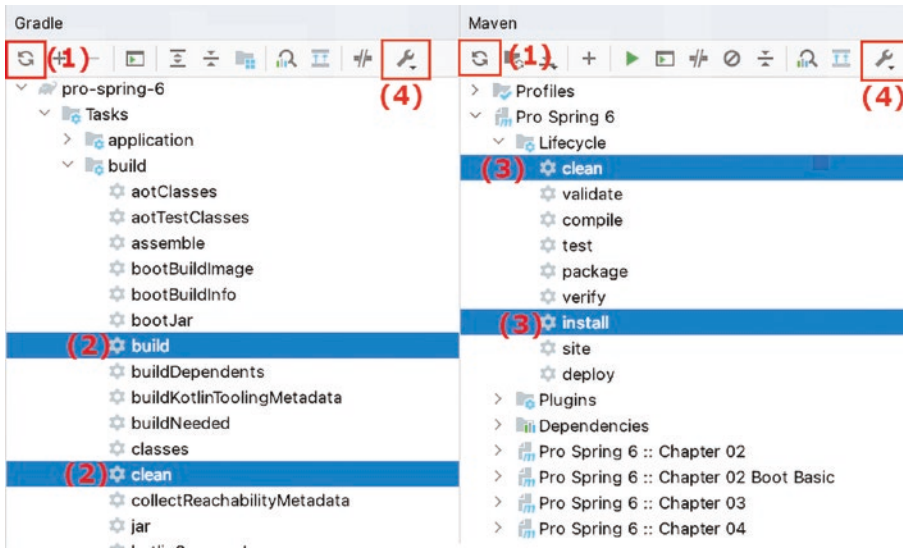


Figure A-6. Selecting the project type IntelliJ IDEA.

Before getting to work, you should build the project. This can be done from IntelliJ IDEA by clicking the Refresh button, as shown by (1) in Figure A-7. Clicking this button will cause IntelliJ IDEA to scan the configuration of the project and resolve dependencies. This includes downloading missing libraries and doing an internal light build of the project (just enough to remove compile-time errors caused by missing dependencies).



**Figure A-7.** IntelliJ IDEA Gradle and Maven View for building the project.

The Gradle clean and build tasks, marked with (2) in Figure A-7, execute a full build of the project. You can also do the same from the command line by executing the Gradle build command, as depicted below:

```
./gradlew #because of the default configured tasks
# or
./gradlew clean build
```

This will execute the following set of tasks on every module(here shown only for chapter02):

```
00:11:02: Executing 'build clean'...

Starting Gradle Daemon...

> Task :compileJava NO-SOURCE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :jar
> Task :assemble
> Task :compileTestJava NO-SOURCE
> Task :processTestResources NO-SOURCE
> Task :testClasses UP-TO-DATE
> Task :test NO-SOURCE
> Task :check UP-TO-DATE
```

- > Task :build
- > Task :chapter02:compileJava
- > Task :chapter02:processResources
- > Task :chapter02:classes
- > Task :chapter02:jar
- > Task :chapter02:assemble
- > Task :chapter02:compileTestJava
- > Task :chapter02:processTestResources NO-SOURCE
- > Task :chapter02:testClasses
- > Task :chapter02:test
- > Task :chapter02:check
- > Task :chapter02:build
- ...

The Maven clean and install goals marked with (3) in Figure A-7 execute a full build of the project. You can also do the same from the command line by executing the Gradle build command, as depicted below:

```
./mvnw #because of the default configured goals
# or
./mvnw clean install
```

If you have multiple JDKs installed, IntelliJ IDEA might not select the expected one to build your project with Gradle/Maven. In this case, click on the button marked with (4) in Figure A-7 and select Gradle Settings/Maven Settings and set JDK 19 in the pop-up that appears.

The pop-up box for configuring the JDK Gradle uses is depicted in Figure A-8.

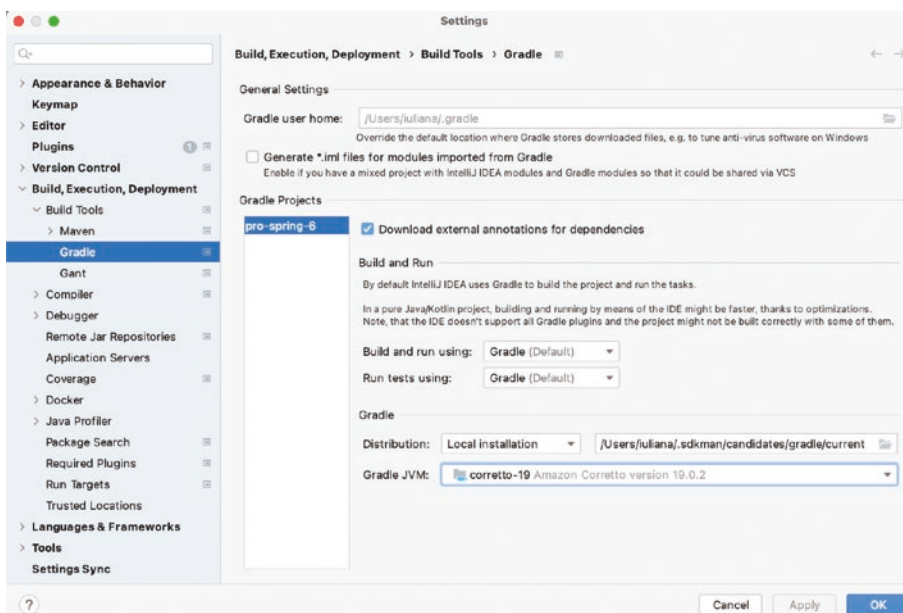


Figure A-8. IntelliJ IDEA JDK configuration pop-up for Gradle.

The pop-up box for configuring the JDK Maven uses is depicted in Figure A-9.

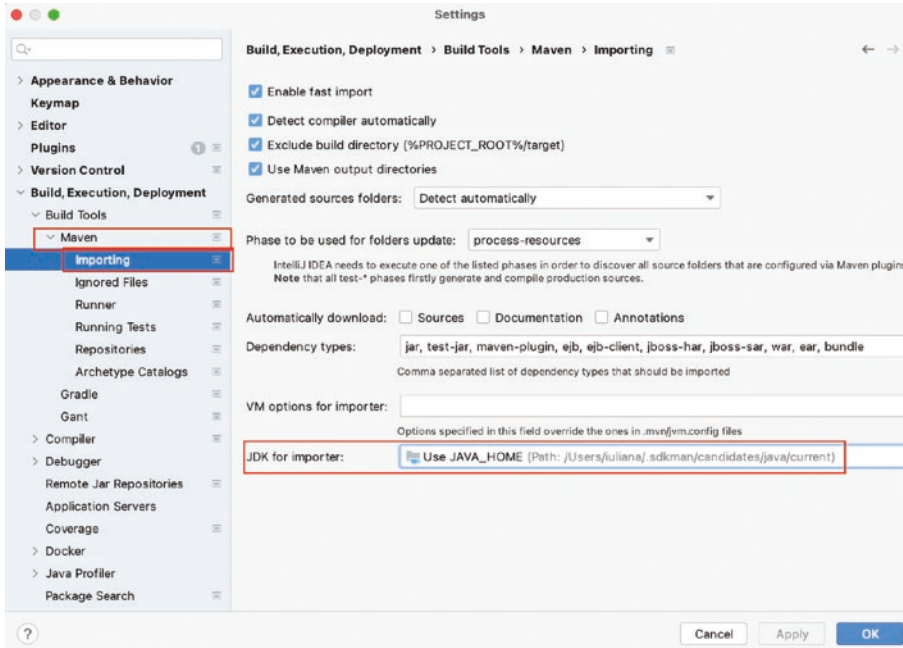


Figure A-9. IntelliJ IDEA JDK configuration pop-up for Maven.

You need to expand the **Maven** node and select **Importing** to see the **JDK for importer** selector.

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