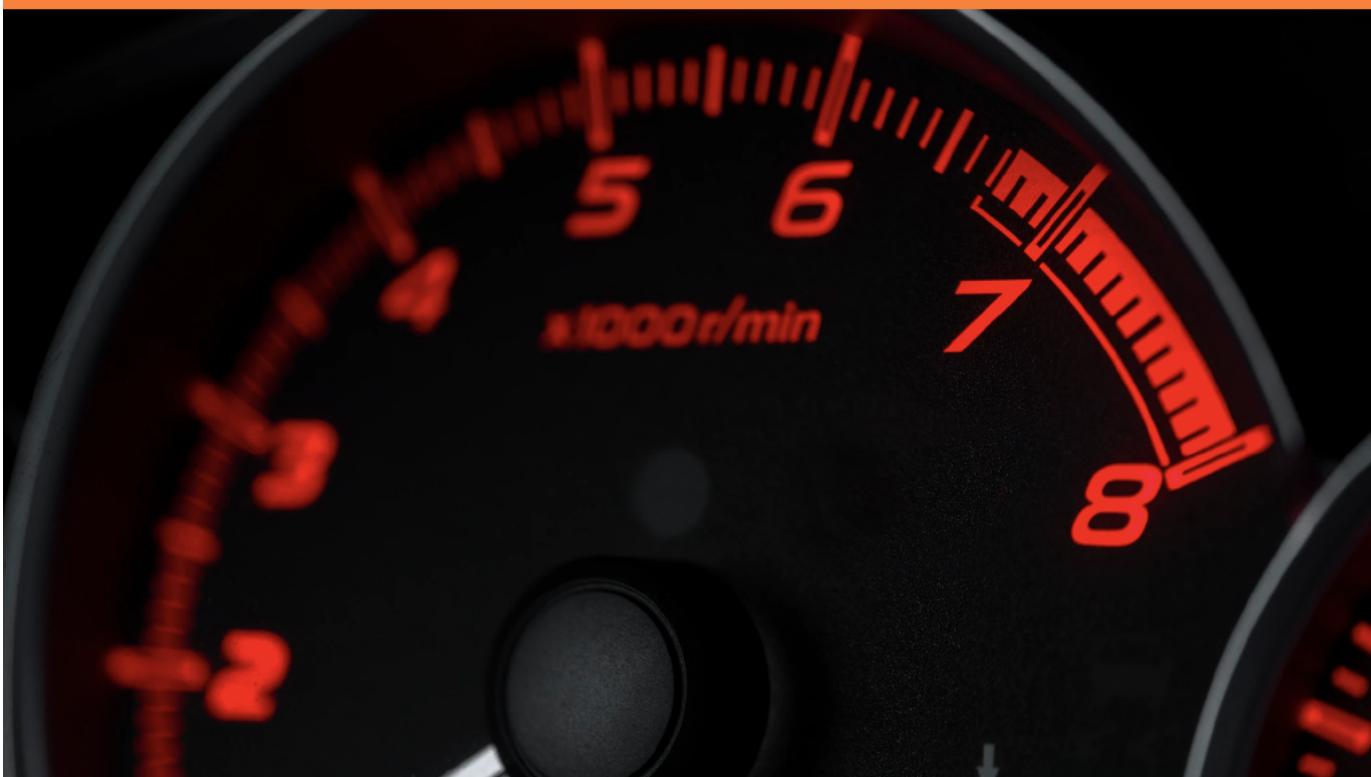


agoncal fascicle

Compliments of
Red Hat
Developer

Practising Quarkus



Antonio Goncalves
Foreword by Clement Escoffier

Practising Quarkus

Quarkus

Antonio Goncalves

2020-10-24

Table of Contents

Foreword	3
About the Author	4
Acknowledgments	5
Introduction	7
Where Does This Fascicle Come From?	7
Who Is This Fascicle For?	8
How Is This Fascicle Structured?	8
Conventions	9
The Sample Application	10
Downloading and Running the Code	11
Getting Help	12
Contacting the Author	12
1. First Step with Quarkus	13
2. Understanding Quarkus	15
2.1. Understanding Quarkus	15
2.2. Understanding MicroProfile	15
2.3. Summary	17
3. Getting Started	18
3.1. What Will You Build in This Fascicle?	18
3.1.1. Overall Architecture	18
3.1.2. User Interface	19
3.2. Setting up the Development Environment on macOS	21
3.2.1. Installing the Required Tools	21
3.2.2. Installing the Startup Code	22
Directory Structure	22
Maven Parent POM	23
3.2.3. Executing the Startup Code	25
3.2.4. Running the Infrastructure	25
3.2.5. Building the Angular Web Application	26
3.2.6. Checking Listening Ports	27
3.3. Summary	27
4. Developing the REST Number Microservice	28
4.1. What Will You Build in This Chapter?	28
4.1.1. Overall Architecture	28
4.1.2. Directory Structure	29
4.1.3. Maven Dependencies	29
4.2. Number REST Endpoint	32
4.2.1. The Number Resource	33

4.2.2. The Book Numbers Class	34
4.3. Injecting Configuration Value	35
4.4. Customising the JSON Output	36
4.5. OpenAPI	38
4.5.1. Customising the OpenAPI Contract of the Number REST Endpoint	40
4.5.2. Customising the BookNumber POJO	41
4.5.3. Customising the OpenAPI Contract of the Application	42
4.5.4. The Customised OpenAPI Contract	43
4.5.5. Swagger UI	44
4.6. Application Startup and Shutdown	46
4.6.1. Displaying the Current Environment	48
4.7. Running the Application	48
4.7.1. Live Reload	49
4.7.2. Configuring the Application	49
Configuring the Quarkus Listening Port	50
Configuring Logging	50
4.7.3. Testing the Application	50
Testing the Business Logic	51
Testing the OpenAPI	52
4.7.4. Executing the Application	53
4.8. Summary	54
5. Developing the REST Book Microservice	56
5.1. What Will You Build in This Chapter?	56
5.1.1. Overall Architecture	56
5.1.2. Directory Structure	57
5.1.3. Maven Dependencies	58
5.2. Book Entity	61
5.2.1. Adding Operations	63
5.3. Transactional Book Service	64
5.4. Book REST Endpoint	67
5.4.1. Dependency Injection	71
5.5. Validating Data	72
5.6. OpenAPI	75
5.6.1. Customising the OpenAPI Contract of the Application	75
5.6.2. The Customised OpenAPI Contract	75
5.6.3. Swagger UI	79
5.7. Application Startup and Shutdown	80
5.8. Running the Application	81
5.8.1. Configuring the Application	81
Configuring the Quarkus Listening Port	82
Configuring Hibernate	82

Configuring the Datasource	82
5.8.2. Adding Data	82
5.8.3. Testing the Application	83
Firing the Infrastructure	83
Testing the Business Logic	84
5.8.4. Running the Infrastructure	90
5.8.5. Executing the Application	91
5.9. Summary	91
6. Installing the Vintage Store User Interface	93
6.1. What Will You Build in This Chapter?.....	93
6.1.1. Overall Architecture.....	93
6.1.2. Directory Structure.....	94
6.1.3. NPM and Maven Dependencies.....	95
6.2. Angular Application.....	97
6.2.1. Services and Models.....	102
6.2.2. UI Components	104
6.3. Running the Application.....	106
6.3.1. Building the Web Application	106
6.3.2. Installing the Web Application on Quarkus	106
6.3.3. Executing the Application	107
6.4. Summary	107
7. Adding Communication and Fault Tolerance	108
7.1. What Will You Build in This Chapter?.....	108
7.1.1. Overall Architecture.....	108
7.1.2. Directory Structure	109
7.1.3. Maven Dependencies.....	110
7.2. CORS	111
7.3. REST Client	113
7.3.1. Book Microservice Invoking the Number Microservice	113
7.3.2. The Remote Number Microservice Interface	114
7.3.3. Configuring the REST Client Invocation	115
7.3.4. Executing the REST Client Invocation	115
7.4. Fallbacks	116
7.5. Timeout.....	118
7.6. Running the Application	120
7.6.1. Testing the Application	120
7.7. Summary	121
8. Monitoring the Microservices	123
8.1. What Will You Build in This Chapter?.....	123
8.1.1. Overall Architecture.....	123
8.1.2. Directory Structure	123

8.1.3. Maven Dependencies	124
8.2. Health Check	124
8.2.1. Running the Default Health Check	125
8.2.2. Adding a Liveness Health Check	126
8.2.3. Adding a Readiness Health Check	127
8.3. Metrics	129
8.4. Running the Application	131
8.4.1. Testing the Application	131
Testing Health Check	132
Testing Metrics	132
8.4.2. Running the Infrastructure	133
8.4.3. Executing the Application	133
8.4.4. Adding Load to the Application	133
8.4.5. Monitoring the Application	135
8.4.6. Collecting Metrics on Prometheus	136
Configuring Prometheus	136
Adding Graphs to Prometheus	136
8.5. Summary	138
9. Creating Executables and Building Containers	139
9.1. What Will You Build in This Chapter?	139
9.1.1. Overall Architecture	139
9.1.2. Maven Dependencies	140
9.2. Trying to Go Native	141
9.2.1. Building Native Executables	142
9.2.2. Testing the Native Executable	143
9.3. Containers	146
9.3.1. Building Executable JARs	146
9.3.2. Building Containers	147
9.3.3. Running Containers	148
9.4. Summary	151
10. Summary	152
Appendix A: Setting up the Development Environment on macOS	153
A.1. Homebrew	153
A.1.1. A Brief History of Homebrew	153
A.1.2. Installing Homebrew on macOS	153
A.1.3. Checking for Homebrew Installation	153
A.1.4. Some Homebrew Commands	154
A.2. Java 11	154
A.2.1. Architecture	154
A.2.2. A Brief History of Java	155
A.2.3. Installing the JDK on macOS	155

A.2.4. Checking for Java Installation	157
A.3. GraalVM 20.2.0	158
A.3.1. Architecture	158
A.3.2. A Brief History of GraalVM	159
A.3.3. Installing GraalVM on macOS	160
A.3.4. Installing the Native Image Generator	161
A.3.5. Checking for GraalVM Installation	161
A.4. Maven 3.6.x	162
A.4.1. A Brief History of Maven	162
A.4.2. Project Descriptor	162
A.4.3. Managing Artifacts	163
A.4.4. Installing Maven on macOS	164
A.4.5. Checking for Maven Installation	164
A.4.6. Some Maven Commands	165
A.5. Testing Frameworks	165
A.5.1. JUnit 5.x	165
A Brief History of JUnit	166
Writing Tests	166
Executing Tests	169
A.5.2. REST Assured 4.1.x	171
A.5.3. Hamcrest 2.2.x	172
A.5.4. TestContainers 1.13.x	174
A.6. cURL 7.x	176
A.6.1. A Brief History of cURL	176
A.6.2. Installing cURL on macOS	176
A.6.3. Checking for cURL Installation	177
A.6.4. Some cURL Commands	177
A.6.5. Formatting the cURL JSON Output with JQ	178
A.7. Docker	179
A.7.1. A Brief History of Docker	179
A.7.2. Installing Docker on macOS	179
A.7.3. Checking for Docker Installation	179
A.7.4. Building, Running, Pushing and Pulling Images	184
Remote Docker Repository	184
Dockerfile	185
Building the Docker Image	186
Running the Docker Image	186
Pushing to a Docker Registry	186
Pulling from a Docker Registry	187
A.7.5. Some Docker Commands	188
A.8. Git	189

A.8.1. A Brief History of Git	189
A.8.2. Installing Git on macOS	189
A.8.3. Checking for Git Installation	189
A.8.4. Cloning Repository	189
Appendix B: Quarkus Versions	191
B.1. Quarkus 1.8 (<i>September 2020</i>)	191
B.2. Quarkus 1.7 (<i>August 2020</i>)	191
B.3. Quarkus 1.6 (<i>July 2020</i>)	191
B.4. Quarkus 1.5 (<i>June 2020</i>)	192
B.5. Quarkus 1.4 (<i>April 2020</i>)	192
B.6. Quarkus 1.3 (<i>March 2020</i>)	192
B.7. Quarkus 1.2 (<i>January 2020</i>)	193
B.8. Quarkus 1.1 (<i>December 2019</i>)	193
B.9. Quarkus 1.0 (<i>November 2019</i>)	193
B.10. Quarkus 0.0.1 (<i>November 2018</i>)	193
Appendix C: Eclipse MicroProfile Specification Versions	195
C.1. MicroProfile 3.3 (<i>February 2020</i>)	195
C.2. MicroProfile 3.2 (<i>November 2019</i>)	195
C.3. MicroProfile 3.1 (<i>October 2019</i>)	195
C.4. MicroProfile 3.0 (<i>June 2019</i>)	195
C.5. MicroProfile 2.2 (<i>February 2019</i>)	196
C.6. MicroProfile 2.1 (<i>October 2018</i>)	196
C.7. MicroProfile 2.0.1 (<i>July 2018</i>)	196
C.8. MicroProfile 2.0 (<i>June 2018</i>)	196
C.9. MicroProfile 1.4 (<i>June 2018</i>)	197
C.10. MicroProfile 1.3 (<i>January 2018</i>)	197
C.11. MicroProfile 1.2 (<i>September 2017</i>)	197
C.12. MicroProfile 1.1 (<i>August 2017</i>)	198
C.13. MicroProfile 1.0	198
Appendix D: References	199
Appendix E: Fascicles by the Same Author	200
E.1. Understanding Bean Validation 2.0	200
E.2. Understanding JPA 2.2	200
E.3. Understanding Quarkus	200
E.4. Practising Quarkus	201
Appendix F: Printed Back Cover	202

Practising Quarkus

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The distribution of the book is made through Amazon KDP (Kindle Direct Publishing).^[1]

Any source code referenced by the author in this text is available to readers at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/tree/1.0>. This source code is available for reproduction and distribution as it uses an MIT licence.^[2]

- www.antoniogoncalves.org
- www.antoniogoncalves.org/category/books
- www.amazon.com/author/agoncal

Version Date: 2020-10-24

To my wonderful kids, Eloise, Ligia and Ennio, who are the best thing life has given me.

Foreword

I started learning Java in 1999. Over the past 20 years, I have witnessed the journey that Java and its ecosystem have been on. But 20 years is a long time, especially for software. Many trends have been called the "next big thing" only to then fade away. How many times have we read about the supposed death of Java? But it is still very much alive!

Corba, Applet, JavaEE, Spring, OSGi, Android, OpenJDK... all of these technologies have shaped the Java we know today. All of these technologies have pushed the limits of Java and have led to an increase in its versatility. That's how Java has endured across the ages: by adapting itself.

Nowadays, Java is facing another challenge. The rise of the Cloud, Containers and Serverless has pushed Java away from the spotlight. Until now, until Quarkus.

And, there is no better way to start with Quarkus than with this fascicle (and its companion fascicle *Understanding Quarkus*). The extensive expertise of Antonio is the perfect tool to guide you towards new horizons. You are going to see *live* how Quarkus mutates Java to make it relevant in Containers, on Kubernetes and in Serverless environments. From the first line of code to production monitoring, this fascicle is your companion. Fasten your seat belt, and get ready to take off!

Clement Escoffier

Vert.x and Quarkus Core Developer at Red Hat

[@clementplop](#)

[1] KDP <https://kdp.amazon.com>

[2] MIT licence <https://opensource.org/licenses/MIT>

About the Author



Antonio Goncalves is a senior software architect living in Paris. Having been focused on Java development since the late 1990s, his career has taken him to many different countries and companies where he now works as a recognised consultant. As a former employee of BEA Systems (acquired by Oracle), he developed a very early expertise on distributed systems. He is particularly fond of open source and is a member of the OSSGTP (Open Source Solution Get Together Paris). Antonio loves to create bonds with the community. So, he created the Paris Java User Group in 2008 and co-created Devoxx France in 2012 and Voxxed Microservices in 2018.^[3]

Antonio wrote his first book on Java EE 5, in French, in 2007. He then joined the JCP to become an Expert Member of various JSRs (Java EE 8, Java EE 7, Java EE 6, CDI 2.0, JPA 2.0, and EJB 3.1) and wrote *Beginning Java EE 7* and *Beginning Java EE 8* with Apress.^[4] Still hooked on sharing his knowledge, Antonio Goncalves decided to then self-publish his later fascicles.

For the last few years, Antonio has given talks at international conferences, mainly on Java, distributed systems and microservices, including JavaOne, Devoxx, GeeCon, The Server Side Symposium, Jazoon, and many Java User Groups. He has also written numerous technical papers and articles for IT websites (DevX) and IT magazines (Java Magazine, Programmez, Linux Magazine). Since 2009, he has been part of the French Java podcast called Les Cast Codeurs.^[5]

In recognition of his expertise and all of his work for the Java community, Antonio has been elected **Java Champion**.^[6]

Antonio is a graduate of the Conservatoire National des Arts et Métiers in Paris (with an engineering degree in IT), Brighton University (with an MSc in object-oriented design), Universidad del País Vasco in Spain, and UFSCar University in Brazil (MPhil in Distributed Systems). He also taught for more than 10 years at the Conservatoire National des Arts et Métiers where he previously studied.

Follow Antonio on Twitter (@agoncal) and on his blog (www.antoniogoncalves.org).

[3] Devoxx France <https://devoxx.fr>

[4] Amazon <https://www.amazon.com/author/agoncal>

[5] Les Cast Codeurs <https://lecastcodeurs.com>

[6] Java Champions <https://community.oracle.com/community/groundbreakers/java/java-champions>

Acknowledgments

In your hands, you have a technical fascicle that comes from my history of writing, learning and sharing. When writing, you need a dose of curiosity, a glimpse of discipline, an inch of concentration, and a huge amount of craziness. And of course, you need to be surrounded by people who help you in any possible way (so you don't get totally crazy). And this is the space to thank them.

First of all, I really want to thank my proofreading team. After the process of writing, I was constantly in contact with Clement, Youness and Mike who reviewed the book and gave me precious advice. I have to say, it was a real pleasure to work with such knowledgeable developers.

It is a great honour to have **Clement Escoffier** writing the foreword of this book. Clement is a software engineer at Red Hat. He has had several professional lives, from academic positions to management. Currently, he is mainly working as a Quarkus and Vert.x developer. He has been involved in projects and products touching many domains and technologies such as OSGi, mobile app development, continuous delivery, DevOps, etc. His main area of interest is software engineering, processes, methods and tools that make the development of software more efficient and also more fun. Clement is an active contributor to many open source projects such as Apache Felix, iPOJO, Wisdom Framework, Eclipse Vert.x, SmallRye, Eclipse MicroProfile and, of course, Quarkus.

Youness Teimouri is currently a Senior Software Developer in Silicon Valley with over 15 years of development experience, particularly in Java, across various countries.^[7] He has utilised Java stack to help numerous companies scale in a variety of industries such as Telecoms, ERP systems, Mobile Banking, and Payment systems, etc. He has co-authored and contributed to some papers on Cloud-Computing and some of my previous books. Youness is fascinated by the endless possibilities of Java in different industries and enjoys mentoring junior developers, inspiring them to develop their own Java skill-set.

Mike François is a senior solution architect specialising in Java technology oriented API, Edge and Cloud architecture.^[8] He started with Java from 2005 and was heavily involved in different communities as technical writer for Developpez.com and Dzone. After several years as a developer, he moved to various places to learn more about dev/ops, testing, methodologies and all kinds of architecture (enterprise, solution, api, technical, cloud, edge).

Thanks to my proofreader, **Gary Branigan**, who added a Shakespearean touch to this fascicle.

And thanks to Emmanuel Bernard and Clement Escoffier for working with me on the original Quarkus workshop at which this fascicle had its genesis.^[9]

I could not have written this fascicle without the help and support of the Java community: blogs, articles, mailing lists, forums, tweets etc.

The fascicle you have in your hands uses a rich Asciidoc 2.0.10 toolchain, making it possible to create PDF, EPUB and MOBI files. I am really grateful to the Asciidoc community and, of course, to Dan Allen who helped me in sorting out a few things so that the end result looks so great.^[10] PlantUML is an amazing tool with a very rich syntax for drawing diagrams... and sometimes, you need a bit of help. So, thanks to the PlantUML community.^[11] As for the text editor used to write this

fascicle, you might have guessed: it's an IDE! Thank you JetBrains for providing me with a free licence for your excellent IntelliJ IDEA.^[12]

Living in Paris, I also have to thank all the bars who have given me shelter so that I could write while drinking coffee and talking to people: La Fontaine, Le Chat Bossu, La Grille, La Liberté and Bottle Shop.

As you might have guessed, I have a passion for IT. But I have other passions such as science, art, philosophy, cooking... and music (I even play jazz guitar). I cannot work without listening to music, so while I was writing this fascicle, I spent most of my time listing to the best radio ever: FIP.^[13] Thank you FIP.

And a big kiss to my wonderful kids, Eloise, Ligia and Ennio. They are the best present life has given me.

Thank you all!

[7] Youness Teimouri <http://www.youness-teimouri.com>

[8] Mike François https://twitter.com/mike_francois

[9] Quarkus Workshop <https://quarkus.io/quarkus-workshops/super-heroes>

[10] AsciiDoctor <http://asciidoc.org>

[11] PlantUML <http://plantuml.com>

[12] IntelliJ IDEA <https://www.jetbrains.com/idea>

[13] FIP <https://www.fip.fr>

Introduction

In the late 90s, I was working on J2EE 1.2: the very first release of the *Java Enterprise Edition*. It was also the time where companies started to realise the potential of the Internet for their business. For a few months, I worked for a famous English airline company setting up their e-commerce website. Yes, it was a time where you would usually buy a flight or train ticket at a travel agency. This revolutionary move (buying flights online) came at a technical cost: a cluster for static content (HTML, CSS, images), a cluster for the web tier (Servlets and JSPs), a cluster for Stateless EJBs, a cluster for Entity Beans, and a cluster for the database. And as you can imagine, load balancing, failover and sticky sessions for every tier were loaded with application servers. This e-commerce website went live... and it worked!

Then came Struts, Spring and Hibernate. Full J2EE application servers shrank down to servlet containers such as Tomcat or Jetty. We could see things moving, such as architectures becoming stateless, failover being abandoned, migrations from SOAP to REST and mobile devices taking over web crawling. Then came the *Internet of Things* (IoT), the cloud, microservices, *Function as a Service* (FaaS), and it never stops moving. Other things didn't change, like the good old *Gang of Four* design patterns, architecture design patterns, unit testing frameworks and building tools. We reinvented some wheels and gave them different names, but we also learnt dozens of new promising programming languages (running on top of the JVM or not) and agile techniques. Thanks to these evolutions that I have witnessed, today you can sit down, read this fascicle and write some code.

Where Does This Fascicle Come From?

Involved in J2EE since 1998, I followed its evolution and joined the Java EE expert group from version 6 to version 8. During that time, I wrote a book in French called "*Java EE 5*".^[14] The book was published by a French editor and got noticed. I was then contacted by Apress, an American editor, to work on an English version. I liked the challenge. So, I changed the structure of the book, updated it, translated it, and I ended up with a "*Beginning Java EE 6*" book. A few years later, Java EE 7 was released, so I updated my book, added a few extra chapters, and ended up with a "*Beginning Java EE 7*" that was 500 pages long.^[15] This process of writing got a bit painful (some text editors shouldn't be used to write books), inflexible (it's hard to update a paper book frequently) and I also had some arguments with my editor.^[16]

Parallel to that, the history of Java EE 8 was also somewhat painful and long.^[17] I was still part of the Expert Group, but nobody really knew why the experts' mailing list was so quiet. No real exchange, no real vision, no real challenges. That's when I decided not to work on a Java EE 8 book. But the community said otherwise. I started receiving emails about updating my book. I used to always meet someone at a conference going "*Hey, Antonio, when is your next book coming out?*" My answer was "*No way!*"

I decided to take stock. What was holding me back from writing? Clearly it was my editor and Java EE 8. So, I decided to get rid of both. I extracted the chapters I wanted from my Java EE 7 book and updated them. That's where the idea of writing "*fascicles*", instead of an entire book, came from. Then, I looked at self-publishing, and here I am at Amazon Kindle Publishing.^[18]

After self-publishing a few fascicles, I saw that Red Hat was working on a game changer: Quarkus. I started to look at it at a very early stage, and got the idea of creating a workshop. I contacted the

Quarkus team to submit my idea: Emmanuel Bernard and Clement Escoffier liked it, and we put together a workshop and gave it at a few conferences.^[19] This workshop inspired me to write this fascicle. I did with the Quarkus team and is thus structured in a different way and easier to read.

I hope you'll find this fascicle useful.

Who Is This Fascicle For?

Quarkus has its genesis in the JBoss community. JBoss has extensive experience of running applications on application servers (JBoss EAP, WildFly) and building reactive applications on the JVM (with Eclipse Vert.x for example). Due to its extension mechanism, Quarkus supports several Java frameworks (e.g. Hibernate, Camel, etc.) as well as specifications (e.g. a subset of Jakarta EE, or MicroProfile which is a set of specifications to develop microservices in Java).

So, this fascicle is for the Java community as a whole and for those of you interested in microservice architectures. The only requirements to follow and understand this fascicle are having a knowledge of Java and having some knowledge of relational databases and Docker.

How Is This Fascicle Structured?

This fascicle concentrates on Quarkus 1.9.0.Final. Its structure will help you to discover this technology as well as helping you to further dive into it if you already have some experience of it.

This fascicle starts with [Chapter 1, First Step with Quarkus](#) by showing a few lines of Quarkus code. That's because, as developers, we like to read code first when learning a new technology.

[Chapter 2, Understanding Quarkus](#) briefly presents Quarkus, the problems it addresses and explains the common concerns discussed throughout the fascicle. This chapter also looks at the standardisation side of MicroProfile and where it comes from.

[Chapter 3, Getting Started](#) is all about getting your environment ready so you can develop the entire microservice architecture.

In [Chapter 4, Developing the REST Number Microservice](#) you will develop a first microservice named Number which is just a REST endpoint that generates ISBN book numbers and exposes OpenAPI documentation on Quarkus.

In [Chapter 5, Developing the REST Book Microservice](#) you will develop a second microservice. The Book microservice allows transactional create/read/update/delete operations on a PostgreSQL relational database.

[Chapter 6, Installing the Vintage Store User Interface](#) is about packaging and installing an already-developed Angular application in Quarkus. This user interface allows us to interact graphically with the microservices.

In [Chapter 7, Adding Communication and Fault Tolerance](#) you will make all of the components communicate with each other. Communication in a distributed environment can be challenging as you need to deal with network failure and latency. That's when fault-tolerance comes into play.

The more microservices you have in an architecture, the harder it is to monitor them. In [Chapter 8, Monitoring the Microservices](#) you will develop health checks to both microservices so you know they are up and running. You'll also add metrics and visualise them with Prometheus so you can visualise the throughput of each microservice.

[Chapter 9, Creating Executables and Building Containers](#) is used to create native executables for each microservice. You will package these executables with Docker so they can be portable across servers.

[Chapter 10, Summary](#) wraps up with a summary of what you've learnt in this fascicle.

[Appendix A, Setting up the Development Environment on macOS](#) highlights the tools used throughout the fascicle and how to install them.

[Appendix B, Quarkus Versions](#) lists all the Quarkus releases.

[Appendix C, Eclipse MicroProfile Specification Versions](#) lists all the revisions of the MicroProfile specification.

[Appendix D](#) points to some external references which are worth reading if you want to know more about Quarkus.

This is not the only fascicle I have written. You'll find a description of the other fascicles in [Appendix E](#):

- *Understanding Bean Validation 2.0*
- *Understanding JPA 2.2*
- *Understanding Quarkus*
- *Practising Quarkus*

Conventions

This fascicle uses a diverse range of languages, mostly Java, but also JSON, XML, YAML or shell scripts. Each code example is displayed appropriately and appears in **fixed-width font**. All the included code comes from a public Git repository and is continuously tested. Therefore, you shouldn't have any problem with code that is not syntactically correct. In some cases, the original source code has been specially formatted to fit within the available page space, with additional line breaks or modified indentation. To increase readability, some examples omit code where it is seen as unnecessary. But always remember that you can find the entire code online at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/tree/1.0>.

Italics are used to *highlight an important word for the first time*, or to give the definition of an abbreviation or *acronym*. Bold is **rarely used**.



Some useful information.



Something you really should do if you want the code to work properly.



Warns you of a possible technical problem.

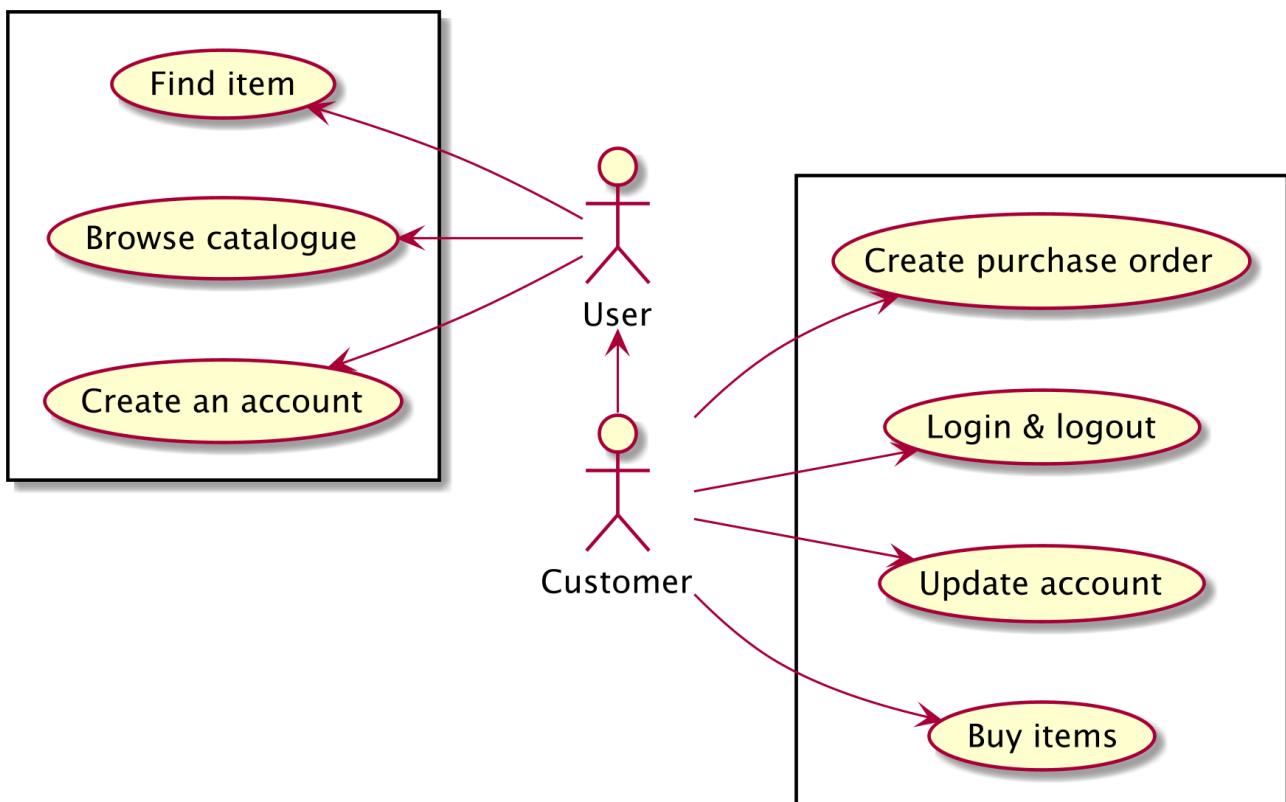
The Sample Application

Throughout the book, you will see snippets of code all belonging to the Vintage Store application. I created this application for my very first book, and I still use it as an example. This application is an e-commerce website allowing users to browse a catalogue of vintage stuff (vinyl, tapes, books and CDs). Using a shopping cart, they can add or remove items as they browse the catalogue and then check out so that they can pay and obtain a purchase order. The application has external interactions with a bank system to validate credit card numbers.

The actors interacting with the system are:

- *Employees* of the company who need to manage both the catalogue of items and the customers' details. They can also browse the purchase orders.
- *Users* who are anonymous persons visiting the website and who are consulting the catalogue of books and CDs. If they want to buy an item, they need to create an account to become customers.
- *Customers* who can login to the system, browse the catalogue, update their account details, and buy items online.
- The external *Bank* to which the system delegates credit card validations.

Figure 1 depicts the use case diagram which describes the system's actors and functionalities.



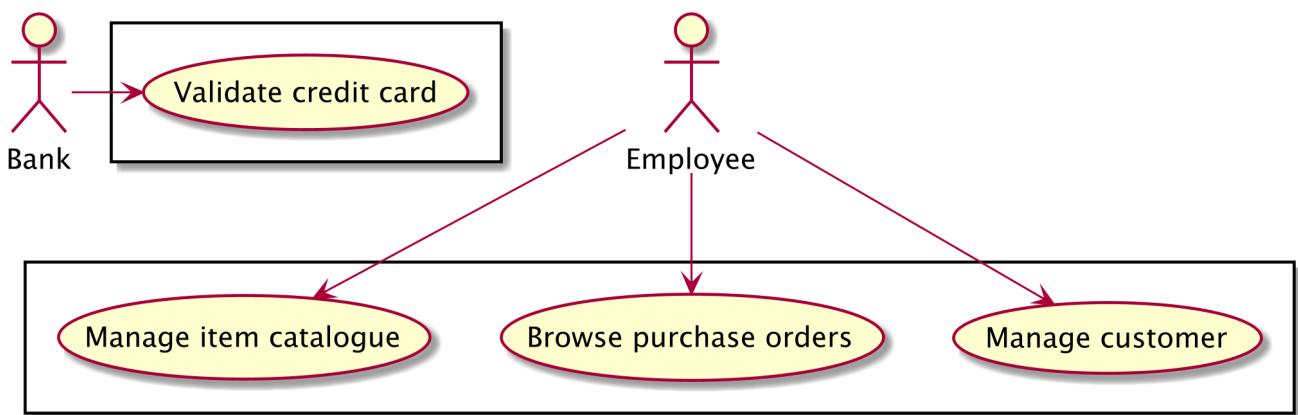


Figure 1. Use case diagram of the Vintage Store application

The Vintage Store application manipulates a few domain objects that are described in Figure 2. Vinyl, tapes, books and CDs, of course, but also chapters, authors, purchase orders, invoices and shopping carts. Don't spend too much time on this diagram for now as you will come across most of these objects throughout this fascicle.

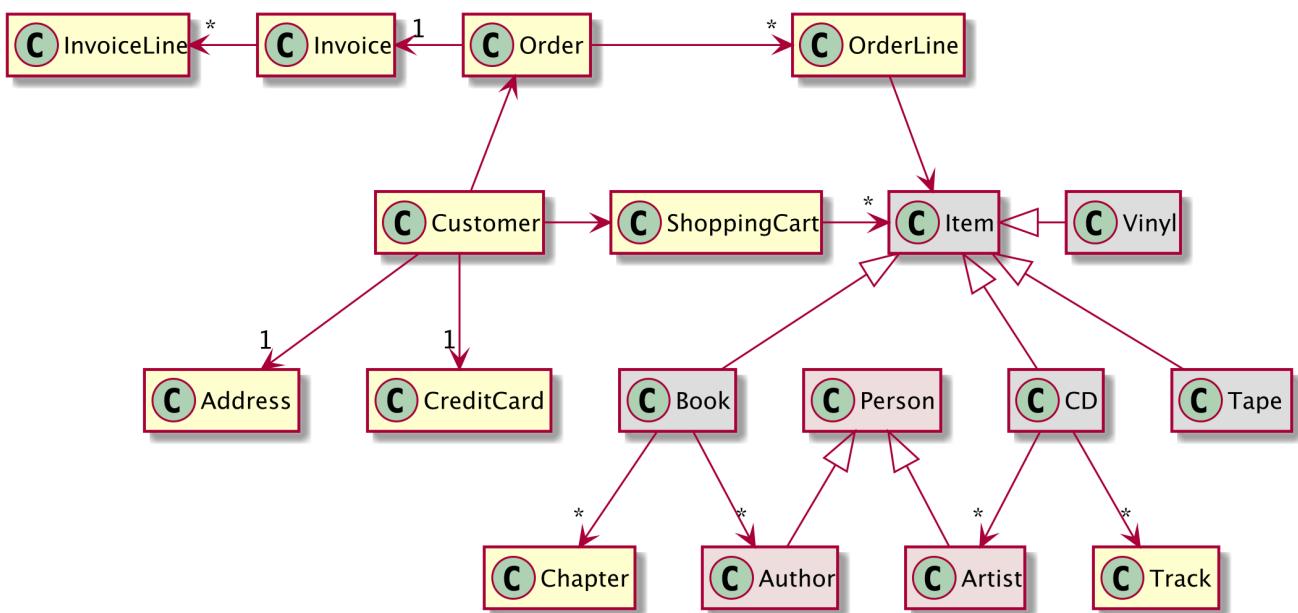


Figure 2. Class diagram of the Vintage Store application



The code you'll see in this fascicle gets its inspiration from the Vintage Store application, but it's not the original application per-se. You can download the code of the original application if you want, but it's not necessary in order to follow the code of this fascicle.^[20]

Downloading and Running the Code

The source code of the examples in the fascicle is available from a public Git repository and can be cloned, downloaded or browsed online at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/tree/1.0>. The code has been developed and tested on the macOS platform but should also work on Windows or Linux. The examples used in this fascicle are designed to be compiled with Java 11, to be built with Maven 3.6.x and to be tested with JUnit 5.x and to store data in an H2 database.

GraalVM 20.2.0 is used to build native images. [Appendix A](#) shows you how to install all of these software packages which will be used in most of the chapters to build, run and test the code.

Getting Help

Having trouble with the code, the content or the structure of the fascicle? Didn't understand something? Not clear enough? I am here to help! Do not hesitate to report issues or any questions at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/issues>. I'll do my best to answer them. This will also allow me to improve the content of this fascicle, and upload a new version through Amazon Kindle Publishing.

Contacting the Author

If you have any questions about the content of this fascicle, please use the instructions above and use the GitHub issue tracker. But if you feel like contacting me, drop me an email at agoncal.fascicle@gmail.com or a tweet at [@agoncal](#). You can also visit my blog at:

- www.antoniogoncalves.org
- www.antoniogoncalves.org/category/books

[14] Autonio's books <http://amazon.com/author/agoncal>

[15] My Java EE Books <https://antoniogoncalves.org/category/books>

[16] The Uncensored Java EE 7 Book <https://antoniogoncalves.org/2014/09/16/the-uncensored-java-ee-7-book>

[17] Opening Up Java EE <https://blogs.oracle.com/theaquarium/opening-up-ee-update>

[18] Amazon Kindle Publishing <https://kdp.amazon.com>

[19] Quarkus workshop <https://quarkus.io/quarkus-workshops/super-heroes>

[20] Code of the Vintage Store application <https://github.com/agoncal/agoncal-application-cdbookstore>

Chapter 1. First Step with Quarkus

If you are reading this fascicle, it's because you are a developer. And like most developers, when you learn a new technology or framework, you like to see some code first. So here is the very first step with Quarkus.

[Listing 1](#) shows a Java class representing an Author REST resource. This resource "listens" to HTTP requests on the `/authors` URL and has two methods: one returning the entire list of sci-fi authors, and another one returning a single author giving the index of the array.

Listing 1. Java Class with JAX-RS Annotations

```
@Path("/authors")
@Produces(MediaType.TEXT_PLAIN)
public class AuthorResource {

    String[] scifiAuthors = {"Isaac Asimov", "Nora Jemisin", "Douglas Adams"};

    @GET
    public String getAllScifiAuthors() {
        return String.join(", ", scifiAuthors);
    }

    @GET
    @Path("/{index}")
    public String getScifiAuthor(@PathParam("index") int index) {
        return scifiAuthors[index];
    }
}
```

If you look carefully at [Listing 1](#), you can see a few JAX-RS annotations (`@Path`, `@Produces`, `@GET`, and `@PathParam`) but no specific Quarkus' code. So where is Quarkus?

Actually, you can find a little bit of Quarkus in [Listing 2](#) (because most of the code is from REST Assured). Here, we use the `@QuarkusTest` annotation to let Quarkus test the *Author* REST resource. We target the URL `/authors` with an HTTP GET method (with and without an index parameter), and we make sure the HTTP status code is `200-OK` and that the content of the HTTP body is correct.

Listing 2. Test Class with a Quarkus Annotation

```
@QuarkusTest
public class AuthorResourceTest {

    @Test
    public void shouldGetAllAuthors() {
        given().
        when()
            .get("/authors").
        then()
            .statusCode(OK.getStatusCode())
            .body(is("Isaac Asimov, Nora Jemisin, Douglas Adams"));
    }

    @Test
    public void shouldGetAnAuthor() {
        given()
            .pathParam("index", 0).
        when()
            .get("/authors/{index}").
        then()
            .statusCode(OK.getStatusCode())
            .body(is("Isaac Asimov"));
    }
}
```

You didn't understand all the code? You did understand it but you feel there is more to it than that? The fascicle you have in your hands is all about Quarkus. Thanks to the chapters that follow, you will understand the basics of this technology and will have plenty of examples so that you can dive into more complex topics.

Chapter 2. Understanding Quarkus

In the previous *First Step with Quarkus* chapter, you've already seen some code. But before going further into more code, we need to step back and define some concepts. This *Understanding* chapter gives you some terminology that will be used in the rest of the fascicle so you don't get lost.

2.1. Understanding Quarkus

Quarkus is *A Kubernetes Native Java stack tailored for OpenJDK HotSpot & GraalVM, crafted from the best of breed Java libraries and standards*.^[21] In practice, Quarkus is an Open Source stack for writing Java applications, specifically back end applications. So Quarkus is not limited to microservices, even though it is highly suited for it.

Java was born in 1995 and, at the time, was mostly used to write GUI applications and Applets. The language was based on the available hardware using single cores and multi-threads. Quickly the language moved to the servers, and we started developing monolithic applications, designed to run on huge machines 24/7 for months (even years), with lots of CPU and memory. The JVM startup time was not an issue, the memory used by the JVM was huge, but we just let the JIT optimise the execution over time and left the GC manage the memory efficiently. Slow startup time and resource consumption don't fit well in our new environment where we need to deploy hundreds of microservices into the cloud, move them around and stop and start them quickly. Instead of scaling an application by adding more CPU and memory, we now scale microservices dynamically by adding more instances. That's where Quarkus, GraalVM, Kubernetes and other projects come into play.

Quarkus tailors applications for GraalVM and HotSpot. The result is that your application will have amazingly fast boot time and incredibly low RSS memory offering high density memory utilisation in container orchestration platforms like Kubernetes.

From a developer's point of view, Quarkus proposes a nice developer experience: it gives you fast live reload, unified configuration and hides the complexity of GraalVM allowing you to easily generate native executables. All this without reinventing the wheel by proposing a new programming model, Quarkus leverages your experience in standard libraries that you already know (e.g. CDI, JPA, Bean Validation, JAX-RS, etc.) as well as many popular frameworks (e.g. Eclipse Vert.x, Apache Camel, etc.).

If you like the format of this fascicle and are interested in Quarkus, check out the references for my *Understanding Quarkus* fascicle in [Appendix E](#). In this *Understanding* fascicle, you will learn about Quarkus' architecture, Microservices, MicroProfile, GraalVM, Reactive Systems and much more.



2.2. Understanding MicroProfile

Having an extension mechanism, Quarkus implements many features and integrates with many external frameworks. But being microservices-oriented, Quarkus implements the entire set of specifications of MicroProfile.

Eclipse MicroProfile addresses the need for enterprise Java microservices.^[22] It is a set of specifications for handling microservices design patterns. MicroProfile enables Jakarta EE developers to leverage their existing skill set while shifting their focus from traditional monolithic applications to microservices. MicroProfile APIs establish an optimal foundation for developing microservices-based applications by adopting a subset of the Jakarta EE standards and extending them to address common microservices' patterns. *Eclipse MicroProfile* is specified under the *Eclipse Foundation* and is implemented by *SmallRye*.

Compliant implementations of Eclipse MicroProfile 3.3 must provide at least the following APIs:

- *Context and Dependency Injection* (CDI) is a standard dependency injection framework included in Java EE and MicroProfile.
- *Java API for RESTful Web Services* (JAX-RS) is a standard Java API that provides support for creating web services according to the *Representational State Transfer* (REST) architectural style.
- *JSON Binding* (JSON-B) is a standard binding layer for converting Java objects to/from JSON documents.
- *JSON Processing* (JSON-P) is a Java API to process (parse, generate, transform and query) JSON messages.
- *Common Annotations* is a set of annotations for common semantic concepts in the Java SE, Java EE and MicroProfile platforms.
- *Configuration* injects configuration property values directly into an application that comes from different sources.
- *Fault Tolerance* provides a simple and flexible solution to build fault tolerant microservices (e.g. timeouts, retries, fallbacks, etc.), which is easy to use and configurable.
- *Health* allows applications to provide information about their state to external viewers.
- *JWT* provides *Role-Based Access Control* (RBAC) using OpenID Connect (OIDC) and JSON Web Tokens (JWT).
- *Metrics* provides a unified way for servers to export monitoring data to management agents.
- *OpenAPI* provides a unified Java API for the OpenAPI v3 specification to expose API documentation.
- *OpenTracing* defines an API that allows services to easily participate in a distributed tracing environment.
- *REST Client* provides a type safe approach using proxies and annotations for invoking RESTful services over HTTP.

MicroProfile 3.3 specifications are described in [Table 1](#). You find specifications that come from Jakarta EE (e.g. CDI, JAX-RS, etc.) as well as brand new specifications that were created with microservices in mind.

Table 1. MicroProfile 3.3 Specifications

Specification	Version	URL
Context and Dependency Injection (CDI)	2.0	https://jcp.org/en/jsr/detail?id=365

Specification	Version	URL
Java API for RESTful Web Services (JAX-RS)	2.1	https://jcp.org/en/jsr/detail?id=370
JSON Binding (JSON-B)	1.0	https://jcp.org/en/jsr/detail?id=367
JSON Processing (JSON-P)	1.1	https://jcp.org/en/jsr/detail?id=374
Common Annotations	1.3	https://jcp.org/en/jsr/detail?id=250
Configuration	1.4	https://microprofile.io/project/eclipse/microprofile-config
Fault Tolerance	2.1	https://microprofile.io/project/eclipse/microprofile-fault-tolerance
Health	2.2	https://microprofile.io/project/eclipse/microprofile-health
JWT	1.1	https://microprofile.io/project/eclipse/microprofile-jwt-auth
Metrics	2.3	https://microprofile.io/project/eclipse/microprofile-metrics
OpenAPI	1.1	https://microprofile.io/project/eclipse/microprofile-open-api
OpenTracing	1.3	https://microprofile.io/project/eclipse/microprofile-opentracing
REST Client	1.4	https://microprofile.io/project/eclipse/microprofile-rest-client

SmallRye is an open source project that implements the Eclipse MicroProfile specifications.^[23] It is community-driven and everyone is welcome to contribute to it. SmallRye implementations are tested against the Eclipse MicroProfile TCKs (*Technology Compatibility Kits*). Several open source projects integrate SmallRye such as Thorntail, WildFly, WebSphere Liberty and Quarkus.

2.3. Summary

This *Understanding* chapter gave you most of the required terminology around Quarkus. There is less code in this chapter than in the following ones, but we needed to make sure you understand all the concepts around Quarkus before going any further.

Quarkus is an Open Source stack for writing Java applications, specifically microservices, that's why it implements MicroProfile... but also much more. That's what you are about to discover in the following chapters.

[21] Quarkus <https://quarkus.io>

[22] MicroProfile <https://microprofile.io>

[23] SmallRye <https://github.com/smallrye>

Chapter 3. Getting Started

This fascicle offers an intro-level, hands-on experience with Quarkus, from the first line of code to making microservices, consuming them, and finally to assembling everything in a consistent system. It should give you a practical introduction to Quarkus. You will first install all the required tools to then develop an entire microservice architecture, mixing HTTP microservices with transactions, database access and monitoring. What you will learn with this fascicle is:

- What Quarkus is and how you can use it,
- How to build an HTTP endpoint (REST API) with Quarkus,
- How to access a relational database in a transactional way with JTA and Hibernate ORM with Panache,
- How you can use Swagger and OpenAPI to provide a clearer picture of your microservice,
- How to test your microservice,
- How you can improve the resilience of your service,
- How to build a native executable.

This fascicle is as self-explanatory as possible. So your job is to follow the instructions by yourself, do what you are supposed to do, and do not hesitate to ask for any clarification or assistance at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/issues>.

3.1. What Will You Build in This Fascicle?

In this fascicle, you will develop an application that allows CRUD (*Create/Read/Update/Delete*) operations on books. Reading a fascicle about microservices, you will be developing several microservices communicating synchronously via REST. You will get an Angular application with the downloaded code so you can visually interact with the microservices.

3.1.1. Overall Architecture

The Vintage Store application is made up of several microservices and a user interface, all monitored by Prometheus:

- BookStore UI: the Angular application allowing you to visually pick up a random book, create/read/delete a book and generate ISBN numbers.
- *Number* REST API: Simple HTTP microservice generating ISBN numbers.
- *Book* REST API: Allows CRUD operations on Books which are stored in a PostgreSQL database.

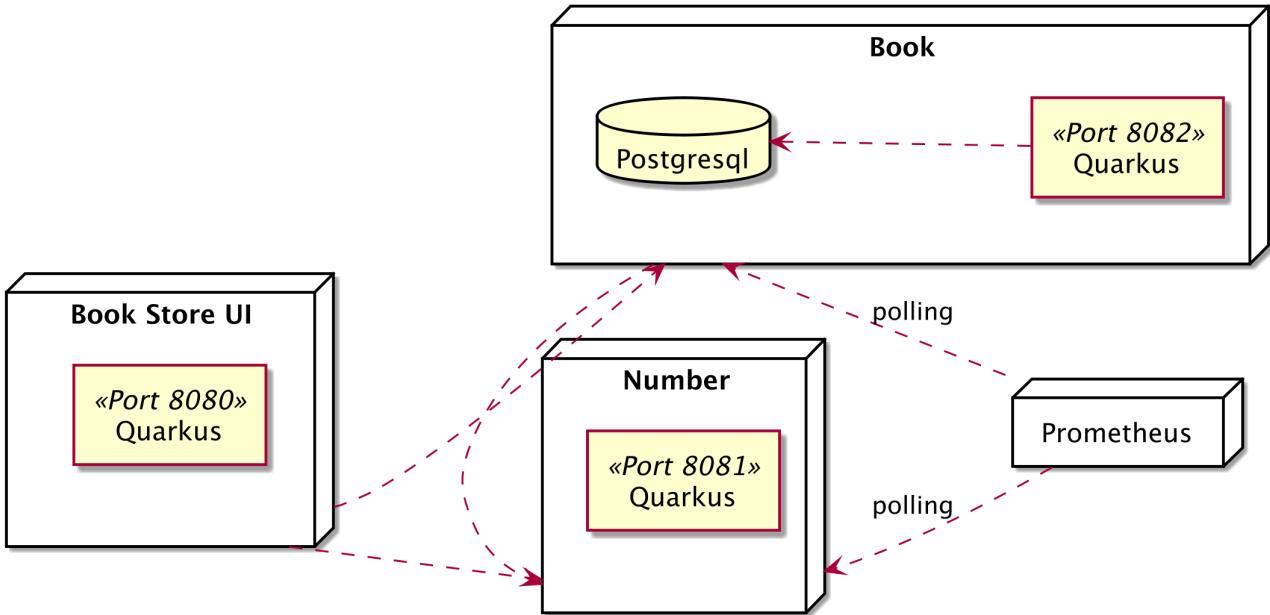


Figure 3. Overall architecture

3.1.2. User Interface

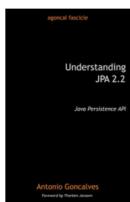
The main page of the Angular application in [Figure 4](#) displays a random book which comes from the *Book* microservice.

The screenshot shows the main page of a web application titled "Book Store". The header includes a navigation bar with "BookStore", "Number", and "Book" dropdown menus. The main content area displays a list of books with the following details:

Book	Author	Description
Understanding JPA	Antonio Goncalves	You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Understanding JPA

Antonio Goncalves



In this fascicle, you will learn Java Persistence API, its annotations for mapping entities, as well as the Java Persistence Query Language and entity life cycle

[Back](#)

Figure 4. Main page displaying a random book

By clicking on the *Book* menu you'll get access to a list of all the books (see [Figure 5](#)) which has several buttons to allow CRUD operations on a specific book.

Book Store

You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Books

[+Create new Book](#)

ID	ISBN	Title	Author	
997	9781980399025	Understanding Bean Validation	Antonio Goncalves	View Delete
998	9781093918977	Understanding JPA	Antonio Goncalves	View Delete
1021	1430246928	Beginning EJB 3, Java EE, 7th Edition	Adam Bien	View Delete
1066	1478289317	Developing Enterprise Applications with Spring: An	Roger Kitain	View Delete
1069	3319054392	ECUMICT 2014: Proceedings of the European Conferen	Nigel Deakin	View Delete
1070	1847195601	EJB 3 Developer Guide: A Practical Guide for devel	Arun Gupta	View Delete
1071	1935182994	EJB 3 in Action	Antoine Sabot-Durand	View Delete
1072	1933988347	EJB 3 in Action	Ed Burns	View Delete
1074	3826616995	Enterprise JavaBeans 3.0 mit Eclipse und JBoss: Pr	Linda Demichel	View Delete
1075	0470565454	Enterprise Software Architecture and Design: Entit	Ed Burns	View Delete

Figure 5. List of books

Figure 6 shows the component that generates book numbers (ISBNs, ASIN and EAN numbers) by invoking the *Number* microservice.

Book Store

You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Book Numbers

Generate

Asin B000FNP6CY

EAN 8 80147596

EAN 13 4692092308513

ISBN 10 0-7236-2833-5

ISBN 13 978-1-640-32604-0

Figure 6. Generating book numbers

3.2. Setting up the Development Environment on macOS

In this section, you will install the required tools, as well as some code so you can start developing with some guidelines.

3.2.1. Installing the Required Tools

First of all, make sure you have a 64-bit computer with admin rights (so you can install all the required tools) and at least 16Gb of RAM (as some tools need some resources such as compiling to native executables). This fascicle makes use of the following software, tools and frameworks. You should install and know (more or less) how they work:

- Any IDE you feel comfortable with (e.g. IntelliJ IDEA, Eclipse IDE, VS Code, etc.),
- JDK 11.0.8,
- GraalVM 20.2.0,
- Maven 3.6.x,
- Docker,
- cURL (or any other command line HTTP client),
- NodeJS.



Make sure your development environment is set up to execute the code in this chapter. You can go to [Appendix A](#) to check that you have all the required tools installed, in particular JDK 11.0.8, GraalVM 20.2.0 and Maven 3.6.x.

To make sure your environment is setup, the following commands should work on your machine:

```
$ java -version  
$ $GRAALVM_HOME/bin/native-image --version  
$ mvn -version  
$ curl --version  
$ docker version  
$ docker-compose version
```

3.2.2. Installing the Startup Code

You will have to develop most of the code but some pieces (like the user interface or the parent `pom.xml` file for example) are given to you. For that, download the zip file <https://raw.githubusercontent.com/agoncal/agoncal-fascicle-quarkus-pract/1.0/dist/agoncal-fascicle-quarkus-practising-1.0.zip>, and unzip it wherever you want.

Directory Structure

The downloaded code is separated into several directories:

```
.  
├── infrastructure      All the required infrastructure (PostgreSQL, Prometheus)  
├── load-bookstore     Stress tool loading books  
├── rest-book           REST microservice for CRUD operations on books  
├── rest-number          REST microservice generating ISBN numbers  
└── ui-bookstore        Angular application
```

Most of these subdirectories are Maven projects and follow the Maven directory structure:

```
.  
└── rest-book  
    ├── src  
    │   ├── main  
    │   │   ├── java  
    │   │   └── resources  
    │   └── test  
    │       └── java  
    └── pom.xml  
    pom.xml
```

The `rest-book` and `rest-number` directories are the ones that you'll have to develop. To guide you, they all have a directory structure as well as an empty `pom.xml` file that you will be changing

throughout the fascicle. The `infrastructure` directory contains all the Docker images' source files that you need. You won't have to change it. Same for the stress tool (under `load-bookstore`) and the Angular user interface (directory `ui-bookstore`) that you will just have to package and install.

Maven Parent POM

At the root you will find the parent `pom.xml` file. The `pom.xml` is the fundamental unit of work in Maven and will be used to build our project. Next, I am going to break down the `pom.xml` file into several parts so you can understand better. First, Listing 3 shows the header of the `pom.xml` with just the `groupId` and `artifactId`.

Listing 3. Header of the pom.xml

```
<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/xsd/maven-4.0.0.xsd">
    <modelVersion>4.0.0</modelVersion>

    <groupId>org.agoncal.fascicle</groupId>
    <artifactId>quarkus-practising</artifactId>
    <version>1.0-SNAPSHOT</version>
    <packaging>pom</packaging>
    <name>Practising Quarkus</name>
```

Listing 4 lists all the Maven modules in the project. This indicates that under each sub-directory you will find a child `pom.xml` that inherits from the parent POM.

Listing 4. Modules Defined in the pom.xml

```
<modules>
    <module>infrastructure</module>
    <module>load-bookstore</module>
    <module>rest-book</module>
    <module>rest-number</module>
    <module>ui-bookstore</module>
</modules>
```



I am using Maven parent POM to ease the development of the Vintage Store application. But bear in mind that microservices are intended to be developed separately, therefore it is good practice not to have POM inheritance.

Listing 5 shows the properties used in the parent POM as well as the child POMs. This is where you find the version of Quarkus for example.

Listing 5. Properties in the pom.xml

```
<properties>
    <version.java>11</version.java>
    <quarkus-plugin.version>1.9.0.Final</quarkus-plugin.version>
    <quarkus.platform.version>1.9.0.Final</quarkus.platform.version>
    <javafaker.version>1.0.2</javafaker.version>
    <testcontainers.version>1.15.0-rc2</testcontainers.version>
    <surefire-plugin.version>3.0.0-M5</surefire-plugin.version>
    <compiler-plugin.version>3.8.1</compiler-plugin.version>
    <exec-plugin.version>1.6.0</exec-plugin.version>
    <frontend-maven-plugin.version>1.9.1</frontend-maven-plugin.version>
    <node.version>v14.13.0</node.version>
    <npm.version>6.14.8</npm.version>
    <maven.compiler.parameters>true</maven.compiler.parameters>
    <maven.compiler.source>${version.java}</maven.compiler.source>
    <maven.compiler.target>${version.java}</maven.compiler.target>
    <project.build.sourceEncoding>UTF-8</project.build.sourceEncoding>
    <project.reporting.outputEncoding>UTF-8</project.reporting.outputEncoding>
</properties>
```

In Listing 6 we define the Quarkus BOM (*Bill of Materials*) in the dependencies management. It allows you to skip having to define the version of the different Quarkus dependencies that will be used in the child poms. Java Faker is used to generate some random data.

Listing 6. Quarkus BOM

```
<dependencyManagement>
    <dependencies>
        <dependency>
            <groupId>io.quarkus</groupId>
            <artifactId>quarkus-universe-bom</artifactId>
            <version>${quarkus.platform.version}</version>
            <type>pom</type>
            <scope>import</scope>
        </dependency>
        <dependency>
            <groupId>com.github.javafaker</groupId>
            <artifactId>javafaker</artifactId>
            <version>${javafaker.version}</version>
        </dependency>
    </dependencies>
</dependencyManagement>
```



At this point, you can import the Maven project into an IDE (most modern Java IDEs include built-in support for Maven).

3.2.3. Executing the Startup Code

Now that you have the initial structure in place, navigate to the root directory and run:

```
$ mvn install
```

By running this command, Maven downloads all the required dependencies and builds the initial code. You should have the following output:

```
[INFO] -----
[INFO] Reactor Summary for Practising Quarkus 1.0:
[INFO]
[INFO] Practising Quarkus ..... SUCCESS
[INFO] Practising Quarkus :: Infrastructure ..... SUCCESS
[INFO] Practising Quarkus :: Load ..... SUCCESS
[INFO] Practising Quarkus :: Books REST Microservice .... SUCCESS
[INFO] Practising Quarkus :: Numbers REST Microservice .. SUCCESS
[INFO] Practising Quarkus :: UI Bookstore ..... SUCCESS
[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
```

Notice the **BUILD SUCCESS** end result. If your build is not successful, please look for a similar problem at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/issues> and create a new issue if you can't find any. Once again, make sure to follow the maven installation notes in [Appendix A](#) before going any further, in case there is an error.

3.2.4. Running the Infrastructure

Any microservice system is going to rely on a set of technical services. For the Vintage Store application, we are going to use:

- A PostgreSQL database for the REST *Book* microservice,
- Prometheus to monitor all the components of the application.

We will use Docker to start all these services, so you don't have to worry about installing or setting them up. For that, navigate to the **infrastructure** sub-directory. Here, you will find a **docker-compose.yaml** files (see [Listing 7](#)) which defines all the required Docker containers. Notice that there is a **db-init** directory with an **initialize-databases.sql** script which sets up our databases and a monitoring directory (all this will be explained later).

Listing 7. Docker Compose File with All the Infrastructure

```
version: "3"
services:
  database:
    image: "postgres:12.1"
    container_name: "books-database"
    ports:
      - "5432:5432"
    volumes:
      - ./db-init/initialize-databases.sql:/docker-entrypoint-initdb.d/init.sql
  monitoring:
    image: "prom/prometheus:v2.21.0"
    container_name: "books-monitoring"
    ports:
      - 9090:9090
    volumes:
      - ./monitoring/prometheus.yaml:/etc/prometheus/prometheus.yaml
```

Then execute `docker-compose -f docker-compose.yaml up -d`. This will download all the Docker images and start the containers. Then, run the `docker container ls` command. You should see all the running containers. The output should look like this:

CONTAINER ID	IMAGE	PORTS	NAMES
94fe93e795be	postgres:12.1	0.0.0.0:5432->5432/tcp	books-database
bb051ab4dd57	prom/prometheus:v2.21.0	0.0.0.0:9090->9090/tcp	books-monitoring

Once all the containers are up and running, you can shut them down and even remove them with the following commands:

```
$ docker-compose -f docker-compose.yaml down
$ docker-compose -f docker-compose.yaml rm
```

Again, if you can't start your infrastructure, check out <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/issues> for help.

3.2.5. Building the Angular Web Application

The Angular application needs NodeJS and NPM available so that we can package and install the user interface. Under `ui-bookstore` execute the following Maven commands to install NodeJS and NPM.

```
ui-bookstore$ mvn generate-resources -Pinstall-node-and-npm
```

This installs NodeJS and NPM locally to our project (under the `ui-bookstore/node` directory). At this stage, the following commands should work:

```
ui-bookstore$ node/node -v  
ui-bookstore$ node/npm -version
```

Now that we have all the required tools installed, we need to install the Angular dependencies of the application. For that, execute the following Maven command:

```
ui-bookstore$ mvn generate-resources -Pnpm-install
```

You should now see a `node_modules` directory under `ui-bookstore`.

3.2.6. Checking Listening Ports

Each microservice listens to a port, as well as the containers of the infrastructure. Just make sure the following ports are free so you don't run into any conflicts. Running on a macOS, you can use `lsof` command to check if a process is listening on a specific port:

```
$ lsof -i tcp:5005      // Quarkus debug port  
$ lsof -i tcp:8080      // UI  
$ lsof -i tcp:8081      // Book REST API  
$ lsof -i tcp:8082      // Number REST API  
$ lsof -i tcp:5432      // PostgreSQL  
$ lsof -i tcp:9090      // Prometheus
```

3.3. Summary

In this chapter, you've downloaded a zip file with all the quick start code to build and run the Vintage Store application, made of several microservices. There is no need to install Quarkus per-se. It is just a Maven dependency that will ultimately execute our code. Thanks to Docker, installing a database such as PostgreSQL or a monitoring tool such as Prometheus is as easy as writing a few YAML lines.

In the coming chapters, you will have to fill in the gaps: developing the entire code of our microservice, making the microservices talk to each other in a reliable way, installing an Angular application, configuring, monitoring and building native executables.

Chapter 4. Developing the REST Number Microservice

At the heart of the Vintage Store application comes ISBN numbers. We need to expose a REST API that generates ISBN numbers so that, when we create a new book, we can have ISBN numbers. For that, we will create a *Number* microservice. It uses HTTP to expose a REST API and will then be used by another microservice named *Book*. The *Number* microservice generates all sorts of numbers: ISBN (*International Standard Book Number*), ASIN (*Amazon Standard Identification Number*) and EAN (*European Article Number*). In this chapter, you will create a JAX-RS endpoint running inside Quarkus. Nothing outstanding but a good first step to discovering Quarkus.

4.1. What Will You Build in This Chapter?

In this chapter, you will:

- Implement a REST API using JAX-RS and Quarkus,
- Inject external configuration,
- Customise the JSON Output,
- Enable OpenAPI and Swagger UI on the *Number* endpoint,
- Display a banner when Quarkus starts up,
- Configure Quarkus logging and HTTP port listening.

4.1.1. Overall Architecture

[Figure 7](#) shows the architecture of what you will be building in this chapter. The *Number* REST API runs on Quarkus, on port 8081, and exposes an OpenAPI contract.

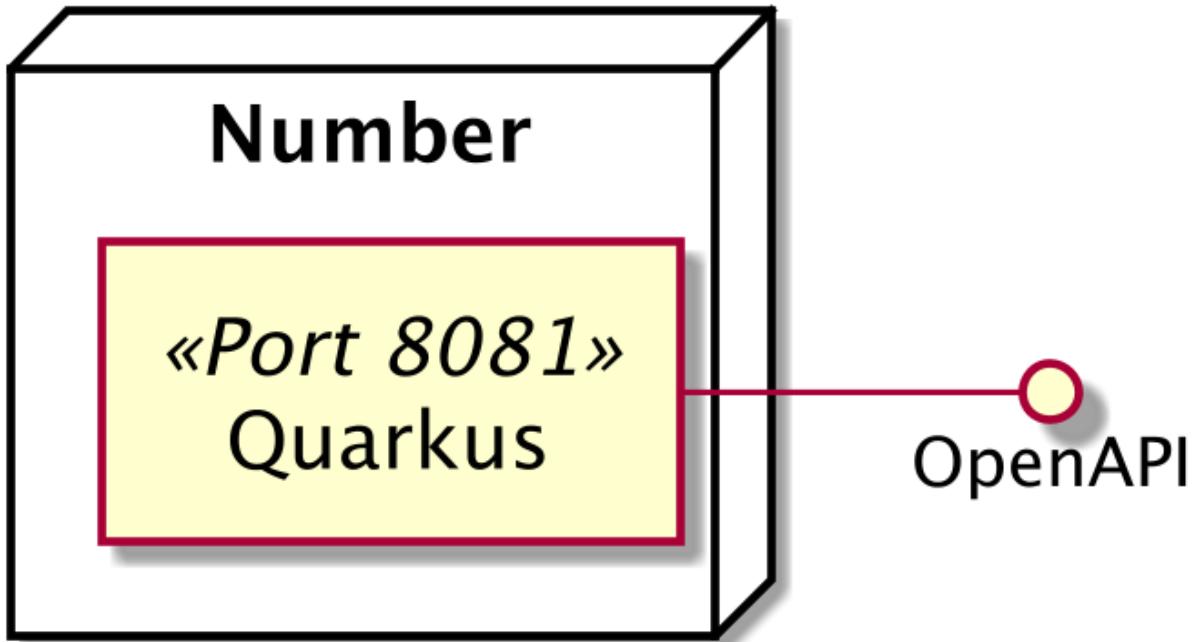
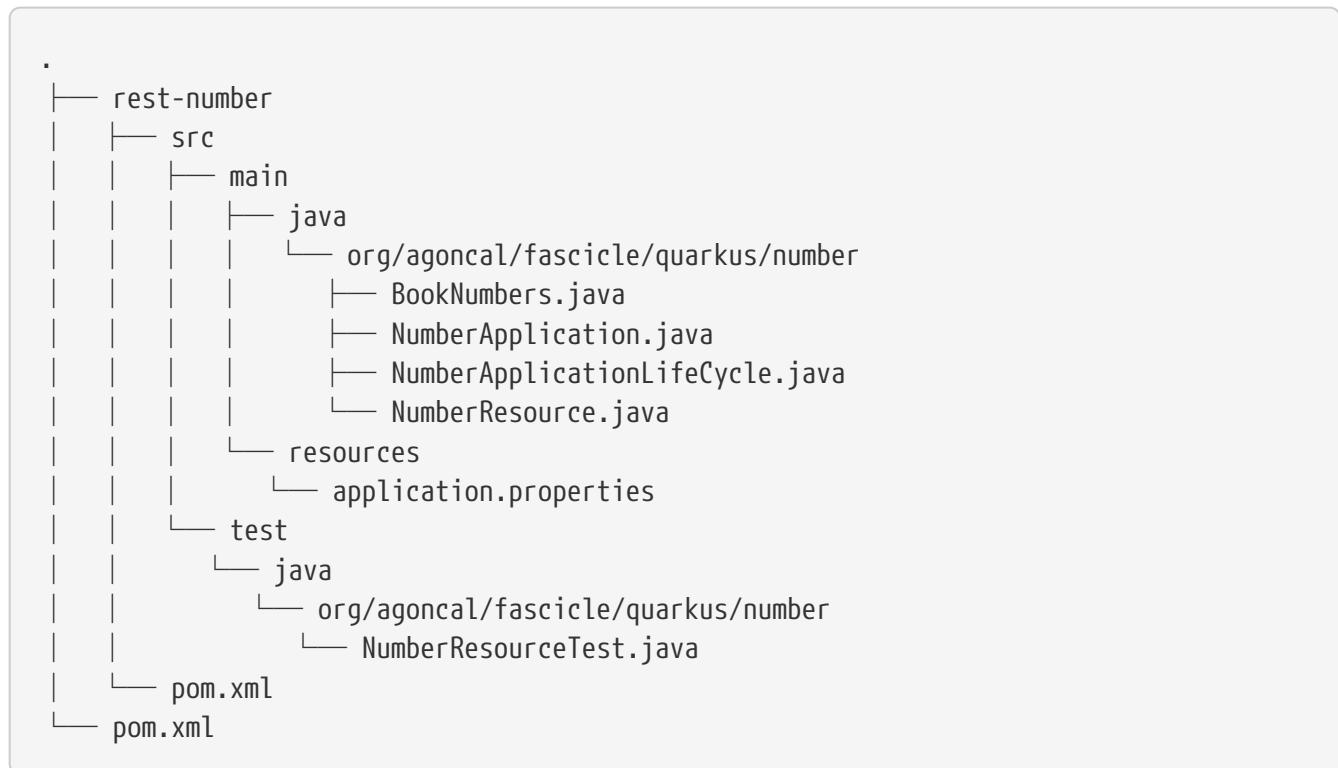


Figure 7. Overall architecture

4.1.2. Directory Structure

After coding all the required artifacts at the end of this chapter, you will end up having the following directory structure for the *Number* microservice



4.1.3. Maven Dependencies

At the moment, the `pom.xml` file that is under the `rest-number` directory only has a header (see Listing 8) inheriting from the Parent POM, but it's not enough. You will need to add a few extra dependencies to make the *Number* REST API work under Quarkus.

Listing 8. Header of the pom.xml

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

    <parent>
        <groupId>org.agoncal.fascicle</groupId>
        <artifactId>quarkus-practising</artifactId>
        <version>1.0-SNAPSHOT</version>
    </parent>

    <groupId>org.agoncal.fascicle.quarkus-practising</groupId>
    <artifactId>rest-number</artifactId>
    <version>1.0-SNAPSHOT</version>
    <name>Practising Quarkus :: Numbers REST Microservice</name>
```

The dependencies section in [Listing 9](#) gives us all the required dependencies to compile and execute the *Number* REST API. This section only declares the dependencies, not the versions, as they are defined on the parent POM:

- **quarkus-resteasy**: REST framework implementing JAX-RS.
- **quarkus-resteasy-jsonb**: JSON-B serialisation support for RESTEasy.
- **quarkus-smallrye-openapi**: Documents the REST APIs with OpenAPI and comes with Swagger UI.
- **javafaker**: Used to generate fake ISBN, ASIN and EAN numbers.

Listing 9. Maven Dependencies

```
<dependencies>
    <dependency>
        <groupId>io.quarkus</groupId>
        <artifactId>quarkus-resteasy</artifactId>
    </dependency>
    <dependency>
        <groupId>io.quarkus</groupId>
        <artifactId>quarkus-resteasy-jsonb</artifactId>
    </dependency>
    <dependency>
        <groupId>io.quarkus</groupId>
        <artifactId>quarkus-smallrye-openapi</artifactId>
    </dependency>
    <dependency>
        <groupId>com.github.javafaker</groupId>
        <artifactId>javafaker</artifactId>
    </dependency>
```

Testing an application with Quarkus is very easy. For that, you need to add the dependencies listed in [Listing 10](#):

- **quarkus-junit5**: JUnit 5 support in Quarkus.
- **rest-assured**: Framework to easily test REST endpoints.



If you want to know more about JUnit and REST Assured you can check [Appendix A](#).

Listing 10. Test Dependencies

```
<dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-junit5</artifactId>
    <scope>test</scope>
</dependency>
<dependency>
    <groupId>io.rest-assured</groupId>
    <artifactId>rest-assured</artifactId>
    <scope>test</scope>
</dependency>
</dependencies>
```

The last part of the `pom.xml` in [Listing 11](#) shows the plugins required to execute and test our code:

- **quarkus-maven-plugin**: The Quarkus plugin is responsible for creating the final jar and for running the development mode.
- **maven-compiler-plugin**: The Maven compiler plugin is used to compile the sources of the project.
- **maven-surefire-plugin**: The Surefire plugin is used during the test phase to execute the unit tests of the application.

Listing 11. Building Steps

```
<build>
  <plugins>
    <plugin>
      <groupId>io.quarkus</groupId>
      <artifactId>quarkus-maven-plugin</artifactId>
      <executions>
        <execution>
          <goals>
            <goal>build</goal>
          </goals>
        </execution>
      </executions>
    </plugin>
    <plugin>
      <artifactId>maven-compiler-plugin</artifactId>
    </plugin>
    <plugin>
      <artifactId>maven-surefire-plugin</artifactId>
      <configuration>
        <systemProperties>
          <java.util.logging.manager>
            org.jboss.logmanager.LogManager</java.util.logging.manager>
          </systemProperties>
        </configuration>
      </plugin>
    </plugins>
  </build>
```

Notice that we also set the `java.util.logging` system property to make sure that the tests use the correct logging manager. With all these test dependencies and plugins in place, a simple `mvn compile` will compile the Java code, and `mvn test` will execute the Quarkus tests. But for now, we still don't have any code to compile or test: let's write our *Number* REST endpoint.

4.2. Number REST Endpoint

Quarkus integrates JAX-RS through the RESTEasy implementation. In this section we will use JAX-RS APIs and annotations to develop our *Number* REST endpoint. The *Number* endpoint is a REST web service that uses JAX-RS annotations to generate all sorts of book numbers.

Java API for RESTful Web Services (JAX-RS) is a specification that provides support for creating web services according to the Representational State Transfer (REST) architectural style.^[24] JAX-RS provides a set of annotations and classes/interfaces to simplify the development and deployment of REST endpoints. It also brings a client API to programmatically invoke REST endpoints.

The Java API for RESTful Web Services APIs and annotations are all defined under the `javax.ws.rs`. Table 2 lists the main subpackages defined in JAX-RS 2.1 (under the root `javax.ws.rs` package).^[25]

Table 2. Main javax.ws.rs Subpackages

Subpackage	Description
<code>root</code>	Root package of the CDI APIs
<code>client</code>	Classes and interfaces of the new JAX-RS client API
<code>container</code>	Container-specific JAX-RS API
<code>core</code>	Low-level interfaces and annotations used to create RESTful web resources
<code>ext</code>	APIs that provide extensions to the types supported by the JAX-RS API

Along with APIs, JAX-RS comes with a set of annotations. Table 3 lists a subset of the most commonly used annotations.

Table 3. Main JAX-RS Annotations

Annotation	Description
<code>@GET, @POST, @PUT, @DELETE</code>	Indicates that the annotated method responds to HTTP GET, POST, PUT or DELETE requests
<code>@Path</code>	Identifies the URI path that a resource class or class method will serve requests for
<code>@PathParam</code>	Binds the value of a URI template parameter or a path segment
<code>@QueryParam</code>	Binds the value(s) of an HTTP query parameter to a resource method parameter
<code>@Produces, @Consumes</code>	Defines the media types that the methods of a resource can produce or accept

4.2.1. The Number Resource

The `NumberResource` in Listing 12 uses some of these JAX-RS annotations. As you can see, `NumberResource` is a very simple REST endpoint, returning a JSON representation of random numbers on the `/api/numbers/book` path. It returns a `BookNumbers` object containing ISBN, ASIN and EAN numbers all randomly generated by the Java Faker. The generation date is set using the Java time `Instant` class

The Java Faker library is a port of Ruby's faker gem that generates fake data.^[26] It's useful when you're developing a project and need some pretty data for a showcase. Here, we use it to generate some random data.

Listing 12. REST Endpoint Generating Book Numbers

```
@Path("/api/numbers/book")
public class NumberResource {

    private static final Logger LOGGER = Logger.getLogger(NumberResource.class);

    @GET
    @Produces(MediaType.APPLICATION_JSON)
    public Response generateBookNumbers() throws InterruptedException {
        LOGGER.info("Generating book numbers");
        Faker faker = new Faker();
        BookNumbers bookNumbers = new BookNumbers();
        bookNumbers.setIsbn10(faker.code().isbn10(separator));
        bookNumbers.setIsbn13(faker.code().isbn13(separator));
        bookNumbers.setAsin(faker.code().asin());
        bookNumbers.setEan8(faker.code().ean8());
        bookNumbers.setEan13(faker.code().ean13());
        bookNumbers.setGenerationDate(Instant.now());
        return Response.ok(bookNumbers).build();
    }
}
```

4.2.2. The Book Numbers Class

The `NumberResource` returns the `BookNumbers` object defined in [Listing 13](#). As you can see, `BookNumbers` is just a simple POJO (*Plain Old Java Object*) with attributes, getters and setters. It holds the values of several generated book numbers.

Listing 13. Java Class Holding Book Numbers

```
public class BookNumbers {

    private String isbn10;
    private String isbn13;
    private String asin;
    private String ean8;
    private String ean13;
    private Instant generationDate;

    // Constructors, getters, setters
}
```

As you can see, the definition for the `separator` is missing and for that reason, the code of the `Number` REST endpoint does not compile yet, but if it did, you would have the following output:

```
$ curl http://localhost:8080/api/numbers/book | jq

{
  "asin": "B0000AB07P",
  "ean13": "6615352338240",
  "ean8": "13354022",
  "generationDate": "2020-01-11T09:25:18.541227Z",
  "isbn10": "1932563601",
  "isbn13": "9791961975483"
}
```



`jq` is a nice tool to manipulate JSON in the shell. If you want to know more about `jq` and install it, see [Appendix A](#).

4.3. Injecting Configuration Value

If you look carefully at [Listing 12](#) you will notice that the `generateBookNumbers()` method of the `NumberResource` uses a `separator` variable. `separator` is a boolean that indicates to Java Faker whether ISBN numbers should be generated with a separator or not. We could easily add a `boolean separator` attribute and manually set it to `true` or `false` depending on our needs, but there is a better way to do it: use an external property. For that purpose, Quarkus uses the Eclipse MicroProfile Configuration.

In a microservice architecture, the fact that there is no central runtime implies that there is no single point of configuration, but several points. Each microservice has its own configuration. But sometimes two microservices might want to share a common configuration. In that case, it can be helpful that they access configurations from multiple sources homogeneously and transparently. *Eclipse MicroProfile Configuration* provides applications and microservices with the means to obtain configuration properties through several sources (internal and external to the application), through dependency injection or lookup.^[27]

The Eclipse MicroProfile Configuration APIs and annotations are all defined under the `org.eclipse.microprofile.config` package. [Table 4](#) lists the main subpackages defined in Eclipse MicroProfile Configuration version 1.4 (under the root `org.eclipse.microprofile.config` package).^[28]

Table 4. Main org.eclipse.microprofile.config Subpackages

Subpackage	Description
<code>root</code>	Root package of the Configuration APIs
<code>inject</code>	CDI support
<code>spi</code>	Internal SPIs (<i>Service Provider Interfaces</i>) implemented by the provider

Along with APIs, Configuration comes with a set of annotations. [Table 5](#) lists a subset of the most commonly used annotations.

Table 5. Main Configuration Annotations

Annotation	Description
<code>@ConfigProperty</code>	Binds the injection point with a configured value

So when we generate new ISBN numbers, we want to be able to have separators, or not, depending on the value that can be configured. For that, MicroProfile Configuration can inject the configuration in the application thanks to the `@ConfigProperty` annotation. Edit the `NumberResource`, and introduce the following configuration properties:

```
@ConfigProperty(name = "number.separator", defaultValue = "false")
boolean separator;
```



When injecting a configured value, you can use `@Inject @ConfigProperty` or just `@ConfigProperty`. The `@Inject` annotation is not necessary for members annotated with `@ConfigProperty`, a different behaviour from Eclipse MicroProfile Configuration.

If you do not provide a value for this property in the `application.properties`, the application startup fails with a `javax.enterprise.inject.spi.DeploymentException`. To avoid that, we use a default value (set using the property `defaultValue`). The injected property is initialized with the default value if the configuration does not provide a value for `number.separator`.

By default, Quarkus reads the `application.properties` file. Create the `src/main/resources/application.properties` file and add the following content:

```
number.separator=true
```

Now if you run `mvn compile quarkus:dev` (under the parent project folder) and curl the URL `http://localhost:8080/api/numbers/book` you should see separators on the ISBN numbers.

```
$ curl http://localhost:8080/api/numbers/book | jq

{
  "asin": "B0000AB07P",
  "ean13": "6615352338240",
  "ean8": "13354022",
  "generationDate": "2020-01-11T09:25:18.541227Z",
  "isbn10": "1-932563-60-1",
  "isbn13": "979-1-9619754-8-3"
}
```

Alternatively, you can open `http://localhost:8080/api/numbers/book` in your browser.

4.4. Customising the JSON Output

The JSON output from the `Number` REST endpoint is not exactly what we want. We would like to

change the name of some keys (e.g. `isbn_13` instead of `isbn13`), and prevent sending back the `generationDate`. To change the JSON binding, Quarkus uses the JSON-B specification.

JSON Binding (JSON-B) is a standard binding layer for converting Java objects to/from JSON documents.^[29] It defines a default mapping algorithm for converting existing Java classes to JSON while enabling developers to customise the mapping process through the use of Java annotations.

The JSON Binding APIs are all defined under the `javax.json.bind` package. [Table 6](#) lists the main subpackages defined in JSON-B 1.0 (under the root `javax.json.bind` package).^[30]

Table 6. Main javax.json.bind Subpackages

Subpackage	Description
<code>root</code>	Root package of the JSON-B APIs
<code>adapter</code>	APIs to define a custom mapping for a given Java type
<code>annotation</code>	JSON-B mapping annotations
<code>config</code>	Classes and interface to configure the mapping provider
<code>serializer</code>	JSON-B internals for custom serialisers
<code>spi</code>	Internal SPIs (<i>Service Provider Interfaces</i>) implemented by the provider

Along with APIs, JSON-B comes with a set of annotations. [Table 7](#) lists a subset of the most commonly used annotations.

Table 7. Main JSON-B Annotations

Annotation	Description
<code>@JsonbDateFormat</code>	Customises the date format of a field
<code>@JsonbProperty</code>	Allows customisation of a field name
<code>@JsonbNumberFormat</code>	Customises the number format of a field
<code>@JsonbTransient</code>	Prevents mapping of a field

[Listing 14](#) shows the `BookNumbers` class with some JSON-B mapping annotations. For example, the `@JsonbProperty` tells the JSON-B provider to change the name `isbn10` to `isbn_10`. As for `@JsonbTransient`, it prevents the generation date from being present on the JSON output.

Listing 14. BookNumbers Class with JSON-B Annotations

```
public class BookNumbers {  
  
    @JsonbProperty("isbn_10")  
    private String isbn10;  
    @JsonbProperty("isbn_13")  
    private String isbn13;  
    private String asin;  
    @JsonbProperty("ean_8")  
    private String ean8;  
    @JsonbProperty("ean_13")  
    private String ean13;  
    @JsonbTransient  
    private Instant generationDate;  
  
    // Constructors, getters, setters  
}
```

Without any other change to the Quarkus runtime or configuration, if you execute `mvn quarkus:dev` and go back to the same URL, you will see that the JSON has changed and looks like the following:

```
$ curl http://localhost:8080/api/numbers/book | jq  
  
{  
  "asin": "B000A3PI3G",  
  "ean_13": "7438504344437",  
  "ean_8": "38833700",  
  "isbn_10": "1-383-10381-X",  
  "isbn_13": "978-0-929138-68-8"  
}
```

4.5. OpenAPI

Quarkus applications can expose an API description through the OpenAPI specification. The OpenAPI specification helps you to describe your RESTful APIs to the consumers by available endpoints, allowed operations on each endpoint, input/output parameters for each operation, etc. For that it's just a matter of adding the `smallrye-openapi` extension in a `pom.xml`, and that's exactly what we did in [Listing 9](#).

Exposing RESTful APIs has become an essential part of all modern applications. From the microservices developer's point of view, it is important to understand how to interact with these APIs and how to test that they are still valid and backward compatible. For that, there needs to be a clear and complete contract. Therefore a standard API documentation mechanism is required and can also be used for API testing. That's when OpenAPI comes along.^[31]

Eclipse MicroProfile OpenAPI provides a Java API for the OpenAPI v3 specification that all application developers can use to expose their API documentation.^[32] It aims to provide a set of Java

interfaces and programming models which allow Java developers to natively produce OpenAPI v3 documents from their JAX-RS endpoints.

The Eclipse MicroProfile OpenAPI APIs and annotations are all defined under the main `org.eclipse.microprofile.openapi` package, either at the root, or under the other subpackages. [Table 8](#) lists the main subpackages defined in Eclipse MicroProfile OpenAPI version 1.1 (under the root `org.eclipse.microprofile.openapi` package).^[33]

Table 8. Main org.eclipse.microprofile.openapi Subpackages

Subpackage	Description
<code>root</code>	Root package of the OpenAPI APIs
<code>annotations</code>	Set of annotations to produce a valid OpenAPI document
<code>models</code>	Interfaces to define OpenAPI document programmatically
<code>spi</code>	Internal SPIs (<i>Service Provider Interfaces</i>) implemented by the provider

Along with APIs, OpenAPI comes with a set of annotations. [Table 9](#) lists a subset of the most commonly used annotations.

Table 9. Main OpenAPI Annotations

Annotation	Description
<code>@APIResponse</code>	Describes the endpoint's response (response code, data structure, types, etc)
<code>@Operation</code>	Describes a single API operation on a path
<code>@OpenAPIDefinition</code>	Root document object of the OpenAPI document
<code>@Parameter</code>	The name of the method parameter
<code>@RequestBody</code>	A brief description of the request body
<code>@Schema</code>	Allows the definition of input and output data types
<code>@Tag</code>	Used to add tags to the REST endpoint contract to provide more description

Start the application (`mvn quarkus:dev`) and make a request to the URL <http://localhost:8080/openapi>. As you can see in [Listing 15](#), Quarkus automatically generates the OpenAPI documentation for the *Number* REST endpoint. This is an example of what we call an OpenAPI contract for a REST endpoint.

Listing 15. Default OpenAPI YAML Contract

```
openapi: 3.0.3
info:
  title: Generated API
  version: "1.0"
paths:
  /api/numbers/book:
    get:
      responses:
        200:
          description: OK
```

You can use cURL to change the HTTP header and to retrieve the OpenAPI document in several formats:



- YAML: `curl http://localhost:8080/openapi`
- JSON: `curl -H "Accept: application/json" http://localhost:8080/openapi`

But this contract lacks documentation. The Eclipse MicroProfile OpenAPI allows you to customise the methods' description of your REST endpoints as well as the entire application itself.

4.5.1. Customising the OpenAPI Contract of the Number REST Endpoint

Eclipse MicroProfile OpenAPI has a set of annotations to customise each REST endpoint class, method and parameter to make the OpenAPI contract richer and clearer for consumers. [Listing 16](#) shows what the `NumberResource` endpoint looks like once annotated.

Listing 16. Customising the OpenAPI Contract of the REST endpoint

```
@Path("/api/numbers/book")
@Tag(name = "Number Endpoint")
public class NumberResource {

    private static final Logger LOGGER = Logger.getLogger(NumberResource.class);

    @ConfigProperty(name = "number.separator", defaultValue = "false")
    boolean separator;

    @Operation(summary = "Generates book numbers", description = "These book numbers have several formats: ISBN, ASIN and EAN")
    @ApiResponse(responseCode = "200", content = @Content(mediaType = MediaType.APPLICATION_JSON, schema = @Schema(implementation = BookNumbers.class)))
    @GET
    @Produces(MediaType.APPLICATION_JSON)
    public Response generateBookNumbers() throws InterruptedException {
        LOGGER.info("Generating book numbers");
        Faker faker = new Faker();
        BookNumbers bookNumbers = new BookNumbers();
        bookNumbers.setIsbn10(faker.code().isbn10(separator));
        bookNumbers.setIsbn13(faker.code().isbn13(separator));
        bookNumbers.setAsin(faker.code().asin());
        bookNumbers.setEan8(faker.code().ean8());
        bookNumbers.setEan13(faker.code().ean13());
        bookNumbers.setGenerationDate(Instant.now());
        return Response.ok(bookNumbers).build();
    }
}
```

The `@Tag` annotation gives some information about the entire endpoint. On the other hand, `@Operation` focuses on each method while `@ApiResponse` lists all the possible HTTP status code that can be returned by a method (here, a `200` when the method is invoked successfully). The `implementation` attribute of the `@Schema` annotation is important here. It provides the real implementation of the `Response` and allows the OpenAPI to reference (`$ref`) the `BookNumbers` class (as you will see in [Listing 19](#)).

4.5.2. Customising the BookNumber POJO

The `generateBookNumbers()` method returns a `BookNumbers` object. As you can see in [Listing 17](#), this object can also be annotated with `@Schema` to provide a more textual description. For example, we can inform the consumers which attributes are required in the JSON document (`@Schema(required = true)`).

Listing 17. Customising the OpenAPI Contract for the BookNumber Class

```
@Schema(description = "Several formats of book numbers")
public class BookNumbers {

    @Schema(required = true)
    @JsonbProperty("isbn_10")
    private String isbn10;
    @Schema(required = true)
    @JsonbProperty("isbn_13")
    private String isbn13;
    private String asin;
    @JsonbProperty("ean_8")
    private String ean8;
    @JsonbProperty("ean_13")
    private String ean13;
    @JsonbTransient
    private Instant generationDate;

    // Constructors, getters, setters
}
```

4.5.3. Customising the OpenAPI Contract of the Application

The previous annotations allow you to customise the contract for a given REST endpoint. But it's also important to customise the contract for the entire application. Eclipse MicroProfile OpenAPI also has a set of annotations to serve that purpose. The difference is that these annotations cannot be used on the endpoint itself, but instead on another Java class which is meant to be configuring the entire application. For this, you need to create the `src/main/java/org/agoncal/fascicle/quarkus/number/NumberApplication` class with the content described in [Listing 18](#). Note that this class extends `javax.ws.rs.core.Application`.

Listing 18. Custom OpenAPI Documentation for the Application

```
@ApplicationPath("/")
@OpenAPIDefinition(
    info = @Info(title = "Number API",
        description = "This API allows to generate all sorts of numbers",
        version = "1.0",
        contact = @Contact(name = "@agoncal", url = "https://twitter.com/agoncal")),
    externalDocs = @ExternalDocumentation(url = "https://github.com/agoncal/agoncal-fascicle-quarkus-pract", description = "All the Practising Quarkus code"),
    tags = {
        @Tag(name = "api", description = "Public API that can be used by anybody"),
        @Tag(name = "numbers", description = "Anybody interested in numbers")
    }
)
public class NumberApplication extends Application {
```

4.5.4. The Customised OpenAPI Contract

After applying all the previous modifications to the contract meta-data, if you go back to the <http://localhost:8080/openapi> endpoint you will see the customised OpenAPI contract described in Listing 19.

Listing 19. Customised OpenAPI YAML Contract

```
openapi: 3.0.3
info:
  title: Number API
  description: This API allows to generate all sorts of numbers
  contact:
    name: '@agoncal'
    url: https://twitter.com/agoncal
    version: "1.0"
  externalDocs:
    description: All the Practising Quarkus code
    url: https://github.com/agoncal/agoncal-fascicle-quarkus-pract
  servers:
    - url: http://localhost:8081
  tags:
    - name: api
      description: Public API that can be used by anybody
    - name: numbers
      description: Anybody interested in numbers
    - name: Book Numbers generator service
  paths:
    /api/numbers/book:
      get:
        tags:
          - Book Numbers generator service
        summary: Generates book numbers
        description: 'These book numbers have several formats: ISBN, ASIN and EAN'
        responses:
          200:
            description: OK
            content:
              application/json:
                schema:
                  $ref: '#/components/schemas/BookNumbers'
  components:
    schemas:
      BookNumbers:
        description: Several formats of book numbers
        required:
          - isbn-10
          - isbn-13
        type: object
        properties:
          asin:
```

```
    type: string
ean-13:
    type: string
ean-8:
    type: string
isbn-10:
    type: string
isbn-13:
    type: string
```

The contract in [Listing 19](#) is much richer than the one in [Listing 15](#). There is information about the entire *Number* application, as well as all the paths that are accessible through HTTP. In the contract in [Listing 19](#), notice the reference to the `BookNumbers` (`$ref: '#/components/schemas/BookNumbers'`) on the `generateBookNumbers` method. For the consumer of this contract, the returned structure is much clearer than the one defined in [Listing 15](#).

4.5.5. Swagger UI

Visualising an OpenAPI contract in YAML or JSON can be cumbersome if the contract is too large. Instead, we can use Swagger UI. In fact, the Quarkus extension `smallrye-openapi` comes with a `swagger-ui` extension embedding a properly configured Swagger UI page.

When building APIs, developers want to analyse them quickly. Swagger UI is a great tool that permits you to visualise and interact with your APIs.^[34] It's automatically generated from the OpenAPI contract, with the visual documentation making it easy for back end implementation and client side consumption.

By default, Swagger UI is accessible at the URL `/swagger-ui`. So, once your application is started, you can go to <http://localhost:8080/swagger-ui>, and you will see the contract in a visual format as shown in [Figure 8](#).

Number API 1.0 OAS3

/openapi

This API allows to generate all sorts of numbers

@agoncal - Website

All the Practicing Quarkus code

api Public API that can be used by anybody



numbers Anybody interested in numbers



Number Endpoint



GET /api/numbers/book Generates book numbers

These book numbers have several formats: ISBN, ASIN and EAN

Parameters

Try it out

No parameters

Responses

Code	Description	Links
200	OK	No links

Media type

application/json

Controls Accept header.

Example Value | Schema

```
{  
    "asin": "string",  
    "ean_13": "string",  
    "ean_8": "string",  
    "isbn_10": "string",  
    "isbn_13": "string"  
}
```

Figure 8. Swagger UI contract of the Number endpoint

You can visualise your API's operations and schemas, but you can also invoke them by simply clicking on the *GET* button and then the *Execute* button as shown in Figure 9.

Number Endpoint

GET /api/numbers/book Generates book numbers

These book numbers have several formats: ISBN, ASIN and EAN

Parameters

No parameters

Responses

Curl

```
curl -X GET "http://0.0.0.0:8081/api/numbers/book" -H "accept: application/json"
```

Request URL

```
http://0.0.0.0:8081/api/numbers/book
```

Server response

Code	Details	
200	<p>Response body</p> <pre>[{"asin": "B00007GWYK", "ean_13": "8414482844069", "ean_8": "33036489", "isbn_10": "1-85703-911-4", "isbn_13": "979-1-9657563-9-2"}]</pre> <p>Download</p> <p>Response headers</p> <pre>content-length: 121 content-type: application/json</pre>	
Responses		
Code	Description	Links
200	OK	No links

Figure 9. Invoking the generateBookNumbers method

4.6. Application Startup and Shutdown

You often need to execute custom actions when the application starts and clean up everything when the application stops. For example, up to now, when our application starts, the logs are pretty plain (see [Listing 20](#)) and show a "Quarkus" banner.

Listing 20. Original Startup and Shutdown Quarkus Logs

```
--/ _\ \ / / / _ | / _\ \ // / / / / _/
-/ / / / / _ \| , _/ , < / / / \ \ \
--\_\ \_\ / / | / / | / / | / \_\ / / /
INFO rest-number 1.0 started in 1.417s. Listening on: http://0.0.0.0:8080
INFO Profile dev activated. Live Coding activated.
INFO Installed features: [cdi, resteasy, resteasy-jsonb, smallrye-openapi, swagger-ui]
(...)
INFO Quarkus stopped in 0.002s
```

So what we want to do is to add a nice "Number" text banner when Quarkus starts up, and display a message when it shuts down. First of all, we need to disable the original "Quarkus" banner. For that, it's just a matter of setting the `banner.enabled` to `false` in the `application.properties` file:

quarkus.banner.enabled=false

Now that the original banner is disabled, go to the following website (<http://patorjk.com/software/taag>) and pick up your favourite "Number" text banner. Then, create a new class named `NumberApplicationLifecycle` in the `org.agoncal.fascicle.quarkus.number` package, and copy your banner so you end up with content similar to [Listing 21](#).

Listing 21. Displaying a Banner at Startup

Notice the `@ApplicationScoped` annotation. It's a CDI annotation (more on this in [Chapter 5](#)) allowing Quarkus to register this class when the application starts. Thanks to the CDI `@Observes` annotation, the `NumberApplicationLifeCycle` can observe events and react in a certain way. That's because Quarkus fires CDI events, including at startup and shutdown.

CDI events allow beans to interact with no compile time dependency at all. One bean can define an event (using the `javax.enterprise.event.Event` interface), another bean can fire the event (by calling the `fire()` method), and yet another bean can handle the event (using the `@Observes` annotation). The beans can be in separate packages and even in separate JARs of the application. This basic schema follows the observer/observable design pattern from the *Gang of Four*.^[35]

Thanks to CDI events, the `NumberApplicationLifeCycle` is automatically invoked:

- On startup with the `StartupEvent` so it can execute code (here, displaying the banner) when the application is starting,
 - On shutdown with the `ShutdownEvent` when the application is terminating.

Run the application with `mvn clean quarkus:dev`, and a banner similar to Listing 22 is printed to the

console. When the application is stopped, the second log message is printed.

Listing 22. Startup Banner With Development Profile

```
INFO [-----]
INFO | \ | |
INFO | \ \ | |
INFO | . ` | | | | ' _ \ | ' _ \ / _ \ ' __|
INFO | | \ | | | | | | | | | | | | | | | | |
INFO \| \ \ / _ , _ | | | | | | | | | | | | | |
INFO                                     Powered by Quarkus
INFO The application Number is starting with profile dev
INFO Quarkus started in 1.137s. Listening on: http://0.0.0.0:8080
INFO Profile dev activated. Live Coding activated.
INFO Installed features: [cdi, resteasy, resteasy-jsonb, smallrye-openapi, swagger-ui]
(...)
INFO The application Number is stopping...
INFO Quarkus stopped in 0.002s
```

4.6.1. Displaying the Current Environment

Quarkus supports the notion of configuration profiles. This allows you to have multiple configurations in the same file and select them via a profile name.

By default, Quarkus has three profiles, although it is possible to create your own and use as many as you like. The built-in profiles are:

- **dev**: Activated when in development mode (when running `mvn quarkus:dev`).
 - **test**: Activated when running tests.
 - **prod**: The default profile when not running in development or test mode.

As shown in Listing 21, if we want to display the current profile, we can use the `ProfileManager` from Quarkus. For that, in the `NumberApplicationLifecycle` class, we add a log invoking the `ProfileManager.getActiveProfile()` method.

```
LOGGER.info("The application Number is starting with profile " + ProfileManager.getActiveProfile());
```

When we run `mvn quarkus:dev` the log displays "*The application Number is starting with profile dev*". Later on, we will see how the *test* profile will be used when running some tests. In [Chapter 9](#) we will build a native image of our microservices and will run the application in production mode (the profile will show "prod" instead of "dev" when run in production mode).

4.7. Running the Application

By now you've already executed the *Number* REST endpoint by starting Quarkus and invoking some

cURL commands. But let's go further by hot reloading the application, configuring it, and of course, testing our endpoint.

4.7.1. Live Reload

So far we've been using `mvn quarkus:dev` to execute our application. This command runs Quarkus in development mode. This enables hot reload with background compilation, which means that when you modify your Java files and/or your resource files and invoke a REST endpoint, these changes will automatically take effect. This works also for resource files like the configuration property and HTML files. Invoking a cURL command or refreshing the browser triggers a scan of the workspace, and if any changes are detected, the Java files are recompiled and the application is redeployed; your request is then serviced by the redeployed application. Let's see this live reload in action. For that, make sure `mvn quarkus:dev` is still running.

With Quarkus running, cURL the following URL <http://localhost:8080/api/numbers/book>. You should see something like this:

```
{  
  "asin": "B000A3PI3G",  
  "ean_13": "7438504344437",  
  "ean_8": "38833700",  
  "isbn_10": "1-383-10381-X",  
  "isbn_13": "978-0-929138-68-8"  
}
```

Now, update the method `NumberResource.generateBookNumbers()` by setting a dummy ASIN number with `bookNumbers.setAsin("dummy")`. Save the `NumberResource` file if your IDE does not do it automatically, and execute the cURL command again. As you can see, the output has changed without you having to stop and restart Quarkus:

```
{  
  "asin": "dummy",  
  "ean_13": "7438504344437",  
  "ean_8": "38833700",  
  "isbn_10": "1-383-10381-X",  
  "isbn_13": "978-0-929138-68-8"  
}
```

You can also change the `application.properties` file by setting the `number.separator` to `false`. Execute the cURL command again, and you will notice that the ISBN numbers do not use separators anymore.

4.7.2. Configuring the Application

Talking about configuration, let's go further. Up to now we've used the `application.properties` file to externalise and configure the `number.separator` property. Now, let's use the `application.properties` file to change the HTTP listening port and configure the logs

Configuring the Quarkus Listening Port

Because we will end-up running several microservices, let's configure Quarkus so it listens to a different port than 8080. This is quite easy as we just need to add one property in the `application.properties` file:

```
quarkus.http.port=8081
```

Now you need to restart the application to change the port. From now on, check the endpoint at <http://localhost:8081/api/numbers/book> instead of <http://localhost:8080/api/numbers/book>.

Configuring Logging

Quarkus comes with default logging properties. It displays the timestamp of the message, the package, the thread, etc.:

```
2020-01-15 15:56:19,218 INFO [io.quarkus] (main) Quarkus started in 1.131s. Listening on: http://0.0.0.0:8081
2020-01-15 15:56:19,219 INFO [io.quarkus] (main) Profile dev activated. Live Coding activated.
2020-01-15 15:56:19,219 INFO [io.quarkus] (main) Installed features: [cdi, resteasy, resteasy-jsonb, smallrye-openapi, swagger-ui]
```

But we might want to change this default logging mechanism. Runtime configuration of logging is also done through the `application.properties` file. The configuration can be done at several levels. It comes with different properties so you can have the logging that suits you the best.^[36] In the `application.properties` file below, the log level is set to `DEBUG`, the timestamp only displays the date, not the time, and the packages are written with only one letter.

```
quarkus.log.console.enable=true
quarkus.log.console.format=%d{HH:mm:ss} %-3p [%c{1.}] %s%e%n
quarkus.log.console.level=DEBUG
quarkus.log.console.color=true
```

The end result looks like this:

```
16:02:28 INFO [i.quarkus] Quarkus started in 1.125s. Listening on: http://0.0.0.0:8081
16:02:28 INFO [i.quarkus] Profile dev activated. Live Coding activated.
16:02:28 INFO [i.quarkus] Installed features: [cdi, resteasy, resteasy-jsonb, smallrye-openapi, swagger-ui]
```

4.7.3. Testing the Application

So far so good, but wouldn't it be better with a few tests, just in case? In the `pom.xml` file in [Listing 10](#), you can see 2 test dependencies:

- **quarkus-junit5**: Quarkus supports Junit 4 and Junit 5 tests. Here we use Junit 5.
- **rest-assured**: We now want to test our *Number* REST endpoint and REST Assured is a nice library to do it.

As shown in [Listing 11](#), we also need to setup the Surefire Maven plugin to make tests work. The version of the Surefire plugin must be set, as the default version does not support Junit 5 yet. We also set the `java.util.logging` system property to make sure tests will use the correct log manager.

We're all set now, let's write some tests.

Testing the Business Logic

In [Listing 23](#) we use the `QuarkusTest` runner to instruct JUnit to start the application before the tests. Then, the `shouldGenerateBookNumber()` method checks the HTTP response status code and the JSON content. Notice that these tests use REST Assured.^[37]

Listing 23. Testing the Generation of Book Numbers

```
@QuarkusTest
public class NumberResourceTest {

    @Test
    void shouldGenerateBookNumber() {
        given()
            .header(HttpHeaders.ACCEPT, MediaType.APPLICATION_JSON).
        when()
            .get("/api/numbers/book").
        then()
            .statusCode(OK.getStatusCode())
            .body("$", hasKey("isbn_10"))
            .body("$", hasKey("isbn_13"))
            .body("$", hasKey("asin"))
            .body("$", hasKey("ean_8"))
            .body("$", hasKey("ean_13"))
            .body("$", not(hasKey("generationDate")));
    }
}
```



If you want to know more on REST Assured or Hamcrest matchers, check [Appendix A](#).

Now execute the test with `mvn test` or from your IDE. The test should pass and you should see similar logs as in [Listing 24](#).

Listing 24. Tests Successful Output

There are a few interesting pieces of information on these logs. First of all, you notice that Quarkus starts and runs the application. Thanks to `@QuarkusTest` you get real integration tests with the Quarkus runtime. And when you look at the timestamps, you can see that starting and shutting down the application is quite quick. Quarkus makes your integration run quickly. While Quarkus will listen on port 8080 by default, when running tests it defaults to 8081. This allows you to run tests while having the application running in parallel.

Thanks to our `NumberApplicationLifeCycle` that displays the current active profile, the log is now "The application Number is starting with profile test" (test instead of dev).

Testing the OpenAPI

Let's add a few extra test methods that would make sure OpenAPI and Swagger UI are packaged in the application. In Listing 25 we just check that when accessing the URLs `/openapi` and `/swagger-ui`, a return code `200-OK` is returned.

Listing 25. Testing the OpenAPI and SwaggerUI

```
@Test
void shouldPingOpenAPI() {
    given()
        .header(HttpHeaders.ACCEPT, MediaType.APPLICATION_JSON).
    when()
        .get("/openapi").
    then()
        .statusCode(OK.getStatusCode());
}

@Test
void shouldPingSwaggerUI() {
    given().
    when()
        .get("/swagger-ui").
    then()
        .statusCode(OK.getStatusCode());
}
```

4.7.4. Executing the Application

So far we've been running the *Number* microservice using `mvn quarkus:dev`. This development mode is really handy as it brings us live reload: we can execute the application, change some code, and Quarkus automatically restarts taking into account our changes. But this has a cost as the startup time is slower. In fact, if you check the banner displayed at startup in [Listing 22](#) you will see "*Live Coding activated*" written as well as "*Profile dev activated*".

To execute our microservice in production mode, first, we need to package it with the `mvn package` command. That will result in an executable JAR under the `target` directory. In our case, the executable JAR is called `rest-number-1.0-runner.jar`. Having an executable JAR, we can execute it with `java -jar target/rest-number-1.0-runner.jar`. By doing so you will get traces that look like Listing 26.

Listing 26. Startup Banner With Production Profile

You'll notice a few things. First of all, the application has started slightly faster compared to development mode. Also, the logs show the message "*Profile prod activated*" and the message "*Live Coding activated*" has disappeared. By default, Quarkus disables Swagger UI in production mode. So, in the "*Installed features*" we no longer have the `swagger-ui` extension.

Invoke a cURL command on the following URL <http://localhost:8081/api/numbers/book> and you will get a JSON representation of book numbers:

```
{  
  "asin": "B000A3PI3G",  
  "ean_13": "7438504344437",  
  "ean_8": "38833700",  
  "isbn_10": "1-383-10381-X",  
  "isbn_13": "978-0-929138-68-8"  
}
```

4.8. Summary

In this chapter, you developed a first microservice: the *Number* REST endpoint generates book numbers (ISBN, EAN and ASIN). In terms of business code, the endpoint is quite simple. What you focused on in this chapter was to develop a class with JAX-RS annotations and to execute it with Quarkus. Then, we used the Eclipse MicroProfile Configuration to inject a boolean value allowing the ISBN numbers to have separators, or not. This boolean is configurable externally in the `application.properties` file. Thanks to the JSON Binding we used a few annotations to customise the JSON output.

Quarkus comes with the `smallrye-openapi` extension that brings the OpenAPI and Swagger UI documentation for free in development mode. With a few Eclipse MicroProfile OpenAPI annotations, we managed to customise the documentation so that it's more explicit.

Testing a Quarkus application is quite easy: one annotation `@QuarkusTest` and we get the entire runtime environment for testing. And when we finally need to execute an application in production, Quarkus can create an executable JAR suitable for production (no live reload and no Swagger UI).

In the next chapter, you will develop the *Book* microservice. It is a more complex microservice in terms of technology as it will access a relational database in a transactional way using object-relational mapping.

[24] JAX-RS <https://jcp.org/en/jsr/detail?id=370>

[25] JAX-RS GitHub <https://github.com/eclipse-ee4j/jaxrs-api>

[26] Ruby faker <https://github.com/faker-ruby>

[27] Configuration <https://microprofile.io/project/eclipse/microprofile-config>

[28] Configuration GitHub <https://github.com/eclipse/microprofile-config>

[29] JSON-B <https://jcp.org/en/jsr/detail?id=367>

[30] JSON-B GitHub <https://github.com/eclipse-ee4j/jsonb-api>

[31] OpenAPI Specification <https://github.com/OAI/OpenAPI-Specification>

[32] OpenAPI <https://microprofile.io/project/eclipse/microprofile-open-api>

[33] OpenAPI GitHub <https://github.com/eclipse/microprofile-open-api>

[34] Swagger UI <https://swagger.io/tools/swagger-ui>

[35] Observer Pattern https://en.wikipedia.org/wiki/Observer_pattern

[36] Configuring Logging <https://quarkus.io/guides/logging>

[37] REST Assured <http://rest-assured.io>

Chapter 5. Developing the REST Book Microservice

So far the Vintage Store application is only made of one microservice: the *Number* REST endpoint. In this chapter, you will develop one extra microservice: a *Book* REST endpoint. The *Book* endpoint's role is to allow CRUD (*Create/Read/Update/Delete*) operations on books. In this chapter, you will create a *Book* entity and persist/update/delete/retrieve it from a PostgreSQL database in a transactional way.



Remember that if you get stuck, you can get the entire code of the fascicle at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/tree/1.0>

5.1. What Will You Build in This Chapter?

In this chapter, you will:

- Implement another REST API using JAX-RS,
- Constrain and validate business data with Bean Validation,
- Access the PostgreSQL database using Hibernate ORM with Panache,
- Use JTA transactions,
- Compose the application using CDI beans,
- Enable OpenAPI and Swagger UI on the *Book* endpoint,
- Display a banner at startup,
- Configure the datasource, logging and the HTTP port listening.

5.1.1. Overall Architecture

Figure 10 shows the architecture of what you will be building in this chapter. The *Number* REST API that we've built previously runs on Quarkus, on port 8081, and exposes an OpenAPI contract. As for the new *Book* REST API, it also runs on Quarkus (port 8082) and accesses a PostgreSQL database to store and retrieve books.

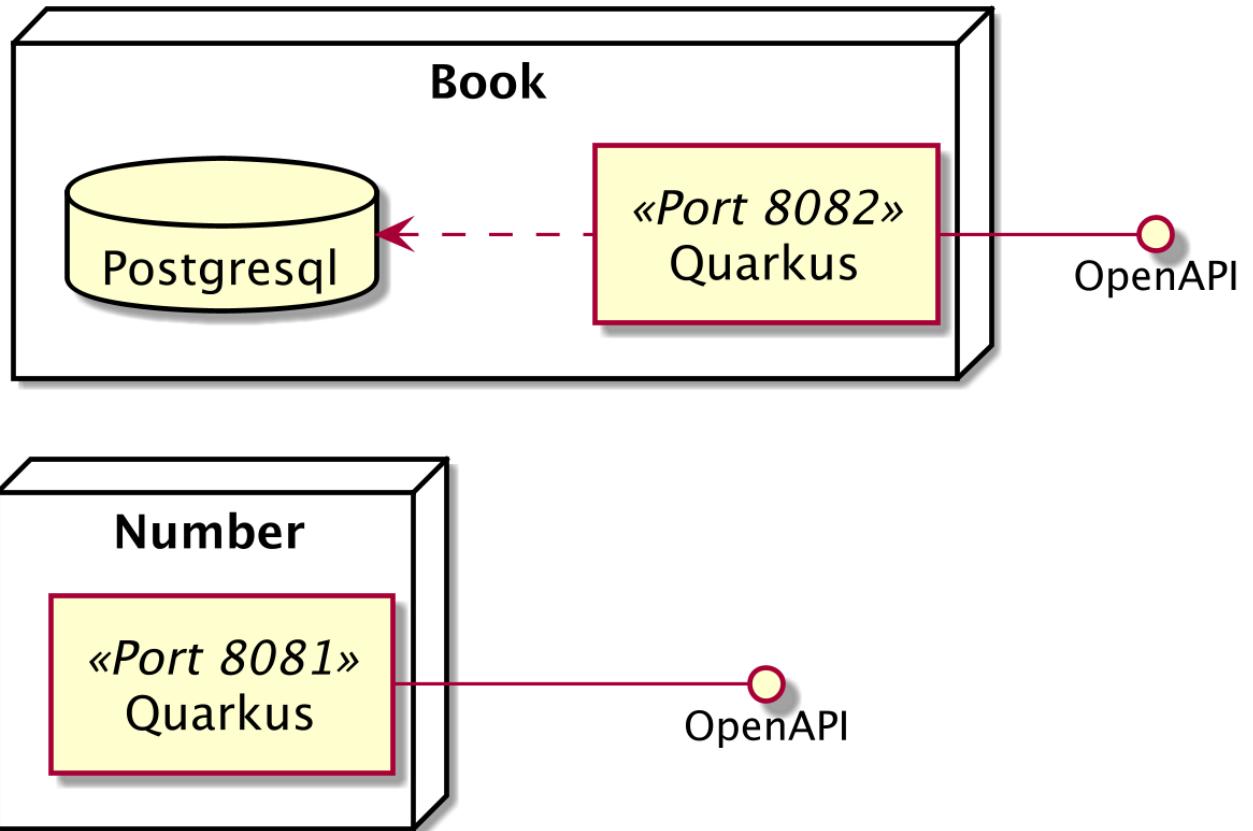


Figure 10. Overall architecture

5.1.2. Directory Structure

At the end of this chapter, after coding all the required artifacts, you will end up with the following directory structure for the *Book* microservice:

```

.
├── rest-book
│   ├── src
│   │   ├── main
│   │   │   ├── java
│   │   │   │   └── org/agoncal/fascicle/quarkus/book
│   │   │   │       ├── Book.java
│   │   │   │       ├── BookApplication.java
│   │   │   │       └── BookApplicationLifeCycle.java
│   │   │   └── BookResource.java
│   │   └── BookService.java
│   └── resources
│       ├── application.properties
│       └── import.sql
└── test
    └── java
        └── org/agoncal/fascicle/quarkus/book
            └── BookResourceTest.java

```

pom.xml
pom.xml

5.1.3. Maven Dependencies

Like the previous chapter, you will start with the minimalist `pom.xml` described in [Listing 27](#). Basically it's just a header with the same `<groupId>` as the *Number* microservice `pom.xml` but with a different `<artifactId>`. It also inherits from the Parent POM.

Listing 27. Header of the pom.xml

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

    <parent>
        <groupId>org.agoncal.fascicle</groupId>
        <artifactId>quarkus-practising</artifactId>
        <version>1.0-SNAPSHOT</version>
    </parent>

    <groupId>org.agoncal.fascicle.quarkus-practising</groupId>
    <artifactId>rest-book</artifactId>
    <version>1.0-SNAPSHOT</version>
    <name>Practising Quarkus :: Books REST Microservice</name>
```

In the dependencies section in [Listing 28](#) you find some of the same dependencies used in the previous chapter:

- `quarkus-resteasy`: REST framework implementing JAX-RS.
- `quarkus-resteasy-jsonb`: JSON-B serialisation support for RESTEasy.
- `quarkus-smallrye-openapi`: Documents the REST APIs with OpenAPI and comes with Swagger UI.

But with the *Book* microservice being more complex, we need to add a few extra Maven dependencies:

- `quarkus-hibernate-orm-panache`: Hibernate ORM with Panache.
- `quarkus-jdbc-postgresql`: PostgreSQL JDBC driver.
- `quarkus-hibernate-validator`: Bean Validation to constrain our business model.

Listing 28. Maven Dependencies

```
<dependencies>
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-resteasy</artifactId>
  </dependency>
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-resteasy-jsonb</artifactId>
  </dependency>
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-hibernate-orm-panache</artifactId>
  </dependency>
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-jdbc-postgresql</artifactId>
  </dependency>
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-hibernate-validator</artifactId>
  </dependency>
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-openapi</artifactId>
  </dependency>
```

As you saw in the previous chapter, testing a microservice with Quarkus is easy. As described in [Listing 29](#) you just need a few test dependencies (`quarkus-junit5` for JUnit support and `rest-assured`). But the *Book* microservice needs a PostgreSQL database to run, therefore, it also needs a PostgreSQL database to execute the tests. For that we add two extra test dependencies from TestContainers:

- `junit-jupiter`: JUnit support for TestContainers.
- `postgresql`: PostgreSQL JDBC driver for TestContainers.

Basically, TestContainers will use Docker to download and execute an instance of PostgreSQL. This allows us to run our integration test with a live database.



If you want to know more about TestContainers, you can check [Appendix A](#).

Listing 29. Test Dependencies

```
<dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-junit5</artifactId>
    <scope>test</scope>
</dependency>
<dependency>
    <groupId>io.rest-assured</groupId>
    <artifactId>rest-assured</artifactId>
    <scope>test</scope>
</dependency>
<dependency>
    <groupId>org.testcontainers</groupId>
    <artifactId>testcontainers</artifactId>
    <version>${testcontainers.version}</version>
    <scope>test</scope>
</dependency>
<dependency>
    <groupId>org.testcontainers</groupId>
    <artifactId>junit-jupiter</artifactId>
    <version>${testcontainers.version}</version>
    <scope>test</scope>
</dependency>
<dependency>
    <groupId>org.testcontainers</groupId>
    <artifactId>postgresql</artifactId>
    <version>${testcontainers.version}</version>
    <scope>test</scope>
</dependency>
</dependencies>
```

The last part of the `pom.xml` in Listing 30 shows the required plugins to execute and test our code. The `Book` REST endpoint uses the same plugins as the `Number` REST endpoint that you saw in the previous chapter.

Listing 30. Building Steps

```
<build>
  <plugins>
    <plugin>
      <groupId>io.quarkus</groupId>
      <artifactId>quarkus-maven-plugin</artifactId>
      <executions>
        <execution>
          <goals>
            <goal>build</goal>
          </goals>
        </execution>
      </executions>
    </plugin>
    <plugin>
      <artifactId>maven-compiler-plugin</artifactId>
    </plugin>
    <plugin>
      <artifactId>maven-surefire-plugin</artifactId>
      <configuration>
        <systemProperties>
          <java.util.logging.manager>
            org.jboss.logmanager.LogManager</java.util.logging.manager>
        </systemProperties>
      </configuration>
    </plugin>
  </plugins>
</build>
```

5.2. Book Entity

The *Book* REST endpoint allows us to insert/update/delete and select books from the PostgreSQL relational database. When dealing with database access in Java, one can use JDBC (*Java DataBase Connectivity*).^[38] But this low-level API can be verbose and quite cumbersome for simple use cases. To ease the relational-database access, Quarkus implements the JPA specification.

Java Persistence API (JPA) is a Java specification that manages objects stored in a relational database.^[39] JPA gives the developer an object-oriented view in order to transparently use entities instead of tables. It also comes with a query language (*Java Persistence Query Language*, or JPQL), allowing complex queries over objects.

The Java Persistence API APIs are all defined under the `javax.persistence` package. **Table 10** lists the main subpackages defined in JPA 2.2 (under the root `javax.persistence` package).

Table 10. Main javax.persistence Subpackages

Subpackage	Description
<code>root</code>	Root package of the JPA APIs

Subpackage	Description
<code>criteria</code>	Java Persistence Criteria API, allowing the writing of queries in an object-oriented way
<code>metamodel</code>	Java Persistence Metamodel API, bringing type safety to the queries
<code>spi</code>	Internal SPIs (<i>Service Provider Interfaces</i>) implemented by the provider



If you like the format of this fascicle and are interested in Java Persistence API, check out the references for my *Understanding JPA 2.2* fascicle in [Appendix E](#).

Along with APIs, JPA comes with a set of annotations. [Table 11](#) lists a subset of the most commonly used annotations.

Table 11. Main JPA Annotations

Annotation	Description
<code>@Entity</code>	POJOs become persistent objects when annotated with <code>@Entity</code>
<code>@Column</code>	Specifies the mapped column for a persistent property (name, length, unique, etc.)
<code>@GeneratedValue</code>	Defines the value generation policy of primary keys
<code>@Id</code>	Specifies the primary key of an entity
<code>@Table</code>	Specifies the primary table for the annotated entity
<code>@Transient</code>	Specifies that the property is not persistent
<code>@OneToOne</code> , <code>@OneToMany</code> , <code>@ManyToOne</code> , <code>@ManyToMany</code>	Relation multiplicity

To manipulate books in a relational database, we would create a `Book` entity using some of these JPA annotations. But with Quarkus, we can go further. Quarkus brings even more simplicity to JPA with a framework called Panache.

Hibernate ORM is the Quarkus JPA implementation and offers you the full breadth of a JPA object-relational mapper. It makes complex mappings and queries possible, but it does not make simple and common mappings trivial. Hibernate ORM with Panache (pronounced *pa·nash*) focuses on simplifying your JPA entities as well as your repositories.



Panache is about more than just making JPA easier. In fact, there is also a MongoDB with Panache extension and an experimental RESTful web services with Panache extension. MongoDB with Panache provides active record style entities (and repositories) and focuses on making entities trivial to map to a MongoDB database. To differentiate both technologies, we use the terms *Hibernate ORM with Panache* and *MongoDB with Panache*.

The `Book` entity in [Listing 31](#) represents a book with a title, an author, ISBN numbers, a price and so on. Being a JPA entity it is annotated with `@Entity` and some attributes are annotated with `@Column`.

And to define our `Book` JPA entity to be a Panache entity, we simply need to extend `PanacheEntity`.

Listing 31. Book Panache Entity with JPA Annotations

```
@Schema(description = "Book representation")
@Entity
public class Book extends PanacheEntity {

    @Schema(required = true)
    public String title;
    @Column(name = "isbn_13")
    public String isbn13;
    @Column(name = "isbn_10")
    public String isbn10;
    public String author;
    @Column(name = "year_of_publication")
    public Integer yearOfPublication;
    @Column(name = "nb_of_pages")
    public Integer nbOfPages;
    public Integer rank;
    public BigDecimal price;
    @Column(name = "small_image_url")
    public URL smallImageUrl;
    @Column(name = "medium_image_url")
    public URL mediumImageUrl;
    @Column(length = 10000)
    public String description;

}
```



Notice that the `Book` entity is also annotated with the `@Schema` annotation from OpenAPI. This will be useful when we later check the documentation of the Book REST endpoint.

Have you noticed that in [Listing 31](#) we use public fields and got rid of getters and setters? Under the hood, Panache generates all getters and setters that are missing, and rewrites every access to these fields to use the accessor methods. This way you can still write useful accessors, but only when you need them. Did you also notice that we do not require to specify a default constructor anymore?

5.2.1. Adding Operations

`Book` needs to be stored, updated and retrieved from a database. Thanks to Panache, once `Book` extends `PanacheEntity`, it gets most of the common operations for free. Below are some operations you are able to do on a `Book` Panache entity:

```

// creating a book
Book book = new Book();
book.title = "H2G2";
book.rank = 9;

// persist it
book.persist();

// getting a list of all Book entities
List<Book> books = Book.listAll();

// finding a specific book by ID
book = Book.findById(id);

// counting all books
long countAll = Book.count();

```

But we are missing a business method. In our use case, we need to return a random book. For that, it's just a matter of adding the method `findRandom()` shown in [Listing 32](#) to our `Book` entity.

Listing 32. Book Panache Entity with an Operation

```

public static Book findRandom() {
    long countBooks = Book.count();
    int randomBook = new Random().nextInt((int) countBooks);
    return Book.findAll().page(randomBook, 1).firstResult();
}

```

5.3. Transactional Book Service

Thanks to JPA annotations, we are able to map our `Book` entity to a relational database. Panache brings CRUD operations so we can now persist or retrieve a book easily (e.g. `book.persist()` or `Book.count()`). What we are missing is a transactional layer so we can insert, update or delete a book in a transactional way. To manipulate the `Book` entity we need to develop a transactional `BookService` class. The idea is to wrap methods that modify the database (e.g. `entity.persist()`) within a transaction. For that, Quarkus implements the JTA specification.

In Java, transaction management is done through the *Java Transaction API* (JTA) specified by JSR 907.^[40] JTA defines a set of interfaces for the application or the container in order to demarcate transaction boundaries, and it also defines APIs to deal with the transaction manager.

The Java Transaction API APIs are all defined under the `javax.transaction` package. [Table 12](#) lists the main subpackages defined in JTA 1.2 (under the root `javax.transaction` package).^[41]

Table 12. Main javax.transaction Subpackages

Subpackage	Description
<code>root</code>	Root package of the JTA APIs

Subpackage	Description
xa	Interfaces and classes to accomplish distributed XA transactions [42]

Along with APIs, JTA comes with a set of annotations. [Table 13](#) lists a subset of the most commonly used annotations.

Table 13. Main JTA Annotations

Annotation	Description
@Transactional	Gives the ability to declaratively control transaction boundaries
@TransactionScoped	Provides the ability to define bean instances whose life cycle is scoped to the currently active transaction

The `BookService` class in [Listing 33](#) is a CDI bean with a life-cycle bound to the life of the application (`@ApplicationScoped`). Then, to be transactional, it's just a matter of marking the entire class, or the methods we need with `@Transactional`.

Listing 33. Transactional Book Service

```
@ApplicationScoped
@Transactional(Transaction.TxType.REQUIRED)
public class BookService {

    private static final Logger LOGGER = Logger.getLogger(BookService.class);

    @Inject
    EntityManager em;

    public Book persistBook(@Valid Book book) {
        Book.persist(book);
        return book;
    }

    @Transactional(Transaction.TxType.SUPPORTS)
    public List<Book> findAllBooks() {
        return Book.listAll();
    }

    @Transactional(Transaction.TxType.SUPPORTS)
    public Optional<Book> findBookById(Long id) {
        return Book.findByIdOptional(id);
    }

    @Transactional(Transaction.TxType.SUPPORTS)
    public Book findRandomBook() {
        Book randomBook = null;
        while (randomBook == null) {
            randomBook = Book.findRandom();
        }
        return randomBook;
    }

    public Book updateBook(@Valid Book book) {
        Book entity = em.merge(book);
        return entity;
    }

    public void deleteBook(Long id) {
        Book.deleteById(id);
    }
}
```

`@Transactional` can be used to control transaction boundaries at the method level or at the class level to ensure every method is transactional. That means that `findAllBooks`, `findBookById` and `findRandomBook` have a transaction of type `SUPPORTS` and `persistBook`, `updateBook` and `deleteBook` of type `REQUIRED`. These transaction types are explained in [Table 14](#).

Table 14. Transaction Types

Attribute	Description
REQUIRED	This attribute (default value) means that a method must always be invoked within a transaction. The container creates a new transaction if the method is invoked from a non-transactional client. If the client has a transaction context, the business method runs within the client's transaction. You should use REQUIRED if you are making calls that should be managed in a transaction, but you can't assume that the client is calling the method from a transaction context.
REQUIRES_NEW	The container always creates a new transaction before executing a method, regardless of whether the client is executed within a transaction. If the client is running within a transaction, the container suspends that transaction temporarily, creates a second one, commits or rolls it back, and then resumes the first transaction. This means that the success or failure of the second transaction has no effect on the existing client transaction. You should use REQUIRES_NEW when you don't want a rollback to affect the client.
SUPPORTS	The transactional method inherits the client's transaction context. If a transaction context is available, it is used by the method; if not, the container invokes the method with no transaction context. You should use SUPPORTS when you have read-only access to the database table.
MANDATORY	The container requires a transaction before invoking the business method but should not create a new one. If the client has a transaction context, it is propagated; if not, a <code>javax.transaction.TransactionalException</code> is thrown.
NOT_SUPPORTED	The transactional method cannot be invoked in a transaction context. If the client has no transaction context, nothing happens; if it does, the container suspends the client's transaction, invokes the method, and then resumes the transaction when the method returns.
NEVER	The transactional method must not be invoked from a transactional client. If the client is running within a transaction context, the container throws a <code>javax.transaction.TransactionalException</code> .

5.4. Book REST Endpoint

To expose a REST API of these transactional services, we need a REST endpoint. Like in the previous chapter, `BookResource` uses JAX-RS and OpenAPI annotations to expose a documented contract and a set of methods to allow CRUD operations.

[Listing 34](#) shows the header of the `BookResource` class. The `@Path` annotation tells us that the API will be accessible through the `/api/books` and will mostly produce and consume JSON. The `getRandomBook()` is accessible through an HTTP GET on `/api/books/random` and returns a random book from the database (invoking the `BookService.findRandomBook()` method). Both OpenAPI annotations `@Operation` and `@APIResponse` document the `getRandomBook()` method while `@Tag` gives a description to the entire endpoint. We will talk about `@Inject` and *Dependency Injection* in the next section.

Listing 34. Book REST Endpoint Retrieving a Random Book

```
@Path("/api/books")
@Produces(MediaType.APPLICATION_JSON)
@Consumes(MediaType.APPLICATION_JSON)
@Tag(name = "Book Endpoint")
public class BookResource {

    @Inject
    BookService service;

    private static final Logger LOGGER = Logger.getLogger(BookResource.class);

    @Operation(summary = "Returns a random book")
    @APIResponse(responseCode = "200", content = @Content(mediaType = MediaType
        .APPLICATION_JSON, schema = @Schema(implementation = Book.class)))
    @GET
    @Path("/random")
    public Response getRandomBook() {
        Book book = service.findRandomBook();
        LOGGER.debug("Found random book " + book);
        return Response.ok(book).build();
    }
}
```

The `getAllBooks()` method in [Listing 35](#) returns the entire list of books from the database (notice the `SchemaType.ARRAY` type in the OpenAPI documentation). If the invocation returns at least one book, a `200-OK` is returned by the response. If the list of books is empty, a `204-No Content` is automatically sent as a response.

Listing 35. Retrieving All the Books

```
@Operation(summary = "Returns all the books from the database")
@APIResponse(responseCode = "200", content = @Content(mediaType = MediaType
    .APPLICATION_JSON, schema = @Schema(implementation = Book.class, type = SchemaType
    .ARRAY)))
@APIResponse(responseCode = "204", description = "No books")
@GET
public Response getAllBooks() {
    List<Book> books = service.findAllBooks();
    LOGGER.debug("Total number of books " + books);
    return Response.ok(books).build();
}
```

[Listing 36](#) details the `getBook()` method that returns a book giving an identifier. To invoke this method you will need an HTTP GET on `/api/books` passing the book id (e.g. `/api/books/1234`). The binding of the parameter is made using the JAX-RS `@PathParam` annotation. The `@Parameter` annotation comes from OpenAPI and brings documentation to the REST contract.

Listing 36. Retrieving a Book By Identifier

```
@Operation(summary = "Returns a book for a given identifier")
@APIResponse(responseCode = "200", content = @Content(mediaType = MediaType
.APPLICATION_JSON, schema = @Schema(implementation = Book.class)))
@APIResponse(responseCode = "404", description = "The book is not found for the given
identifier")
@GET
@Path("/{id}")
public Response getBook(@Parameter(description = "Book identifier", required = true)
@PathParam("id") Long id) {
    Optional<Book> book = service.findBookById(id);
    if (book.isPresent()) {
        LOGGER.debug("Found book " + book);
        return Response.ok(book).build();
    } else {
        LOGGER.debug("No book found with id " + id);
        return Response.status(NOT_FOUND).build();
    }
}
```

The `createBook` method (see [Listing 37](#)) takes a JSON representation of a book from the HTTP request, and persists a book into the database thanks to the transactional method `persistBook()` from the `BookService`. Notice that once the book is persisted, `createBook()` returns the URI of the newly created book, not the book itself, and a return code `201-Created` (thanks to the `Response.created()` method). With this URL, the consumer would be able to do an HTTP GET if needed. On the contrary, the `updateBook()` method returns the updated book. Both methods use the `@Valid` annotation from Bean Validation that we will see in the following section. Here we see the HTTP verbs in action: `@POST` to create a new book, `@PUT` to update an existing one.

Listing 37. Persisting and Updating a Book Into the Database

```
@Operation(summary = "Creates a valid book")
@ApiResponse(responseCode = "201", description = "The URI of the created book",
content = @Content(mediaType = MediaType.APPLICATION_JSON, schema = @Schema
(implementation = URI.class)))
@POST
public Response createBook(@RequestBody(required = true, content = @Content(mediaType
= MediaType.APPLICATION_JSON, schema = @Schema(implementation = Book.class))) @Valid
Book book, @Context UriInfo uriInfo) {
    book = service.persistBook(book);
    UriBuilder builder = uriInfo.getAbsolutePathBuilder().path(Long.toString(book.id));
    LOGGER.debug("New book created with URI " + builder.build().toString());
    return Response.created(builder.build()).build();
}

@Operation(summary = "Updates an existing book")
@ApiResponse(responseCode = "200", description = "The updated book", content =
@Content(mediaType = MediaType.APPLICATION_JSON, schema = @Schema(implementation =
Book.class)))
@PUT
public Response updateBook(@RequestBody(required = true, content = @Content(mediaType
= MediaType.APPLICATION_JSON, schema = @Schema(implementation = Book.class))) @Valid
Book book) {
    book = service.updateBook(book);
    LOGGER.debug("Book updated with new valued " + book);
    return Response.ok(book).build();
}
```

To delete a book, the `deleteBook()` method in [Listing 38](#) takes a book identifier as a parameter and is accessible on an HTTP DELETE invocation. If the delete succeeds, a **204-NO CONTENT** is sent back as a response.

Listing 38. Deleting a Book

```
@Operation(summary = "Deletes an existing book")
@ApiResponse(responseCode = "204", description = "The book has been successfully
deleted")
@DELETE
@Path("/{id}")
public Response deleteBook(@Parameter(description = "Book identifier", required =
true) @PathParam("id") Long id) {
    service.deleteBook(id);
    LOGGER.debug("Book deleted with " + id);
    return Response.noContent().build();
}
```

All the methods of the `BookResource` have been annotated with OpenAPI annotations. Remember that `@Operation` informs us about the method, usually giving it a description, `@ApiResponse` documents all the possible responses returned by the method, and `@Parameter` describes the

parameters that each method takes. Thanks to these OpenAPI annotations, the OpenAPIv3 contract will be clearer and more documented.

5.4.1. Dependency Injection

The `BookResource` deals with all the REST concerns: it intercepts HTTP GET, POST, PUT, DELETE calls, deals with the JSON representation of a `Book`, sends back HTTP status codes, etc. But to actually insert, update or retrieve a book from the PostgreSQL database, it delegates all the calls to the transactional `BookService`. This separation of concerns is good because it simplifies the development and maintenance of an application.^[43] But that means that `BookResource` depends on `BookService`. This dependence can be achieved with dependency injection and Quarkus, at its core, uses CDI to do dependency injection. Dependency injection in Quarkus is based on ArC which is a CDI-lite dependency injection solution tailored for Quarkus' architecture.^[44]

Context and Dependency Injection (CDI) is a central technology in Jakarta EE or in MicroProfile.^[45] Its programming model turns nearly every component into an injectable, interceptable and manageable bean. CDI is built on the concept of "*loose coupling, strong typing*", meaning that beans are loosely coupled, but in a strongly-typed way. Decoupling goes further by bringing interceptors, decorators and events to the entire platform. CDI homogenises scopes among beans, as well as context and life cycle management.

The Context and Dependency Injection APIs and annotations are defined under several root packages: `javax.inject`, `javax.enterprise` and `javax.interceptor`. Table 15 lists the main subpackages defined in CDI 2.0.

Table 15. Main CDI Subpackages

Subpackage	Description
<code>javax.inject</code>	Root package of the CDI APIs
<code>javax.enterprise.inject</code>	Core dependency injection APIs
<code>javax.enterprise.context</code>	Scopes and contextual APIs
<code>javax.enterprise.event</code>	Events and observers APIs
<code>javax.enterprise.util</code>	Utility package
<code>javax.interceptor</code>	Contains the Interceptor APIs (JSR 318)

Along with APIs, CDI comes with a set of annotations. Table 16 lists a subset of the most commonly used annotations.

Table 16. Main CDI Annotations

Annotation	Description
<code>@Inject</code>	Identifies injectable constructors, methods, and fields
<code>@Qualifier</code>	Identifies qualifier annotations

Annotation	Description
@ApplicationScoped, @SessionScoped, @RequestScoped, @Singleton, @Dependent	Set of annotations defining the life cycle of a bean
@Observes	Identifies the event parameter of an observer method



Not all the previous CDI annotations are supported by Quarkus. Quarkus does not fully implement CDI but, rather, a lighter version of it (a.k.a CDI-lite). You can check the list of supported features and the list of limitations.^[46]

The way `BookResource` injects a reference of `BookService` is easy and straightforward. As shown in [Listing 39](#), it's just a matter of using the `@Inject` annotation.

Listing 39. Dependency Injection

```
@Path("/api/books")
@Produces(MediaType.APPLICATION_JSON)
@Consumes(MediaType.APPLICATION_JSON)
@Tag(name = "Book Endpoint")
public class BookResource {

    @Inject
    BookService service;
```

5.5. Validating Data

Previously (see [Listing 33](#)), you've seen that the `BookService` uses the `@Valid` annotation on the parameters of a few methods. This is a way to validate data prior to entering a method: if the given parameters are not valid, then the method is not even invoked. This is possible because Quarkus implements Bean Validation.

Validating data is a common task that developers have to do and it is spread throughout all layers of an application (from client to database). This common practice is time-consuming, error prone, and hard to maintain in the long run. Besides, some of these constraints are so frequently used that they could be considered standard (checking for a null value, size, range, etc.). It would be good to be able to centralise these constraints in one place and share them across layers. That's where Bean Validation comes into play.

Bean Validation allows you to write a constraint once and reuse it in different application layers.^[47] It is layer agnostic, meaning that the same constraint can be used from the presentation to the business model layer. Bean Validation is available for server-side applications as well as rich Java client graphical interfaces (Swing, Android, JavaFX etc.).

Bean Validation allows you to apply already-defined common constraints to your application, and also to write your own validation rules in order to validate beans, attributes, constructors, method return values and parameters. The API is very easy to use and flexible as it encourages you to

define your constraints using annotations or XML descriptors.



If you like the format of this fascicle and are interested in Bean Validation, check out the references for my *Understanding Bean Validation 2.0* fascicle in [Appendix E](#).

The Bean Validation APIs and annotations are all defined under the `javax.validation` package. [Table 17](#) lists the main subpackages defined in Bean Validation 2.0 (under the root `javax.validation` package).^[48]

Table 17. Main javax.validation Subpackages

Subpackage	Description
<code>root</code>	Root package of the Bean Validation APIs
<code>bootstrap</code>	Classes used to bootstrap Bean Validation and to create a provider agnostic configuration
<code>constraints</code>	This package contains all the built-in constraints
<code>constraintvalidation</code>	Package containing constructs specific to constraint validators
<code>executable</code>	Package related to the control and execution of validation on constructors and methods
<code>groups</code>	Bean Validation groups for defining a subset of constraints
<code>metadata</code>	Metadata repository for all defined constraints and query API
<code>spi</code>	Internal SPIs (<i>Service Provider Interfaces</i>) implemented by the provider
<code>valueextraction</code>	Package dedicated to extracting values to validate container elements

Along with APIs, Bean Validation comes with a set of annotations. [Table 18](#) lists a subset of the most commonly used annotations.

Table 18. Main Bean Validation Annotations

Annotation	Description
<code>@Constraint</code>	Marks an annotation as being a Bean Validation constraint
<code>@Email</code>	The string has to be a well-formed email address
<code>@Max, @Min</code>	The annotated element must be a number whose value is lower or equal, or higher or equal to the specified value
<code>@Null, @NotNull</code>	The annotated element must be null or not null
<code>@Past, @Future</code>	The annotated element must be an instant, date or time in the past or in the future
<code>@Valid</code>	Marks a property, method parameter or method return type for validation

But what does it mean to be valid? What makes a book valid and a book invalid? Well, it's just a matter of adding the right annotations on the `Book` class or attributes. As you can see in [Listing 40](#), if you add a `@NotNull` annotation on the `title` attribute it will indicate to Bean Validation that the title of a book cannot be null. The `rank` attribute is annotated twice with `@Min(1)` and `@Max(10)` which

indicates that the rank of a book should be between 1 and 10. The `description` of a book can be null, but if not, has to have a length between 1 and 10,000 characters.

Listing 40. Book Panache Entity with Bean Validation Annotations

```
@Schema(description = "Book representation")
@Entity
public class Book extends PanacheEntity {

    @NotNull
    @Schema(required = true)
    public String title;
    @Column(name = "isbn_13")
    public String isbn13;
    @Column(name = "isbn_10")
    public String isbn10;
    public String author;
    @Column(name = "year_of_publication")
    public Integer yearOfPublication;
    @Column(name = "nb_of_pages")
    public Integer nbOfPages;
    @Min(1) @Max(10)
    public Integer rank;
    public BigDecimal price;
    @Column(name = "small_image_url")
    public URL smallImageUrl;
    @Column(name = "medium_image_url")
    public URL mediumImageUrl;
    @Column(length = 10000)
    @Size(min = 1, max = 10000)
    public String description;

}
```

Notice in [Listing 40](#) that you can have JPA column annotations (e.g. `@Column`), Bean Validation constraint annotations (e.g. `@Size`) and OpenAPI annotations (e.g. `@Schema`) on the same attribute.

If you look at the code in [Listing 41](#) you will see that both methods that persist and update a book, pass a `Book` object as a parameter. Thanks to the Bean Validation's `@Valid` annotation, the `Book` object will be checked to see if it's valid or not. If it's not, the method will not be invoked.

Listing 41. Book Service Validating the Book Parameter

```
public Book persistBook(@Valid Book book) {  
    Book.persist(book);  
    return book;  
}  
  
public Book updateBook(@Valid Book book) {  
    Book entity = em.merge(book);  
    return entity;  
}
```

5.6. OpenAPI

In [Listing 31](#) we have added some OpenAPI annotations (e.g. `@Schema`) so the `Book` entity gets some extra information. We've also added some OpenAPI annotations to the `BookResource` class (see [Listing 34](#)). So we already have good documentation on the REST endpoint. Now it's just a matter of having documentation for the overall application.

5.6.1. Customising the OpenAPI Contract of the Application

The `BookApplication` class in [Listing 42](#) is just there to customise the OpenAPI contract for the entire application. `@OpenAPIDefinition` provides metadata about the API such as the team to contact (`@Contact`) or the documentation to know more about the API (`@ExternalDocumentation`).

Listing 42. Custom OpenAPI Documentation for the Application

```
@ApplicationPath("/")  
@OpenAPIDefinition(  
    info = @Info(title = "Book API",  
        description = "This API allows CRUD operations on books",  
        version = "1.0",  
        contact = @Contact(name = "@agoncal", url = "https://twitter.com/agoncal")),  
    externalDocs = @ExternalDocumentation(url = "https://github.com/agoncal/agoncal-  
fascicle-quarkus-pract", description = "All the Practising Quarkus code"),  
    tags = {  
        @Tag(name = "api", description = "Public API that can be used by anybody"),  
        @Tag(name = "books", description = "Anybody interested in books")  
    }  
)  
public class BookApplication extends Application {  
}
```

5.6.2. The Customised OpenAPI Contract

With all the added documentation that we've done on the `Book` entity, `BookResource` and `BookApplication`, the OpenAPI contract looks like the one in [Listing 43](#).

Listing 43. Header of the Custom OpenAPI YAML Contract

```
openapi: 3.0.3
info:
  title: Book API
  description: This API allows CRUD operations on books
  contact:
    name: '@agoncal'
    url: https://twitter.com/agoncal
    version: "1.0"
  externalDocs:
    description: All the Practising Quarkus code
    url: https://github.com/agoncal/agoncal-fascicle-quarkus-pract
  tags:
    - name: api
      description: Public API that can be used by anybody
    - name: books
      description: Anybody interested in books
```

Listing 44 shows the documentation for the root path `/api/books`. You can see the GET, PUT, POST and DELETE methods being documented. Notice that most methods produce or consume a `Book` that is later documented (`$ref: '#/components/schemas/Book'`) in *Listing 46*.

Listing 44. Documentation for GET/POST/PUT/DELETE

```
paths:
  /api/books:
    get:
      summary: Returns all the books from the database
      responses:
        204:
          description: No books
        200:
          description: OK
          content:
            application/json:
              schema:
                type: array
                items:
                  $ref: '#/components/schemas/Book'

    put:
      summary: Updates an existing book
      requestBody:
        content:
          application/json:
            schema:
              $ref: '#/components/schemas/Book'
        required: true
      responses:
```

```

200:
  description: The updated book
  content:
    application/json:
      schema:
        $ref: '#/components/schemas/Book'

post:
  summary: Creates a valid book
  requestBody:
    content:
      application/json:
        schema:
          $ref: '#/components/schemas/Book'
        required: true
  responses:
    201:
      description: The URI of the created book
      content:
        application/json:
          schema:
            format: uri
            type: string

delete:
  summary: Deletes an existing book
  parameters:
    - name: id
      in: path
      description: Book identifier
      required: true
      schema:
        format: int64
        type: integer
  responses:
    204:
      description: The book has been successfully deleted

```

[Listing 45](#) shows the documentation of the other paths: an HTTP GET on `/api/books/random` that returns a random book, and `/api/books/{id}` returning a book by identifier. Both endpoints return a Book.

Listing 45. Documentation for Other GET Invocations

```
/api/books/random:  
get:  
  summary: Returns a random book  
  responses:  
    200:  
      description: OK  
      content:  
        application/json:  
          schema:  
            $ref: '#/components/schemas/Book'  
  
/api/books/{id}:  
get:  
  summary: Returns a book for a given identifier  
  parameters:  
  - name: id  
    in: path  
    description: Book identifier  
    required: true  
    schema:  
      format: int64  
      type: integer  
  responses:  
    204:  
      description: The book is not found for the given identifier  
    200:  
      description: OK  
      content:  
        application/json:  
          schema:  
            $ref: '#/components/schemas/Book'
```

At the end of the YAML documentation (see [Listing 46](#)) you'll find the description and documentation of our `Book` entity.

Listing 46. Documentation of the Book Component

```
components:
schemas:
Book:
  description: Book representation
  required:
  - title
  type: object
  properties:
    id:
      format: int64
      type: integer
    author:
      type: string
    description:
      maxLength: 10000
      minLength: 1
      type: string
    isbn10:
      type: string
    isbn13:
      type: string
    mediumImageUrl:
      $ref: '#/components/schemas/URL'
    nbOfPages:
      format: int32
      type: integer
    price:
      $ref: '#/components/schemas/BigDecimal'
    rank:
      format: int32
      maximum: 10
      minimum: 1
      type: integer
    smallImageUrl:
      $ref: '#/components/schemas/URL'
    title:
      type: string
      nullable: false
    yearOfPublication:
      format: int32
      type: integer
```

5.6.3. Swagger UI

Having YAML or JSON OpenAPI documentation is very useful for other systems to interact with our API, but it can be difficult for a human to read if the contract is too long or complex. That's why you can go to the URL <http://localhost:8080/swagger-ui> and get the visual aspect of the contract thanks to Swagger UI. The Swagger UI web interface looks like the one in [Figure 11](#). It gives you all the

documentation we've just seen, plus you can interact with the *Book* REST endpoint by creating or deleting books from the database.

The screenshot shows the Swagger UI for the Book API. At the top, there's a banner for 'Book API' version 1.0, OAS3, with links to 'openapi', '@agoncal - Website', and 'All the Practicing Quarkus code'. Below this, a section titled 'api' describes it as a Public API that can be used by anybody. The 'books' section is described as Anybody interested in books. The 'default' section contains several endpoints:

- GET /api/books** Returns all the books from the database
- PUT /api/books** Updates an existing book
- POST /api/books** Creates a valid book
- GET /api/books/random** Returns a random book
- GET /api/books/{id}** Returns a book for a given identifier
- DELETE /api/books/{id}** Deletes an existing book

Below these, a 'Schemas' section includes definitions for 'Book', 'URL', and 'BigDecimal'.

Figure 11. Swagger UI contract for the Book endpoint

5.7. Application Startup and Shutdown

In the last chapter, we added a nice banner to the *Number* microservice. Let's do the same for *Book*. First, remember to disable the original "Quarkus" banner by setting the property

Set `quarkus.banner.enabled` to `false` in the `application.properties` file. Then, develop the `BookApplicationLifecycle` (see Listing 47) that is an `@ApplicationScoped` bean that defines two methods:

- `onStart` observes a `StartupEvent` which means it displays a banner and the current profile once Quarkus starts up,
 - `onStop` observes the `ShutdownEvent` and displays a message when Quarkus shuts down.

Listing 47. Displaying a Banner at Startup

```
@ApplicationScoped
class BookApplicationLifeCycle {

    private static final Logger LOGGER = Logger.getLogger(BookApplicationLifeCycle.class);

    void onStart(@Observes StartupEvent ev) {
        LOGGER.info("_____|_");
        LOGGER.info("| ___ \\| | |");
        LOGGER.info("|_|/_ / ___ ___|_|_|_");
        LOGGER.info("| ___ \\\\/_ \\/_/_\\|_|/_/");
        LOGGER.info("|_|/_ / ()|()|_|<|");
        LOGGER.info("\\\\___/_\\___/_\\___/_|_|\\_\\");
        LOGGER.info("Powered by Quarkus");
        LOGGER.info("The application Book is starting with profile " + ProfileManager.getActiveProfile());
    }

    void onStop(@Observes ShutdownEvent ev) {
        LOGGER.info("The application Book is stopping...");
    }
}
```



If you want a nice ascii-art type banner, check the website <http://patorjk.com/software/taag>.

5.8. Running the Application

To run the *Number* microservice seen in the previous chapter was quite straightforward: some configuration and a `mvn quarkus:dev` and that was it. The *Book* microservice is slightly more complex and needs a database to run and to test. Thanks to Docker and TestContainers it is easy to start and stop a PostgreSQL database during tests. But before testing and executing our microservice, let's first configure it.

5.8.1. Configuring the Application

Book microservice needs a bit more extra configuration than the *Number* microservice seen in the previous chapter. That's because it needs to access a database. So we need to configure the database

access as well as Hibernate. But first let's configure the HTTP listening port.

Configuring the Quarkus Listening Port

Number microservice runs on port 8081, so let's change the port for our *Book* microservice so they listen on different ports. As we've seen in the previous chapter, it's just a matter of adding the `quarkus.http.port` property in the `src/main/resources/application.properties` file:

```
quarkus.http.port=8082
```

Configuring Hibernate

Quarkus development mode is really useful for applications that mix microservices and database access. When we use the property `quarkus.hibernate-orm.database.generation` set to `drop-and-create`, the database schema is automatically recreated by Quarkus each time the *Book* entity changes. For that, make sure you have the following configuration in the `application.properties`:

```
quarkus.hibernate-orm.database.generation=drop-and-create
quarkus.hibernate-orm.log.sql=true
quarkus.hibernate-orm.sql-load-script=import.sql
```

Configuring the Datasource

Our project now requires a connection to a PostgreSQL database. The way to obtain connections to a database is to use a datasource.^[49] In Quarkus, the datasource and connection pooling implementation is called Agroal.^[50] To configure the datasource, just add the following configuration in the `application.properties`:

```
quarkus.datasource.db-kind=postgresql
quarkus.datasource.username=book
quarkus.datasource.password=book

quarkus.datasource.jdbc.url=jdbc:postgresql://localhost:5432/books_database
quarkus.datasource.jdbc.min-size=2
quarkus.datasource.jdbc.max-size=8
```

5.8.2. Adding Data

In development mode, for tests or demos, it is useful to have a data set ready. To load some SQL statements when Hibernate starts, we can add `INSERT` SQL statements to a file called `import.sql` (see Listing 48) located in the root of the `resources` directory. It contains SQL statements terminated by a semicolon. The `import.sql` file also works well with Quarkus live reload mode: our *Book* entity or the `import.sql` file changes, and this change is immediately picked up, the schema is updated and the data inserted without restarting the application!

Listing 48. import.sql File

```
INSERT INTO Book(id, isbn_13, title, rank, small_image_url, medium_image_url, price, nb_of_pages, year_of_publication, author, description)
VALUES ( 997, '9781980399025', 'Understanding Bean Validation', 9, 'https://images-na.ssl-images-amazon.com/images/I/31fHenHChZL._SL160_.jpg', 'https://images-na.ssl-images-amazon.com/images/I/31fHenHChZL.jpg', 9.99, 129, 2018, 'Antonio Goncalves', 'In this fascicle will you will learn Bean Validation and use its different APIs to apply constraints on a bean, validate all sorts of constraints and write your own constraints');

INSERT INTO Book(id, isbn_13, title, rank, small_image_url, medium_image_url, price, nb_of_pages, year_of_publication, author, description)
VALUES ( 998, '9781093918977', 'Understanding JPA', 9, 'https://images-na.ssl-images-amazon.com/images/I/3122s2sj0tL._SL160_.jpg', 'https://images-na.ssl-images-amazon.com/images/I/3122s2sj0tL.jpg', 9.99, 246, 2019, 'Antonio Goncalves', 'In this fascicle, you will learn Java Persistence API, its annotations for mapping entities, as well as the Java Persistence Query Language and entity life cycle');
```

5.8.3. Testing the Application

To test the `BookResource` endpoint, we will be using TestContainers to fire a PostgreSQL database and then test CRUD operations. As you will see, these tests are more complex as they start a PostgreSQL database in order to allow CRUD operations to be tested against a real database.

Firing the Infrastructure

`Listing 49` shows the `Database` class that is under the `src/test/java` directory in the `org.agoncal.fascicle.quarkus.book.infrastructure` subpackage. The purpose of this class is to manage the life cycle of a PostgreSQL container. For that, it extends the `QuarkusTestResourceLifecycleManager` class. Thanks to the `start()` and `stop()` methods, the PostgreSQL container is started once before the test case, and stopped at the end.

Listing 49. Resource Declaring a PostgreSQL Database

```
public class Database implements QuarkusTestResourceLifecycleManager {  
  
    private static final PostgreSQLContainer DATABASE = new PostgreSQLContainer<>(  
        "postgres:12.4")  
        .withDatabaseName("books_database")  
        .withUsername("book")  
        .withPassword("book")  
        .withExposedPorts(5432);  
  
    @Override  
    public Map<String, String> start() {  
        DATABASE.start();  
        return Collections.singletonMap("quarkus.datasource.jdbc.url", DATABASE.  
getJdbcUrl());  
    }  
  
    @Override  
    public void stop() {  
        DATABASE.stop();  
    }  
}
```

Testing the Business Logic

Now that we have a PostgreSQL database that is automatically started and stopped during testing, let's test the business logic of our `BookResource` class. Listing 50 shows the header of the `BookResourceTest` class. What's important to notice is the different annotations that annotate this class:

- `@QuarkusTest`: Annotates a Quarkus test
- `@QuarkusTestResource`: Used to define a test resource (e.g. a database, a tool, etc.)
- `@TestMethodOrder`: JUnit annotation used to configure the `MethodOrderer` for the test methods (e.g. `@Order(1), @Order(2)`, etc.)

Then, the header is just a set of constants that will be used to create and update a book and check that the values are correct. `nbBooks` is the number of initial rows that are inserted in the database (coming from the `import.sql` file), and the `bookId` variable holds the current book that is being tested.

Listing 50. Test Case Header

```
@QuarkusTest
@QuarkusTestResource(Database.class)
@TestMethodOrder(MethodOrderer.OrderAnnotation.class)
public class BookResourceTest {

    private static final String DEFAULT_TITLE = "Title";
    private static final String UPDATED_TITLE = "Title (updated)";
    private static final String DEFAULT_AUTHOR = "Author";
    private static final String UPDATED_AUTHOR = "Author (updated)";
    private static final Integer DEFAULT_YEAR_OF_PUBLICATION = 1111;
    private static final Integer UPDATED_YEAR_OF_PUBLICATION = 2222;
    private static final Integer DEFAULT_NB_OF_PAGES = 111;
    private static final Integer UPDATED_NB_OF_PAGES = 222;
    private static final Integer DEFAULT_RANK = 1;
    private static final Integer UPDATED_RANK = 2;
    private static final BigDecimal DEFAULT_PRICE = new BigDecimal(11.0);
    private static final BigDecimal UPDATED_PRICE = new BigDecimal(22.0);
    private static final URL DEFAULT_SMALL_IMAGE_URL = makeUrl("http://www.url.com");
    private static final URL UPDATED_SMALL_IMAGE_URL = makeUrl(
"http://www.updatedurl.com");
    private static final URL DEFAULT_MEDIUM_IMAGE_URL = makeUrl("http://www.url.com");
    private static final URL UPDATED_MEDIUM_IMAGE_URL = makeUrl(
"http://www.updatedurl.com");
    private static final String DEFAULT_DESCRIPTION = "Description";
    private static final String UPDATED_DESCRIPTION = "Description (updated)";
    // Mocking numbers that should be generated by the Number microservice
    public static final String MOCK_ISBN_13 = "Isbn 13";
    public static final String MOCK_ISBN_10 = "Isbn 10";

    private static URL makeUrl(String urlString) {
        try {
            return new URL(urlString);
        } catch (MalformedURLException e) {
            return null;
        }
    }

    private static int nbBooks;
    private static String bookId;
```

The first test method that is executed (`@Order(1)`) in [Listing 51](#) invokes an HTTP GET on `/api/books`. With such a call, the method `getAllBooks()` of the `BookResource` in [Listing 35](#) is executed and returns the entire list of books from the database. The `shouldGetInitialItems()` method checks that the invocation returns a `200-OK` and stores the total number of books into the `nbBooks` variable (this variable is then used in most of the following tests).

Listing 51. Returning All Books from the Database

```
@Test
@Order(1)
void shouldGetInitialItems() {
    List<Book> books =
        given().
        when()
            .get("/api/books").
        then()
            .statusCode(OK.getStatusCode())
            .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
            .extract().body().as(getBookTypeRef());

    nbBooks = books.size();
}

private TypeRef<List<Book>> getBookTypeRef() {
    return new TypeRef<List<Book>>() {
    };
}
```

The second test in [Listing 52](#) creates a new `Book` entity, sets some default values and invokes an HTTP POST on `/api/books`. If you check the `createBook()` method in [Listing 37](#), you can see that once the book is persisted in the database, the URL of its location is returned. So, in this test case, we check that the method returns a `Location` HTTP header, extract the book identifier from it, and do an HTTP GET passing this identifier. The method then checks that the created book is the same as the one that we just got.

Listing 52. Test Case for Creating a New Book

```
@Test
@Order(2)
void shouldAddAnItem() {
    Book book = new Book();
    book.title = DEFAULT_TITLE;
    book.author = DEFAULT_AUTHOR;
    book.yearOfPublication = DEFAULT_YEAR_OF_PUBLICATION;
    book.nbOfPages = DEFAULT_NB_OF_PAGES;
    book.rank = DEFAULT_RANK;
    book.price = DEFAULT_PRICE;
    book.smallImageUrl = DEFAULT_SMALL_IMAGE_URL;
    book.mediumImageUrl = DEFAULT_MEDIUM_IMAGE_URL;
    book.description = DEFAULT_DESCRIPTION;

    // Persists a new book
    String location =
        given()
            .body(book)
            .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
```

```

    .header(HttpHeaders.ACCEPT, MediaType.APPLICATION_JSON).
when()
    .post("/api/books").
then()
    .statusCode(CREATED.getStatusCode())
    .extract().header("Location");

// Extracts the Location and stores the book id
assertTrue(location.contains("/api/books"));
String[] segments = location.split("/");
bookId = segments[segments.length - 1];
assertNotNull(bookId);

// Checks the book has been created
given()
    .pathParam("id", bookId).
when()
    .get("/api/books/{id}").
then()
    .statusCode(OK.getStatusCode())
    .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
    .body("title", Is.is(DEFAULT_TITLE))
    .body("isbn13", Is.is(MOCK_ISBN_13))
    .body("isbn10", Is.is(MOCK_ISBN_10))
    .body("author", Is.is(DEFAULT_AUTHOR))
    .body("yearOfPublication", Is.is(DEFAULT_YEAR_OF_PUBLICATION))
    .body("nbOfPages", Is.is(DEFAULT_NB_OF_PAGES))
    .body("rank", Is.is(DEFAULT_RANK))
    .body("smallImageUrl", Is.is(DEFAULT_SMALL_IMAGE_URL.toString()))
    .body("mediumImageUrl", Is.is(DEFAULT_MEDIUM_IMAGE_URL.toString()))
    .body("description", Is.is(DEFAULT_DESCRIPTION));

// Checks there is an extra book in the database
List<Book> books =
given().
when()
    .get("/api/books").
then()
    .statusCode(OK.getStatusCode())
    .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
    .extract().body().as(getBookTypeRef());

assertEquals(nbBooks + 1, books.size());
}

```

The test case in Listing 53 checks that the `BookResource` endpoint updates the newly created book. It's just a matter of invoking an HTTP PUT with the updated book, and checking that the response is correct.

Listing 53. Test Case for Updating the Created Book

```
@Test
@Order(3)
void shouldUpdateAnItem() {
    Book book = new Book();
    book.id = Long.valueOf(bookId);
    book.title = UPDATED_TITLE;
    book.isbn13 = MOCK_ISBN_13;
    book.isbn10 = MOCK_ISBN_10;
    book.author = UPDATED_AUTHOR;
    book.yearOfPublication = UPDATED_YEAR_OF_PUBLICATION;
    book.nbOfPages = UPDATED_NB_OF_PAGES;
    book.rank = UPDATED_RANK;
    book.price = UPDATED_PRICE;
    book.smallImageUrl = UPDATED_SMALL_IMAGE_URL;
    book.mediumImageUrl = UPDATED_MEDIUM_IMAGE_URL;
    book.description = UPDATED_DESCRIPTION;

    // Updates the previously created book
    given()
        .body(book)
        .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
        .header(HttpHeaders.ACCEPT, MediaType.APPLICATION_JSON).
    when()
        .put("/api/books").
    then()
        .statusCode(OK.getStatusCode())
        .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
        .body("title", Is.is(UPDATED_TITLE))
        .body("isbn13", Is.is(MOCK_ISBN_13))
        .body("isbn10", Is.is(MOCK_ISBN_10))
        .body("author", Is.is(UPDATED_AUTHOR))
        .body("yearOfPublication", Is.is(UPDATED_YEAR_OF_PUBLICATION))
        .body("nbOfPages", Is.is(UPDATED_NB_OF_PAGES))
        .body("rank", Is.is(UPDATED_RANK))
        .body("price", Is.is(UPDATED_PRICE.intValue()))
        .body("smallImageUrl", Is.is(UPDATED_SMALL_IMAGE_URL.toString()))
        .body("mediumImageUrl", Is.is(UPDATED_MEDIUM_IMAGE_URL.toString()))
        .body("description", Is.is(UPDATED_DESCRIPTION));
}
```

Listing 54 checks that the `BookResource` endpoint deletes the book from the database. For that, not only does it test the HTTP status code (`204 No Content`) but also that a book has been removed from the database.

Listing 54. Test Case for Removing the Created Book

```
@Test
@Order(4)
void shouldRemoveAnItem() {
    // Deletes the previously created book
    given()
        .pathParam("id", bookId).
    when()
        .delete("/api/books/{id}").
    then()
        .statusCode(NO_CONTENT.getStatusCode());

    // Checks there is less a book in the database
    List<Book> books =
        given().
    when()
        .get("/api/books").
    then()
        .statusCode(OK.getStatusCode())
        .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
        .extract().body().as(getBookTypeRef());

    assertEquals(nbBooks, books.size());
}
```

Remember that we've annotated the `Book` entity with Bean Validation annotations (see [Listing 40](#)) to make sure the data is valid before persisting. In [Listing 41](#) the `BookService` uses the `@Valid` annotation so the book passed as a parameter is first validated, and then persisted if valid. To test this behaviour, the test case in [Listing 55](#) passes an invalid `Book` (with a `null` title) and checks that persisting it fails (HTTP status code `400 Bad Request`).

Listing 55. Checking That Creating an Invalid Book Is Not Possible

```
@Test
void shouldNotAddInvalidItem() {
    Book book = new Book();
    book.title = null;

    given()
        .body(book)
        .header(HttpHeaders.CONTENT_TYPE, MediaType.APPLICATION_JSON)
        .header(HttpHeaders.ACCEPT, MediaType.APPLICATION_JSON).
    when()
        .post("/api/books").
    then()
        .statusCode(BAD_REQUEST.getStatusCode());
}
```

Now execute the test with `mvn test` or from your IDE. The test should pass.

5.8.4. Running the Infrastructure

To execute the application we now need a PostgreSQL database (and later on we will need Prometheus). Let's use Docker and Docker Compose to ease the installation of this infrastructure.^[51]



If you want to know more about Docker, you can check [Appendix A](#).

At the beginning of this fascicle, you installed some code located under a directory structure. The complete infrastructure of the Vintage Store application is defined in a Docker Compose file under the `infrastructure` directory. There you find all the required code to setup the infrastructure of our microservice architecture. [Listing 56](#) shows the `docker-compose.yaml` file declaring the PostgreSQL database container.

Listing 56. Docker Compose File With a PostgreSQL Container

```
version: "3"
services:
  database:
    image: "postgres:12.1"
    container_name: "books-database"
    ports:
      - "5432:5432"
    volumes:
      - ./db-init/initialize-databases.sql:/docker-entrypoint-initdb.d/init.sql
  monitoring:
    image: "prom/prometheus:v2.21.0"
    container_name: "books-monitoring"
    ports:
      - 9090:9090
    volumes:
      - ./monitoring/prometheus.yml:/etc/prometheus/prometheus.yml
```

At the root of the `infrastructure` directory, just execute a `docker-compose -f docker-compose.yaml up -d` command and you should see a few logs going on and then all the containers get started:

```
infrastructure$ docker-compose -f docker-compose.yaml up -d
Creating network "infrastructure_default" with the default driver
Creating books-database ... done

infrastructure$ docker container ls
CONTAINER ID   IMAGE          PORTS
94f42390deba   postgres:12.1   0.0.0.0:5432->5432/tcp   books-database
```

Now you can either leave the containers up and running or you can shut them down using the following command:

```
infrastructure$ docker-compose -f docker-compose.yaml down
Stopping books-database ... done
```

5.8.5. Executing the Application

Now that the tests pass and our infrastructure is up and running, we are ready to run our application. At this stage, you can either run `mvn quarkus:dev` to start it in development mode, or `mvn package` so you can execute the executable JAR file (`java -jar target/rest-book-1.0-runner.jar`). Once started, check that there are books in the database with, for example, the following cURL command:

```
$ curl http://localhost:8082/api/books/997 | jq

{
  "id": 997,
  "author": "Antonio Goncalves",
  "description": "In this fascicle, you will learn Java Persistence API, its annotations for mapping entities, as well as the Java Persistence Query Language and entity life cycle",
  "isbn13": "9781980399025",
  "mediumImageUrl": "https://images-na.ssl-images-amazon.com/images/I/31fHenHChZL.jpg",
  "nbOfPages": 129,
  "price": 9.99,
  "rank": 9,
  "smallImageUrl": "https://images-na.ssl-images-amazon.com/images/I/31fHenHChZL._SL160_.jpg",
  "title": "Understanding Bean Validation",
  "yearOfPublication": 2018
}
```

5.9. Summary

In this chapter, you've developed a second microservice: the *Book* REST endpoint manipulates books in the database. The *Book* microservice is slightly more complex than the *Number* microservice. Because it stores and retrieves data from a database, we need to use some sort of persistence mechanism. JPA is a perfect technology when it comes to mapping objects to a relational database (Object-Relational Mapping tool). Panache is an extension of JPA allowing you to easily have access to common database operations (e.g. persisting an object, retrieving all the objects, retrieving by identifier, etc.). And if transaction management is needed, then it's just a matter of using a few annotations from JTA on a transactional service that can be injected thanks to CDI. Because manipulating valid information is crucial, you use Bean Validation constraint annotations to make sure the book object has valid data before persisting it.

But it's not because the *Book* microservice is more complex that testing or running it should be. Both *Book* and *Number* microservices are executed and tested the same way. The only difference is

that in the *Book* microservice we use Docker and TestContainers to automatically start a PostgreSQL database container before testing our code, and shutting it down. And thanks to Docker Compose, with just a one line command, we fired a PostgreSQL database and executed our *Book* microservice (either in development or production mode).

In the next chapter, you will package and install an Angular application on Quarkus. The goal of the next chapter is not to teach you Angular as the application has already been coded. But, rather, it's to install it, package it within Quarkus, run it and make it available to a browser.

- [38] JDBC https://en.wikipedia.org/wiki/Java_Database_Connectivity
- [39] JPA <https://jcp.org/en/jsr/detail?id=338>
- [40] JTA <https://jcp.org/en/jsr/detail?id=907>
- [41] JTA GitHub <https://github.com/eclipse-ee4j/jta-api>
- [42] Open XA https://en.wikipedia.org/wiki/X/Open_XA
- [43] Separation of Concerns <https://java-design-patterns.com/principles/#separation-of-concerns>
- [44] ArC <https://github.com/quarkusio/quarkus/tree/master/independent-projects/arc>
- [45] CDI <https://jcp.org/en/jsr/detail?id=365>
- [46] CDI limitations <https://quarkus.io/guides/cdi-reference#limitations>
- [47] Bean Validation <https://jcp.org/en/jsr/detail?id=380>
- [48] Bean Validation GitHub <https://github.com/eclipse-ee4j/beanvalidation-api>
- [49] DataSource <https://docs.oracle.com/en/java/javase/11/docs/api/java.sql/javax/sql/DataSource.html>
- [50] Agroal <https://agroal.github.io>
- [51] Docker <https://www.docker.com>

Chapter 6. Installing the Vintage Store User Interface

So far, the Vintage Store application is made up of two microservices: the *Number* REST endpoint and the *Book* REST endpoint. We've developed them, tested them and invoked a few URLs with cURL. So we know they work. In this chapter, you will package and install an already-developed Angular user interface to interact with them.

6.1. What Will You Build in This Chapter?

The purpose of this chapter is not to develop a web interface and learn yet another web framework. This time you will just:

- Package an already-made Angular application,
- Install the packaged Angular application on a Quarkus instance,
- Execute the application and see if it connects to the two microservices.



When you've downloaded and unzipped the <https://raw.githubusercontent.com/agoncal/agoncal-fascicle-quarkus-pract/1.0/dist/agoncal-fascicle-quarkus-practising-1.0.zip> file, the Angular application is under the `ui-bookstore` directory.

6.1.1. Overall Architecture

Figure 12 shows the architecture that you will have at the end of this chapter. The BookStore UI is exposed via Quarkus (port 8080) while the *Number* microservice listens on port 8081 and the *Book* microservice on port 8082. At this stage, the UI still does not communicate with the microservices.

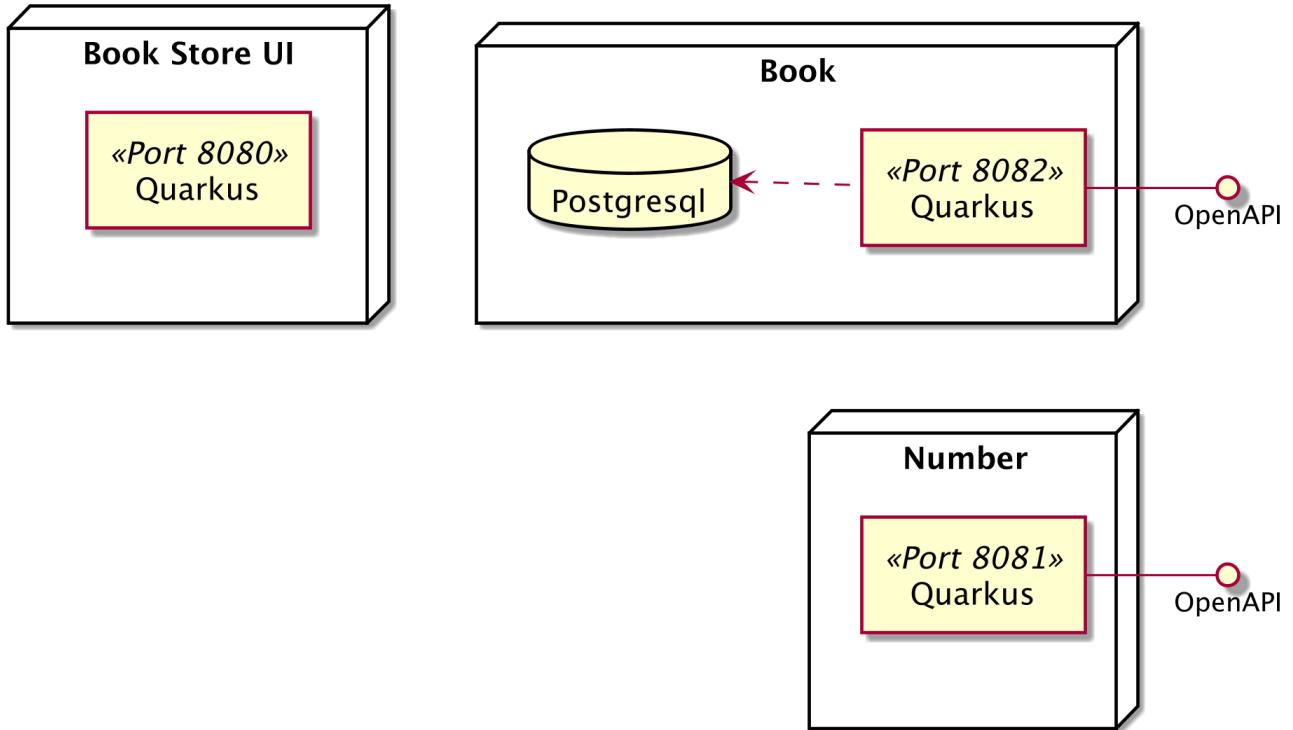


Figure 12. Overall architecture

6.1.2. Directory Structure

The directory structure contains the TypeScript and HTML code of the graphical components to generate new book numbers as well as create/update/delete books from the database. It also contains the code to invoke the microservices through HTTP:

```
. └── ui-bookstore
    ├── pom.xml
    └── src
        ├── app
        │   ├── book
        │   │   ├── book-delete
        │   │   │   ├── book-delete.component.html
        │   │   │   └── book-delete.component.ts
        │   │   ├── book-detail
        │   │   ├── book-form
        │   │   ├── book-list
        │   │   ├── book-random
        │   │   └── book-routing.module.ts
        │   └── book.module.ts
        ├── number
        │   ├── number-generate
        │   ├── number-routing.module.ts
        │   └── number.module.ts
        ├── shared
        │   ├── api
        │   │   ├── bookEndpoint.service.ts
        │   │   └── numberEndpoint.service.ts
        │   └── model
        │       ├── book.ts
        │       └── bookNumbers.ts
        ├── app-routing.module.ts
        ├── app.component.html
        ├── app.component.ts
        └── app.module.ts
        └── index.html
        └── main.ts
            └── styles.scss
        └── angular.json
        └── package.json
```

6.1.3. NPM and Maven Dependencies

Being an Angular application, you will find a `package.json` file which defines all the dependencies that are required (see [Listing 58](#)). Notice that there is also a `pom.xml` file ([Listing 57](#)). This is just a convenient way to install NodeJS and NPM so we can build the Angular application with Maven. The `pom.xml` also allows us to run the Angular application within Quarkus.

Listing 57. Installing NodeJS and NPM Using Maven

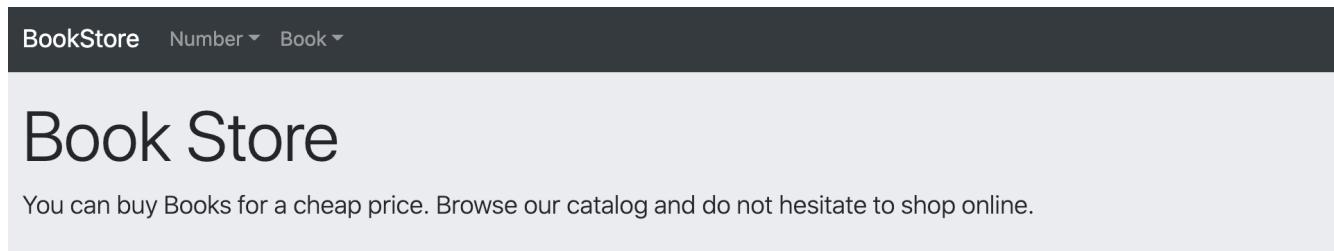
```
<profile>
  <id>install-node-and-npm</id>
  <build>
    <plugins>
      <plugin>
        <groupId>com.github.eirslett</groupId>
        <artifactId>frontend-maven-plugin</artifactId>
        <executions>
          <execution>
            <id>install node and npm</id>
            <goals>
              <goal>install-node-and-npm</goal>
            </goals>
            <phase>generate-resources</phase>
          </execution>
        </executions>
        <configuration>
          <nodeVersion>${node.version}</nodeVersion>
          <npmVersion>${npm.version}</npmVersion>
        </configuration>
      </plugin>
    </plugins>
  </build>
</profile>
<profile>
  <id>npm-install</id>
  <build>
    <plugins>
      <plugin>
        <groupId>com.github.eirslett</groupId>
        <artifactId>frontend-maven-plugin</artifactId>
        <executions>
          <execution>
            <id>npm install</id>
            <goals>
              <goal>npm</goal>
            </goals>
            <phase>generate-resources</phase>
          </execution>
        </executions>
        <configuration>
          <arguments>install</arguments>
        </configuration>
      </plugin>
    </plugins>
  </build>
</profile>
```

Listing 58. Angular Dependencies in package.json File

```
"dependencies": {  
    "@angular/animations": "~9.1.12",  
    "@angular/common": "~9.1.12",  
    "@angular/compiler": "~9.1.12",  
    "@angular/core": "~9.1.12",  
    "@angular/forms": "~9.1.12",  
    "@angular/platform-browser": "~9.1.12",  
    "@angular/platform-browser-dynamic": "~9.1.12",  
    "@angular/router": "~9.1.12",  
    "bootstrap": "^4.5.2",  
    "font-awesome": "^4.7.0",  
    "jquery": "^3.5.1",  
    "ngx-bootstrap": "^5.6.2",  
    "popper": "^1.0.1",  
    "rxjs": "~6.5.4",  
    "tslib": "^1.10.0",  
    "zone.js": "~0.10.2"  
},
```

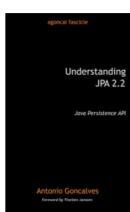
6.2. Angular Application

The main page of the Angular application in [Figure 13](#) displays a random book which comes from the *Book* microservice. If you refresh this page, you will get a different book.



Understanding JPA

Antonio Goncalves



In this fascicle, you will learn Java Persistence API, its annotations for mapping entities, as well as the Java Persistence Query Language and entity life cycle

[◀ Back](#)

Figure 13. Main page displaying a random book

By clicking on the *Book* menu you get access to a list of all the books (see [Figure 14](#)) that has several buttons to allow CRUD operations on a specific book.

Book Store

You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Books

[+Create new Book](#)

ID	ISBN	Title	Author	
997	9781980399025	Understanding Bean Validation	Antonio Goncalves	View Delete
998	9781093918977	Understanding JPA	Antonio Goncalves	View Delete
1021	1430246928	Beginning EJB 3, Java EE, 7th Edition	Adam Bien	View Delete
1066	1478289317	Developing Enterprise Applications with Spring: An	Roger Kitain	View Delete
1069	3319054392	ECUMICT 2014: Proceedings of the European Conferen	Nigel Deakin	View Delete
1070	1847195601	EJB 3 Developer Guide: A Practical Guide for devel	Arun Gupta	View Delete
1071	1935182994	EJB 3 in Action	Antoine Sabot-Durand	View Delete
1072	1933988347	EJB 3 in Action	Ed Burns	View Delete
1074	3826616995	Enterprise JavaBeans 3.0 mit Eclipse und JBoss: Pr	Linda Demichel	View Delete
1075	0470565454	Enterprise Software Architecture and Design: Entit	Ed Burns	View Delete

Figure 14. Listing books

By clicking on "Create new Book" we go to a form (see Figure 15) allowing us to create a new book.

Book Store

You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Book

Title	<input type="text"/>
Author	<input type="text"/>
Nb of pages	<input type="text"/>
Price	<input type="text"/>
Rank	<input type="text"/>
Medium Image Url	<input type="text"/>
Small Image Url	<input type="text"/>
Description	<input type="text"/>

Cancel Save

Figure 15. Creating a new book

On the list of books we have two buttons on each row:

- *View* which gives all the book details (see [Figure 16](#)),
- *Delete* to delete a book from the database (see [Figure 17](#)).

Book Store

You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Book

Title Developing Enterprise Applications with Spring: An End-to-End Approach

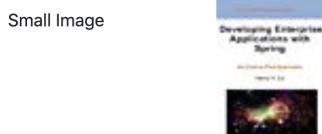
ISBN 13 / 10 1478289317 /

Author Roger Kitain

Nb of pages 422

Price \$59.99

Rank 2



Description This book adopts a unique approach to helping enterprise Java Web application developers learn the latest Spring Frameworks fast. Rather than filled with disjointed, HelloWorld- and foo-bar -like, piecemeal samples to show Spring features one at a time, it is designed to put your total Spring learning experience on a functioning, end-to-end, integrated sample Secure Online Banking Application (SOBA), which can be built with Ant or Maven 3 on Eclipse or STS. To help satisfy your preference, SOBA runs on a variety of App Server/OS/DB platforms including: {Tomcat 6/Tomcat 7, GlassFish 3.1, JBoss 7.1, and WebLogic 12.1.1}, {Windows 7, Mac OS X, and Linux}, and {MySQL 5.1, SQL Server 2008 R2, and Oracle 11g R2}. Using SOBA as a learning platform, this book helps you learn the following core set of the latest Spring 3.1 technologies: Spring Core FrameworkSpring //

◀ Back

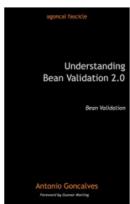
Figure 16. Details of a book

Book Store

You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Understanding Bean Validation

Antonio Goncalves



In this fascicle will you will learn Bean Validation and use its different APIs to apply constraints on a bean, validate all sorts of constraints and write your own constraints

Cancel Delete

Figure 17. Deleting a book

Figure 18 shows the component that generates book numbers (ISBNs, ASIN and EAN numbers) by invoking the *Number* microservice.

Book Store

You can buy Books for a cheap price. Browse our catalog and do not hesitate to shop online.

Book Numbers

Generate

Asin B000FNP6CY

EAN 8 80147596

EAN 13 4692092308513

ISBN 10 0-7236-2833-5

ISBN 13 978-1-640-32604-0

Figure 18. Generating book numbers

6.2.1. Services and Models

You don't need to be an Angular expert, but there are some pieces of code that are worth looking at.
[52] If you look under the `src/app/shared` directory, you will find two sub-directories:

- `api`: Contains the two services (`NumberEndpointService` and `BookEndpointService`) accessing our two microservices.
- `model`: Contains the two interfaces (`Book` and `BookNumbers`) modelling the return types of our microservices.

For example, if you look at [Listing 59](#) you'll see that it matches the `BookNumbers` Java class in [Listing 13](#).

Listing 59. Book TypeScript Interface

```
export interface BookNumbers {  
    asin?: string;  
    ean_13?: string;  
    ean_8?: string;  
    isbn_10: string;  
    isbn_13: string;  
}
```

This interface allows a JSON book representation received from the *Number* REST endpoint to be mapped to an object structure. Then it's just a matter of using this structure in the `NumberEndpointService` defined in [Listing 60](#). The `NumberEndpointService` is a TypeScript class that invokes the method `generateBookNumbers` of our remote JAX-RS `NumberResource` class. It just does an HTTP GET on the `/api/numbers/book` URL.

Listing 60. TypeScript Service Invoking a Remote Microservice

```
@Injectable()
export class NumberEndpointService {

    protected basePath = 'http://localhost:8081';

    constructor(protected httpClient: HttpClient) {
    }

    public generatesBookNumbers(observe: any = 'body', reportProgress: boolean = false): Observable<any> {

        let headers = this.defaultHeaders;

        // to determine the Accept header
        let httpHeaderAccepts: string[] = [
            'application/json'
        ];
        headers = headers.set('Accept', httpHeaderAccepts);

        return this.httpClient.request<BookNumbers>('get', `${this.basePath}/api/numbers/book`,
        {
            headers: headers,
            observe: observe,
            reportProgress: reportProgress
        })
    }
}
```

We see the same behaviour with the *Book* REST endpoint. The `bookEndpoint.service.ts` defines all the methods to access the *Book* REST endpoint through HTTP, and the `book.ts` represents our *Book* entity.

You didn't have to type this code... but neither did I. The code of the interface and the service was generated thanks to a tool called `swagger-codegen`.^[53]

Because both of our microservices expose an OpenAPI contract, `swagger-codegen` just swallows it, and generates the TypeScript code to access it. It's just a matter of running:

```
$ swagger-codegen generate -i http://localhost:8082/openapi -l typescript-angular -o
src/app/shared
```

Here, you see another advantage of exposing an OpenAPI contract: it documents the API which can be read by a human, or processed by tools.

6.2.2. UI Components

In Angular, a graphical component can be composed of a TypeScript class dealing with the behaviour, and an HTML and CSS file for the graphical representation. So the graphical component generating book numbers (shown in [Figure 18](#)) is called `number-generate`, and is made of two files (`html` and `ts`), both living in a `number-generate` subdirectory

```
.  
└── ui-bookstore  
    └── src  
        └── app  
            └── number  
                ├── number-generate  
                │   ├── number-generate.component.html  
                │   └── number-generate.component.ts  
                ├── number-routing.module.ts  
                └── number.module.ts
```

The TypeScript code of the graphical component generating book numbers is shown in [Listing 61](#). When we click on the *Generate* button, the `generateBookNumber()` method is executed, and it then invokes the `NumberEndpointService` (which is the one doing the remote HTTP call). Notice that the `templateUrl` attribute references the HTML page dealing with the graphical representation of the component (see [Listing 62](#)).

Listing 61. TypeScript Code of the Generate Number Graphical Component

```
@Component({  
  templateUrl: 'number-generate.component.html'  
)  
export class NumberGenerateComponent implements OnInit {  
  
  bookNumbers?: BookNumbers;  
  
  constructor(private numberEndpointService: NumberEndpointService) { }  
  
  ngOnInit(): void {  
    this.generateBookNumber();  
  }  
  
  generateBookNumber() {  
    this.numberEndpointService.generatesBookNumbers().subscribe(bookNumbers => this  
.bookNumbers = bookNumbers);  
  }  
}
```

The HTML side of the component generating book numbers is described in [Listing 62](#). It is a classical HTML page using Bootstrap for the graphical layout.^[54]

Listing 62. HTML Code of the Generate Number Graphical Component

```
<h1>
  <span>Book Numbers</span>
  <button class="btn btn-primary float-right create-book" (click)="generateBookNumber()">
    <span class="fa fa-refresh"></span>
    <span>Generate</span>
  </button>
</h1>

<form>
  <div class="form-group row">
    <label for="asin" class="col-sm-2 col-form-label">Asin</label>
    <div class="col-sm-10">
      <input type="text" readonly class="form-control-plaintext" id="asin" value="{{bookNumbers?.asin}}>
    </div>
  </div>
  <div class="form-group row">
    <label for="ean_8" class="col-sm-2 col-form-label">EAN 8</label>
    <div class="col-sm-10">
      <input type="text" readonly class="form-control-plaintext" id="ean_8" value="{{bookNumbers?.ean_8}}>
    </div>
  </div>
  <div class="form-group row">
    <label for="ean_13" class="col-sm-2 col-form-label">EAN 13</label>
    <div class="col-sm-10">
      <input type="text" readonly class="form-control-plaintext" id="ean_13" value="{{bookNumbers?.ean_13}}>
    </div>
  </div>
  <div class="form-group row">
    <label for="isbn_10" class="col-sm-2 col-form-label">ISBN 10</label>
    <div class="col-sm-10">
      <input type="text" readonly class="form-control-plaintext" id="isbn_10" value="{{bookNumbers?.isbn_10}}>
    </div>
  </div>
  <div class="form-group row">
    <label for="isbn_13" class="col-sm-2 col-form-label">ISBN 13</label>
    <div class="col-sm-10">
      <input type="text" readonly class="form-control-plaintext" id="isbn_13" value="{{bookNumbers?.isbn_13}}>
    </div>
  </div>
</form>
```

All the other graphical components follow the same structure and pattern. You can browse through

the rest of the code if you want to learn more about Angular.

6.3. Running the Application

The user interface is a common Angular application. So if you are familiar with Angular and have all the tools installed, you can install the dependencies with an `npm install` or execute it with an `ng serve`. But we can also use Maven.

6.3.1. Building the Web Application

Thanks to the `frontend-maven-plugin` plugin declared on the `pom.xml` under `ui-bookstore` (see Listing 57), we can use a good old Maven command to install NodeJS and NPM. For that, just execute the `generate-resources` Maven goal with a specific profile:

```
ui-bookstore$ mvn generate-resources -Pinstall-node-and-npm
```

The `frontend-maven-plugin` plugin will download NodeJS and npm from <https://nodejs.org/dist> and put it into a `node` folder (created under our `ui-bookstore` directory). NodeJS and npm will only be installed locally to our project, it will not be installed globally on the whole system (and it will not interfere with any NodeJS/npm installations already present if any). At this stage, make sure the following commands work:

```
ui-bookstore$ node/node -v
ui-bookstore$ node/npm -version
```

Now that we have all the tools we need installed, we need to install the Angular dependencies of the application. For that, we could just run `npm install`, but we can use the `frontend-maven-plugin` again with a different profile:

```
ui-bookstore$ mvn generate-resources -Pnpm-install
```

You should now see a `node_modules` directory under `ui-bookstore`. Time to package and install the Angular application on Quarkus.

6.3.2. Installing the Web Application on Quarkus

To install the Angular application into a Quarkus instance, we need to build the application and copy the bundles under the `resources/META-INF/resources` directory. Look at the `package.sh`, that's exactly what it does. `ng build` will compile all the TypeScript code and package all the code and HTML resources into a few bundles. Then, these bundles are copied to the right location.

```
export DEST=src/main/resources/META-INF/resources  
.node_modules/.bin/ng build --prod --base-href ".."  
rm -Rf ${DEST}  
mkdir -p ${DEST}  
cp -R dist/* ${DEST}
```



`package.sh` is a BASH script which works on macOS and Linux but not on Windows.

Execute the `package.sh` script. You will see all the JavaScript and HTML files under `resources/META-INF/resources` directory. We are now ready to go.



If the `ng` command does not work because it can't find node, there is a little hack to solve it. Open the file `ui-bookstore/node_modules/.bin/ng` and change the shebang line from `! /usr/bin/env node` to `! /usr/bin/env ./node/node`. This way `ng` knows it has to use NodeJS installed under the `ui-bookstore/node` directory

6.3.3. Executing the Application

As usual, use the `mvn quarkus:dev` command under the `ui-bookstore` directory to start the Angular application. Be sure you have the *Number* and *Book* microservices running. Once the application is started, go to <http://localhost:8080/ui-bookstore/index.html> (8080 is the default Quarkus port as we didn't change it in the `application.properties` this time). It should display the main web page.

Oops, not working! We must have forgotten something! Let's move on to the next chapter then and make the application work.

6.4. Summary

In this chapter, you've packaged an Angular application and installed it on Quarkus. The idea of this chapter is not for you to learn Angular, but instead package it with NodeJS and NPM and install it on Quarkus. The Angular framework is made for Single Page Applications (SPA), meaning that all necessary HTML, JavaScript, and CSS code is retrieved by the browser with a single page load. But these resources have to be available on an HTTP Server so they can be rendered to the browser. Quarkus can also be used as an HTTP server to render the HTML resources.

What's missing now is the communication between the Angular application and the microservices. In the next chapter, you will solve this communication problem, as well as develop the communication between the *Book* and *Number* microservices in a reliable way.

[52] Angular <https://angular.io>

[53] Swagger-Codegen <https://github.com/swagger-api/swagger-codegen>

[54] Bootstrap <https://getbootstrap.com>

Chapter 7. Adding Communication and Fault Tolerance

So far, we've built one *Book* microservice and one *Number* microservice. Both are totally isolated and do not communicate with each other. We've also deployed an Angular application that is supposed to access both microservices, but the communication is not working. In this chapter, you will make each component communicate with each other.



Any problems, don't hesitate to get the code for the fascicle at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/tree/1.0>

7.1. What Will You Build in This Chapter?

In this chapter, you will:

- Configure CORS so the Angular application can communicate with the microservices,
- Implement the communication between the *Book* and *Number* microservices, thanks to the Eclipse MicroProfile REST Client,
- Deal with fault tolerance thanks to timeouts and fallbacks.

7.1.1. Overall Architecture

Figure 19 shows the architecture of what you will be building in this chapter. The user interface will communicate with both microservices, and the *Book* microservice will invoke the *Number* microservice to get ISBN numbers when creating a new book.

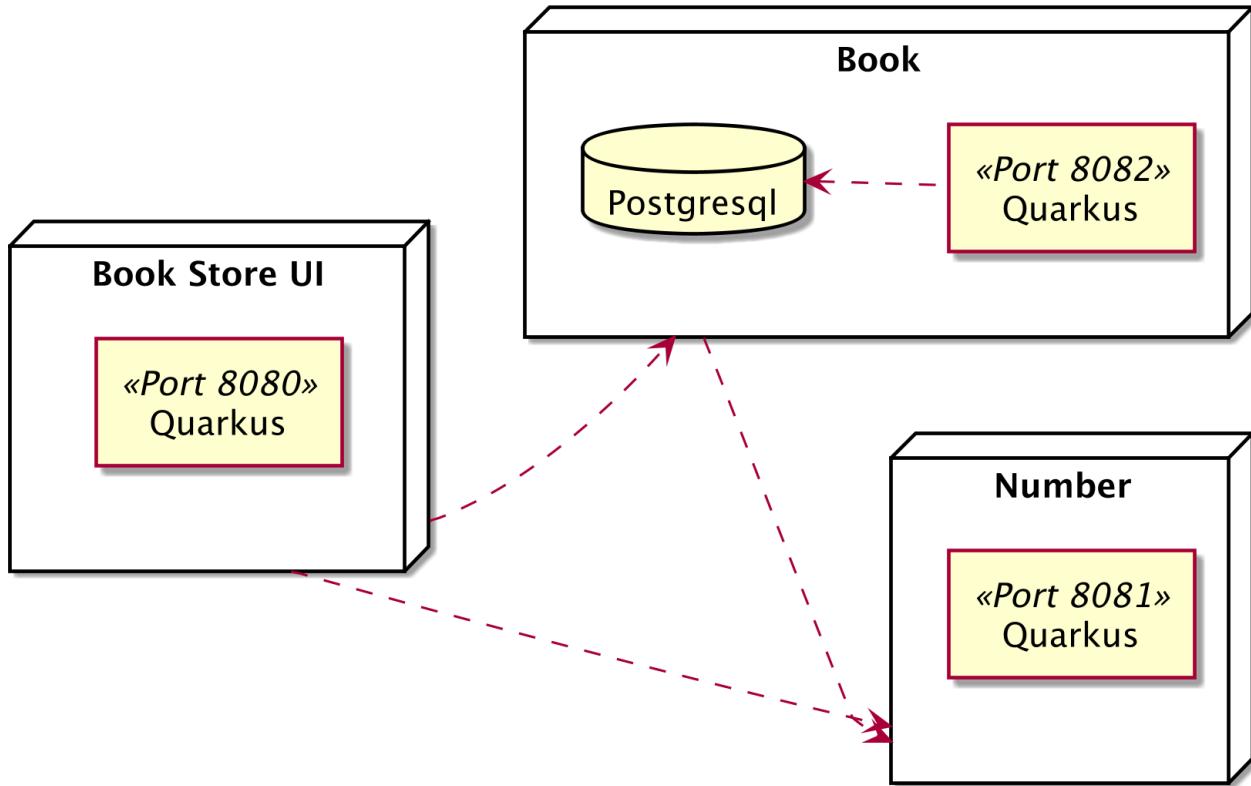


Figure 19. Overall architecture

7.1.2. Directory Structure

Most of the changes in the code will take place under the `client` subpackage of the *Book* microservice. That's where we will add the code to invoke the *Number* microservice, and also, from a test point of view, that's where we'll add a mocked service:

```

.
├── rest-book
│   ├── src
│   │   ├── main
│   │   │   ├── java
│   │   │   │   └── org/agoncal/fascicle/quarkus/book
│   │   │   │       ├── client
│   │   │   │       │   ├── IsbnNumbers.java
│   │   │   │       │   └── NumberProxy.java
│   │   │   │       ├── Book.java
│   │   │   │       ├── BookApplication.java
│   │   │   │       ├── BookApplicationLifeCycle.java
│   │   │   │       ├── BookResource.java
│   │   │   │       └── BookService.java
│   │   │   └── resources
│   │   │       ├── application.properties
│   │   │       └── import.sql
│   │   └── test
│   │       └── java
│   │           └── org/agoncal/fascicle/quarkus/book
│   │               ├── client
│   │               │   └── MockNumberProxy.java
│   │               └── BookResourceTest.java
│   └── pom.xml
└── pom.xml

```

7.1.3. Maven Dependencies

For the *Book* microservice to communicate with the *Number* microservice, we will need a few extra Maven dependencies as shown in [Listing 63](#):

- **quarkus-rest-client**: REST Client in order to interact with REST APIs.
- **quarkus-smallrye-fault-tolerance**: Communication with external systems being inherently unreliable, we need the Fault Tolerance dependency.

Listing 63. REST Client and Fault Tolerance Maven Dependencies

```

<dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-rest-client</artifactId>
</dependency>
<dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-fault-tolerance</artifactId>
</dependency>

```

7.2. CORS

But first, let's solve the problem of communication between the Angular application and our microservices. So when the Angular application wants to access the Book and Number microservices, we actually cross several *origins*: we go from localhost:8080 (port in which the Angular application is running) to localhost:8081 (the *Number* REST endpoint) and localhost:8082 (the *Book* REST endpoint). If you look at the console of your browser, you should see something similar to [Figure 20](#).

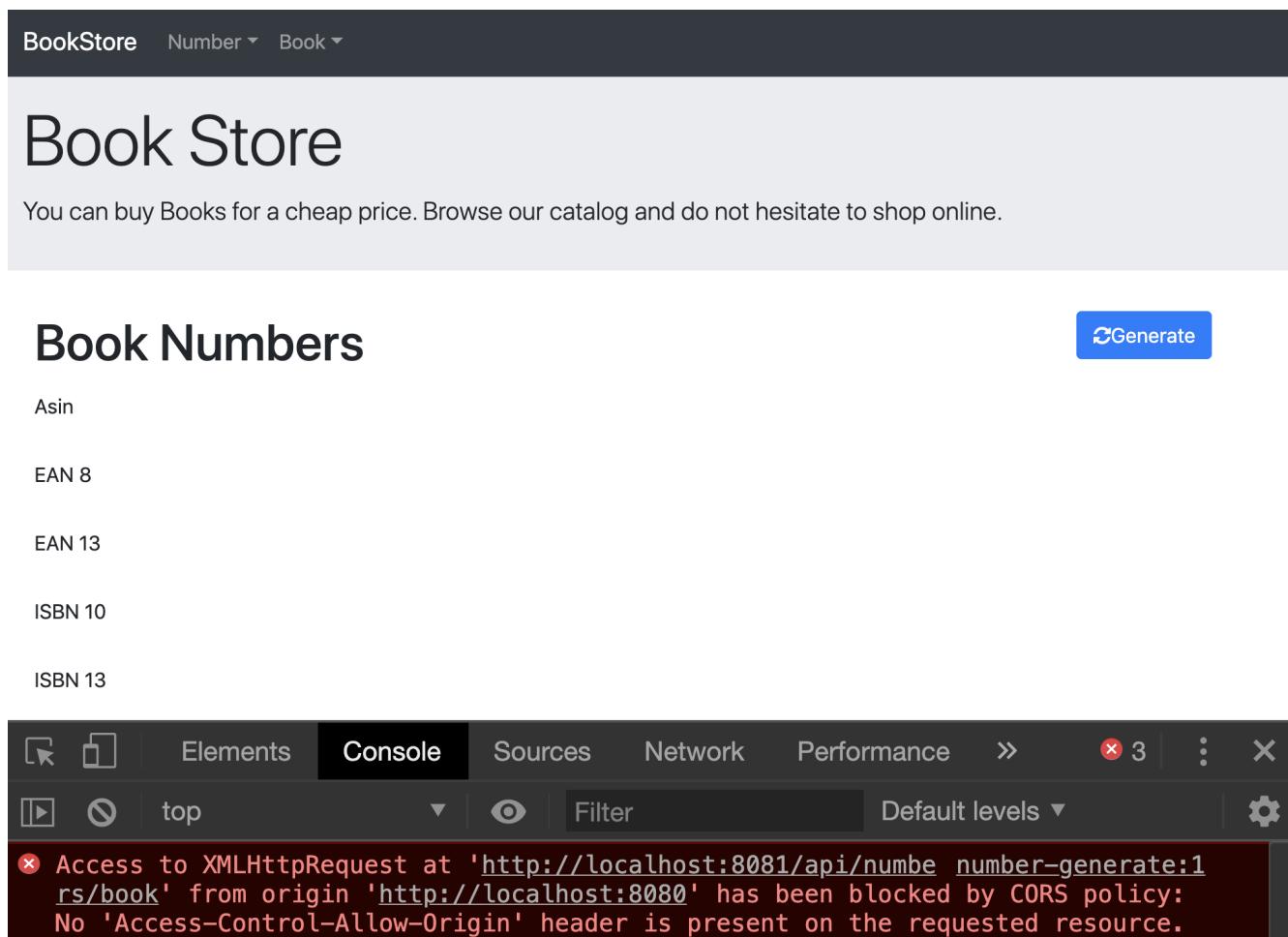


Figure 20. Cross origin issues when generating book numbers

We have a CORS issue.

Cross-origin Resource Sharing (CORS) is a mechanism that allows restricted resources on a web page to be requested from another domain outside the domain from which the first resource was served.^[55]

To solve this CORS issue, Quarkus comes with a CORS filter which intercepts all incoming HTTP requests. It can be enabled in the Quarkus configuration file `application.properties`:

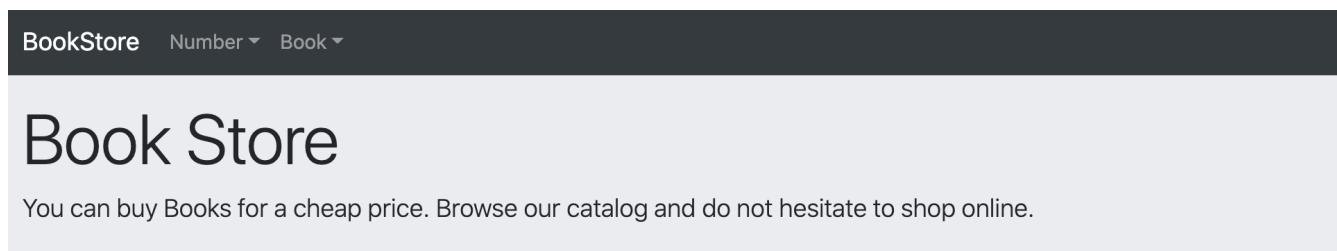
```
quarkus.http.cors=true
```

If you need to be more precise in terms of controlling the origin access, Quarkus comes with a few extra configuration properties (see [Table 19](#)).

Table 19. Some Quarkus CORS Configuration Properties

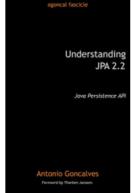
Property	Default
<code>quarkus.http.cors.origins</code> Comma-separated list of origins allowed for CORS. The filter allows any origin if this is not set.	
<code>quarkus.http.cors.methods</code> Comma-separated list of HTTP methods allowed for CORS. The filter allows any method if this is not set.	
<code>quarkus.http.cors.headers</code> Comma-separated list of HTTP headers allowed for CORS. The filter allows any header if this is not set.	
<code>quarkus.http.cors.exposed-headers</code> Comma-separated list of HTTP headers exposed in CORS.	
<code>quarkus.http.cors.access-control-max-age</code> The duration that indicates how long the results of a preflight request can be cached. This value will be returned in an <code>Access-Control-Max-Age</code> response header.	

So make sure you set the `quarkus.http.cors` property to `true` on both the *Number* and *Book* microservice `application.properties` files. If you now run the entire architecture and access the Angular application at <http://localhost:8080/ui-bookstore/index.html> you should finally see the welcome page displaying a random book as in Figure 21.



Understanding JPA

Antonio Goncalves



In this fascicle, you will learn Java Persistence API, its annotations for mapping entities, as well as the Java Persistence Query Language and entity life cycle

[◀ Back](#)

Figure 21. Main page displaying a random book

7.3. REST Client

Now that the Angular application works, let's create the communication link between the *Book* and *Number* REST endpoints. When we create a new book, we want the *Book* microservice to invoke the *Number* microservice in order to get the ISBN numbers. You can do so using the Eclipse MicroProfile REST Client in order to interact with REST APIs with very little effort.

Eclipse MicroProfile REST Client provides a type safe approach using proxies and annotations for invoking RESTful services over HTTP.^[56] The Eclipse MicroProfile REST Client Client builds upon the JAX-RS 2.1 APIs for consistency and ease-of-use.

The Eclipse MicroProfile REST Client APIs and annotations are all defined under the main `org.eclipse.microprofile.rest.client` package, either at the root, or under the other subpackages. Table 20 lists the main subpackages defined in Eclipse MicroProfile REST Client version 1.4 (under the root `org.eclipse.microprofile.rest.client` package).^[57]

Table 20. Main `org.eclipse.microprofile.rest.client` Subpackages

Subpackage	Description
<code>root</code>	Root package of the REST Client APIs
<code>annotation</code>	APIs for annotating client interfaces
<code>ext</code>	APIs for extending REST Client functionality
<code>inject</code>	APIs to aid in CDI-based injection
<code>spi</code>	Internal SPIs (<i>Service Provider Interfaces</i>) implemented by the provider

Along with APIs, REST Client comes with a set of annotations. Table 21 lists a subset of the most commonly used annotations.

Table 21. Main REST Client Annotations

Annotation	Description
<code>@RegisterRestClient</code>	A marker annotation to register a rest client at runtime
<code>@RestClient</code>	CDI qualifier used to indicate that this injection point is meant to use an instance of a type safe REST Client

Let's see how to use Eclipse MicroProfile REST Client in the *Book* microservice to invoke the *Number* microservice.

7.3.1. Book Microservice Invoking the Number Microservice

Remember that in the previous chapters we created a transactional `BookService.persistBook()` method to insert a book into the database. At that moment, we would like to insert the book with its ISBN numbers. That's when we want the *Book* microservice to invoke the *Number* microservice so that it gets the ISBN numbers and then persists the book in the database. For that, we need to add this invocation in the `persistBook()` method as shown in Listing 64.

We use the standard CDI `@Inject` annotation in conjunction with the MicroProfile `@RestClient`

annotation to inject the `NumberProxy` interface. This interface acts like a proxy and allows us to remotely invoke the `Number` microservice through HTTP and return ISBNs with both 10 and 13 digits.

Listing 64. BookService Injecting the Proxy

```
@Inject  
@RestClient  
NumberProxy numberProxy;  
  
public Book persistBook(@Valid Book book) {  
    // The Book microservice invokes the Number microservice  
    IsbnNumbers isbnNumbers = numberProxy.generateIsbnNumbers();  
    book.isbn13 = isbnNumbers.getIsbn13();  
    book.isbn10 = isbnNumbers.getIsbn10();  
  
    Book.persist(book);  
    return book;  
}
```

The sequence of invocation is better described in the sequence diagram shown in [Figure 22](#). The JAX-RS resource invokes the `persist()` method on the service. The service needs to generate ISBN numbers, therefore, it invokes the remote `Number` microservice.

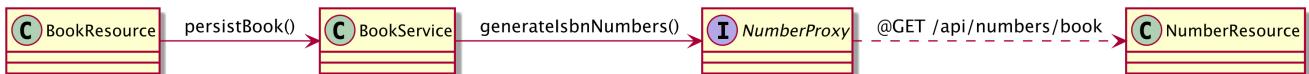


Figure 22. Book microservice invoking the Number microservice

7.3.2. The Remote Number Microservice Interface

Using the Eclipse MicroProfile REST Client is as simple as creating a `NumberProxy` interface (under the `client` subpackage) using the proper JAX-RS and MicroProfile annotations (see [Listing 65](#)):

- `@RegisterRestClient` allows Quarkus to know that this interface is meant to be available for CDI injection as a REST Client,
- `@Path` and `@GET` are the standard JAX-RS annotations used to define how to access the remote service,
- `@Produces` defines the expected content-type.

Listing 65. The Proxy Interface

```
@Path("/api/numbers/book")
@Produces(MediaType.APPLICATION_JSON)
@RegisterRestClient
public interface NumberProxy {

    @GET
    IsbnNumbers generateIsbnNumbers();
}
```

The `generateIsbnNumbers()` method gives our code the ability to get ISBN numbers from the *Number* REST endpoint. The Eclipse MicroProfile REST Client will handle all the networking and marshalling, leaving our code clean of such technical details.

Notice in [Listing 65](#) that the proxy returns a POJO with ISBN numbers of 10 and 13 digits (see [Listing 66](#)). This class contains JSON-B annotations to customise the binding from/to JSON.

Listing 66. The POJO Returned by the Proxy

```
public class IsbnNumbers {

    @JsonbProperty("isbn_10")
    private String isbn10;
    @JsonbProperty("isbn_13")
    private String isbn13;

}
```

7.3.3. Configuring the REST Client Invocation

But where is the *Number* microservice located? In order to determine the base URL to which REST calls will be made, the REST Client uses configuration from the `application.properties` file. The name of the property needs to follow a certain convention which is displayed in the following code:

```
org.agoncal.fascicle.quarkus.book.client.NumberProxy/mp-rest/url=http://localhost:8081
org.agoncal.fascicle.quarkus.book.client.NumberProxy/mp-
rest/scope=javax.inject.Singleton
```

Having this configuration means that all requests performed using the `NumberProxy` interface will use `http://localhost:8081` as the base URL. Using this configuration and the code in [Listing 65](#), calling the `generateIsbnNumbers()` method of `NumberProxy` would result in an HTTP GET request being made to `http://localhost:8081/api/numbers/book`.

7.3.4. Executing the REST Client Invocation

Let's quickly see if this code works. For that, it's just a matter of starting both Quarkus instances and executing a few cURL commands.

First, start both Quarkus instances, one for the *Book* microservice, and the other one for the *Number* microservice:

```
rest-book$ mvn quarkus:dev  
rest-number$ mvn quarkus:dev
```

Then, make sure both microservices are up and running by executing a few HTTP GET cURL commands:

```
$ curl -X GET http://localhost:8081/api/numbers/book  
$ curl -X GET http://localhost:8082/api/books
```

Then create a new book with an HTTP POST cURL command just passing the title, author, and the year of publication of the book:

```
$ curl -X POST -d '{"title":"Practising Quarkus", "author":"Antonio Goncalves",  
"yearOfPublication":"2020"}' -H "Content-Type: application/json"  
http://localhost:8082/api/books -v  
  
< HTTP/1.1 201 Created  
< Location: http://localhost:8082/api/books/1
```

Once the book is created, the cURL command returns its URI (in the **Location** HTTP header). Then, it's just a matter of invoking an HTTP GET on this URI, and checking that the ISBN numbers are set:

```
$ curl -X GET http://localhost:8082/api/books/1 | jq  
{  
  "id": 1,  
  "author": "Antonio Goncalves",  
  "isbn10": "1-361-87642-5",  
  "isbn13": "978-0-85541-146-6",  
  "title": "Practising Quarkus",  
  "yearOfPublication": 2020  
}
```

If the ISBN numbers are set on the newly created book, that means the *Book* microservice has managed to invoke the *Number* microservices. If you check the console of both microservices, you should also see some logs going on.

7.4. Fallbacks

So now you've been creating books for a few hours... and you kill the *Number* microservice. What happens? Well, the *Book* microservice cannot invoke the *Number* microservice anymore and breaks with a **ConnectException**:

```
ERROR [io.qua.ver.htt.run.QuarkusErrorHandler] HTTP Request to /api/books failed
org.jboss.resteasy.spi.UnhandledException: javax.ws.rs.ProcessingException:
RESTEASY004655: Unable to invoke request: java.net.ConnectException: Connection
refused (Connection refused)
```

One of the challenges brought by the distributed nature of microservices is that communication with external systems is inherently unreliable. This increases the demand on the resiliency of applications. To simplify making more resilient applications, Quarkus contains an implementation of the Eclipse MicroProfile Fault Tolerance specification.

As the number of services grows, the odds of any service failing also grows. If one of the involved services does not respond as expected, e.g. because of fragile network communication, we have to compensate for this exceptional situation. *Eclipse MicroProfile Fault Tolerance* allows us to build up our microservices architecture to be resilient and fault tolerant by design. This means we must not only be able to detect any issue but also to handle it automatically.

The Eclipse MicroProfile Fault Tolerance APIs and annotations are all defined under the main `org.eclipse.microprofile.faulttolerance` package, either at the root, or under the other subpackages. Table 22 lists the main subpackages defined in Eclipse MicroProfile Fault Tolerance version 2.1 (under the root `org.eclipse.microprofile.faulttolerance` package).^[58]

Table 22. Main `org.eclipse.microprofile.faulttolerance` Subpackages

Subpackage	Description
<code>root</code>	Root package of the Fault Tolerance APIs
<code>exceptions</code>	Exceptions for Fault Tolerance

Along with APIs, Fault Tolerance comes with a set of annotations. Table 23 lists a subset of the most commonly used annotations.

Table 23. Main Fault Tolerance Annotations

Annotation	Description
<code>@Timeout</code>	Defines a duration for timeout
<code>@Retry</code>	Defines a criteria on when to retry
<code>@Fallback</code>	Provides an alternative solution for a failed execution
<code>@Bulkhead</code>	Isolates failures in part of the system while the rest of the system can still function
<code>@CircuitBreaker</code>	Offers a way to fail fast by automatically failing the execution to prevent the system overloading and an indefinite wait or timeout by the clients
<code>@Asynchronous</code>	Invokes the operation asynchronously

Let's provide a fallback way for persisting a book in case of failure. For example, we could serialise the JSON representation of a book into a file so it can be processed later. For that, we add one fallback method to the `BookService` called `fallbackPersistBook` and a `@Fallback` annotation to the `persistBook()` method (see Listing 67).

Listing 67. Falling Back on Persisting a Book

```
@Inject
@RestClient
NumberProxy numberProxy;

@Fallback(fallbackMethod = "fallbackPersistBook")
public Book persistBook(@Valid Book book) {
    // The Book microservice invokes the Number microservice
    IsbnNumbers isbnNumbers = numberProxy.generateIsbnNumbers();
    book.isbn13 = isbnNumbers.getIsbn13();
    book.isbn10 = isbnNumbers.getIsbn10();

    Book.persist(book);
    return book;
}

private Book fallbackPersistBook(Book book) throws FileNotFoundException {
    LOGGER.warn("Falling back on persisting a book");
    String bookJson = JsonbBuilder.create().toJson(book);
    try (PrintWriter out = new PrintWriter("book-" + Instant.now().toEpochMilli() +
        ".json")) {
        out.println(bookJson);
    }
    throw new IllegalStateException();
}
```

The `fallbackPersistBook()` method must have the same method signature as `persistBook()` (in our case, it takes and returns a `Book` object). In case the *Book* microservice cannot invoke the *Number* microservice, the `fallbackPersistBook()` is invoked and the JSON representation of the book is written on the disk.

Now we are ready to run our application and test the fallbacks. For that, kill the *Number* microservice and start creating new books again. You should see JSON files being created on your disk (under the `target` folder).

Restart the *Number* microservice and keep on creating books: the books are getting persisted on the database with their ISBN numbers.

7.5. Timeout

Sometimes invoking a REST API can take a long time. In fact, the more microservices invoke other microservices, the more network latency you can have. And what happens when an HTTP request takes a long time? Well, it hangs. [Figure 23](#) shows the dev tools of a browser where you can see the request pending.

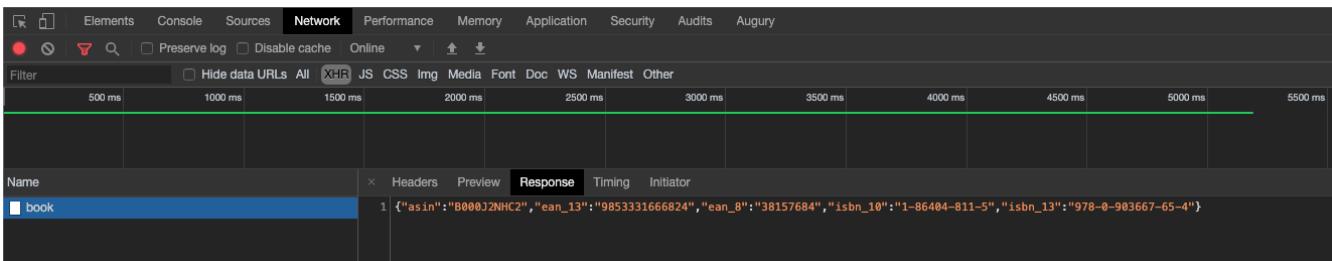


Figure 23. HTTP request hanging

Let's say that getting ISBN numbers actually takes longer than expected. What happens to the *Book* microservice invoking a long-running *Number* microservice to get the ISBN numbers? It hangs too, and we don't want that to happen.

So, let's simulate a long-running process. We can easily do that by updating the `NumberResource` and adding a sleep time on the `generateBookNumbers()` method. As you can see in [Listing 68](#) we can use the configuration capabilities of Quarkus to configure the sleep time.

Now that we can simulate a long-running process of generating ISBN numbers, we would rather time it out than leave it just hanging. For that, we add the `@Timeout` annotation to the method. `@Timeout` waits a number of milliseconds before timing out.

[Listing 68. The Number Microservice Timing Out](#)

```

@ConfigProperty(name = "seconds.sleep", defaultValue = "0")
int secondsToSleep = 0;

@Timeout(250)
@GET
@Produces(MediaType.APPLICATION_JSON)
public Response generateBookNumbers() throws InterruptedException {
    LOGGER.info("Waiting for " + secondsToSleep + " seconds");
    TimeUnit.SECONDS.sleep(secondsToSleep);
    LOGGER.info("Generating book numbers");
    Faker faker = new Faker();
    BookNumbers bookNumbers = new BookNumbers();
    bookNumbers.setIsbn10(faker.code().isbn10(separator));
    bookNumbers.setIsbn13(faker.code().isbn13(separator));
    bookNumbers.setAsin(faker.code().asin());
    bookNumbers.setEan8(faker.code().ean8());
    bookNumbers.setEan13(faker.code().ean13());
    bookNumbers.setGenerationDate(Instant.now());
    return Response.ok(bookNumbers).build();
}

```

Now it's just a matter of adding the property to the `rest-number/src/main/resources/application.properties` file and changing its value depending on if you want to force a timeout or not:

```
seconds.sleep=10
```

Note that the timeout is configured to 250 ms, and a `Thread.sleep` was introduced and can be configured in the `application.properties`. If we set the property to a higher value than the timeout, let's say 10 seconds, then the request should be interrupted. So if we start the *Number* microservice and invoke a book number generation, we should see the following:

```
INFO [o.a.f.q.n.NumberResource] Waiting for 10 seconds
ERROR [i.q.v.h.r.QuarkusErrorHandler] HTTP Request to /api/numbers/book failed
org.jboss.resteasy.spi.UnhandledException: org.eclipse.microprofile.faulttolerance
.exceptions.TimeoutException:
Timeout[org.agoncal.fascicle.quarkus.number.NumberResource#generateBookNumbers] timed
out
```

Now that you've seen timeout in action, you can set the `seconds.sleep` property to 0.

7.6. Running the Application

To run the entire application now we need to start three Quarkus instances:

- The User Interface on port 8080,
- The *Number* microservice on port 8081,
- And the *Book* microservice on port 8082.

Then it's just a matter of using cURL commands to either generate book numbers or persist new books. We can also use the Angular application to ease the creation or deletion of a book. But what about testing?

7.6.1. Testing the Application

So now we have a problem: to run the tests of the *Book* microservice we need the *Number* microservice to be up and running. To avoid this, we need to Mock the *Number* REST API interface.

Quarkus supports the use of mock objects using the CDI `@Alternative` mechanism.^[59] To use this, simply override the bean you wish to mock with a class in the `src/test/java` directory, and put the `@io.quarkus.test.Mock` annotation on the bean. This built-in `Mock` stereotype declares `@Alternative`, `@Priority(1)` and `@Dependent`. So, to mock the `NumberProxy` interface, we just need to implement the `MockNumberProxy` class (under the `org.agoncal.fascicle.quarkus.book.client` package) like in Listing 69.

Listing 69. Class Mocking the Proxy Invocation

```
@Mock  
@ApplicationScoped  
@RestClient  
public class MockNumberProxy implements NumberProxy {  
  
    @Override  
    public IsbnNumbers generateIsbnNumbers() {  
        IsbnNumbers isbnNumbers = new IsbnNumbers();  
        isbnNumbers.setIsbn13(BookResourceTest.MOCK_ISBN_13);  
        isbnNumbers.setIsbn10(BookResourceTest.MOCK_ISBN_10);  
        return isbnNumbers;  
    }  
}
```

So instead of invoking the `NumberProxy`, the alternative `MockNumberProxy` is automatically called during the test phase as shown in [Figure 24](#).

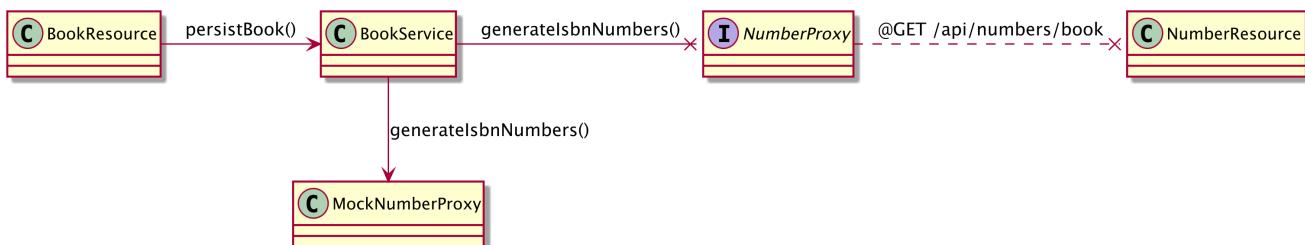


Figure 24. Book microservice invoking a mock during a test

Now if you execute the tests that we created in [Chapter 5, Developing the REST Book Microservice](#), they should pass.

7.7. Summary

In this chapter, you've solved the communication issue between the components that make our architecture. First of all, you've solved the common CORS problem, which happens frequently with single page applications and, of course, microservices: changing origins is by default forbidden, so you need to configure Quarkus to let invocations span throughout several origins.

The communication between microservices is very challenging. In a distributed architecture, you rely on an unreliable network: the network can slow down, can be cut, a microservice can hang and have a domino effect on other microservices, and so on. Thanks to Quarkus and its Eclipse MicroProfile Fault Tolerance implementation, you can develop a fallback mechanism as well as timeout a long-running request.

In the next chapter, you will add health checks to the microservices so you know when they are up or down. You will also add some metrics and use Prometheus so you know if your microservices are correctly responding.

[55] CORS https://en.wikipedia.org/wiki/Cross-origin_resource_sharing

[56] REST Client <https://micropatterns.io/project/eclipse/micropatterns-rest-client>

[57] REST Client GitHub <https://github.com/eclipse/microprofile-rest-client>

[58] Fault Tolerance GitHub <https://github.com/eclipse/microprofile-fault-tolerance>

[59] CDI Alternatives https://docs.jboss.org/weld/reference/latest/en-US/html/beanscdi.html#_alternatives

Chapter 8. Monitoring the Microservices

Now that we have several microservices, observing them starts to be a bit tricky: we can't just look at the logs of all the microservices to see if they are up and running or behaving correctly. In this chapter, you will add health checks and several metrics to the *Number* and *Book* microservices and gather them within Prometheus.

8.1. What Will You Build in This Chapter?

In this chapter, you will:

- Add health checks to our microservices so we know they are up and running,
- Add metrics to all the REST endpoints methods so we can measure the execution time and the number of calls,
- Configure Prometheus so we can visualise all the metrics.

8.1.1. Overall Architecture

Figure 25 shows the architecture that you will have at the end of this chapter. Prometheus sits in the middle of the *Number* and *Book* microservices to gather some metrics and displays them graphically.

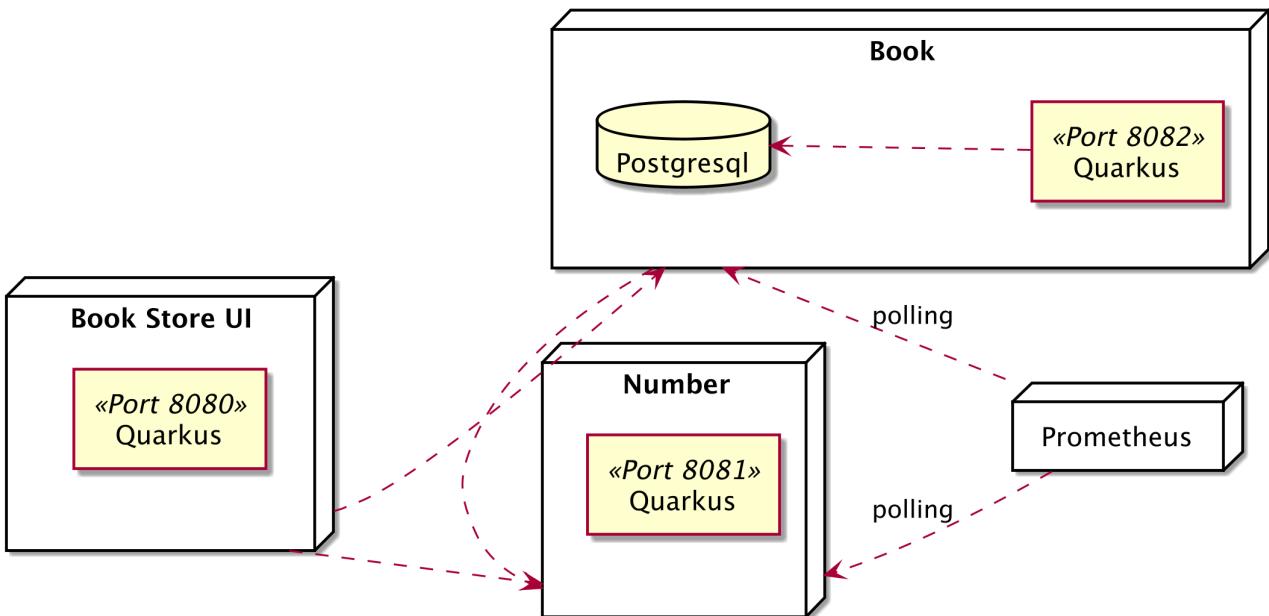


Figure 25. Overall architecture

8.1.2. Directory Structure

In this module, you will add the extra subpackage `health` with the classes needed to handle the health checks. The `load-bookstore` module contains the code to stress the application, simulating users using the microservices. You will end-up with the following directory structure:

```

.
├── load-bookstore
│   └── pom.xml
├── rest-book
│   ├── src
│   │   └── main
│   │       └── java
│   │           └── org/agoncal/fascicle/quarkus/book
│   │               └── health
│   │                   ├── DatabaseConnectionHealthCheck.java
│   │                   └── PingBookResourceHealthCheck.java
│   └── pom.xml
├── rest-number
│   ├── src
│   │   └── main
│   │       └── java
│   │           └── org/agoncal/fascicle/quarkus/number
│   │               └── health
│   │                   └── PingNumberResourceHealthCheck.java
│   └── pom.xml
└── pom.xml

```

8.1.3. Maven Dependencies

To expose the metrics and health for the *Number* and *Book* microservices, we will need a few extra Maven dependencies as shown in [Listing 70](#) in both `rest-book/pom.xml` and `rest-number/pom.xml`:

- `quarkus-smallrye-health`: Eclipse MicroProfile Health dependency so we know our microservices are up and running.
- `quarkus-smallrye-metrics`: Eclipse MicroProfile Metrics dependency to gather metrics relating to the time it takes to process a request.

Listing 70. Observability Maven Dependencies

```

<dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-health</artifactId>
</dependency>
<dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-metrics</artifactId>
</dependency>

```

8.2. Health Check

When using several microservices, it's important to be able to automatically check if they are up and running. A way to do this is to expose some sort of endpoint for each microservice so we can

check its state. That's the purpose of *Eclipse MicroProfile Health*, and it is easily integrated with Quarkus.

Eclipse MicroProfile Health provides the ability to probe the state of a computing node from another machine.^[60] The Eclipse MicroProfile Health APIs allow applications to provide information about their state to external viewers which is typically useful in cloud environments where automated processes must be able to determine whether the application should be discarded or restarted.

The Eclipse MicroProfile Health APIs and annotations are all defined under the `org.eclipse.microprofile.health` package. Table 24 lists the main subpackages defined in Eclipse MicroProfile Health version 2.2 (under the root `org.eclipse.microprofile.health` package).^[61]

Table 24. Main `org.eclipse.microprofile.health` Subpackages

Subpackage	Description
<code>root</code>	Root package of the Health APIs
<code>spi</code>	Internal SPIs (<i>Service Provider Interfaces</i>) implemented by the provider

Along with APIs, Health comes with a set of annotations. Table 25 lists a subset of the most commonly used annotations.

Table 25. Main Health Annotations

Annotation	Description
<code>@Liveness</code>	Used to define a liveness health check procedure
<code>@Readiness</code>	Used to define a readiness health check procedure

8.2.1. Running the Default Health Check

Importing the `smallrye-health` extension directly exposes three REST endpoints:

Eclipse MicroProfile Health allows services to report their health, and it publishes the overall health status to defined endpoints:

- `/health/live`: Returns the result of all liveness checks and determines whether or not your application is up and running.
- `/health/ready`: Returns the result of all readiness checks and determines whether or not your application can process requests.
- `/health`: Accumulates the result of both health check types.

These endpoints are linked to health check procedures annotated respectively with `@Liveness` and `@Readiness` annotations.

For example, to check that the health extension is working as expected, access the *Book* microservice using your browser or cURL at:

- <http://localhost:8082/health/live>
- <http://localhost:8082/health/ready>

- <http://localhost:8082/health>

For now, the checks array is empty as we have not specified any health check procedure yet so let's define some.

8.2.2. Adding a Liveness Health Check

To check that our *Number* microservice is live, we can add a `ping()` method on the `NumberResource` that just returns a `ping` (see [Listing 71](#)).

Listing 71. The Number REST Endpoint Returning a Ping

```
@Path("/api/numbers/book")
public class NumberResource {

    @GET
    @Path("/ping")
    @Produces(MediaType.TEXT_PLAIN)
    public String ping() {
        return "ping";
    }
}
```

Then, we need to create the extra class `PingNumberResourceHealthCheck` (under the `health` subpackage in `rest-number` module) that invokes this `ping()` method. The class in [Listing 72](#) extends `HealthCheck` and overrides the `call()` method. That's where we invoke the endpoint's `ping()` method. If the call succeeds, we return an `up` response (meaning the REST endpoint is live).

Listing 72. Checks the Liveness of the Number Microservice

```
@Liveness
@ApplicationScoped
public class PingNumberResourceHealthCheck implements HealthCheck {

    @Inject
    NumberResource numberResource;

    @Override
    public HealthCheckResponse call() {
        numberResource.ping();
        return HealthCheckResponse.named("Ping Number REST Endpoint").up().build();
    }
}
```

As you can see, health check procedures are defined as implementations of the `HealthCheck` interface which are defined as CDI beans with the CDI qualifier `@Liveness`. `HealthCheck` is a functional interface whose single method `call()` returns a `HealthCheckResponse` object which can be easily constructed by the fluent builder API shown in the example.

As we have started our Quarkus application in dev mode, simply repeat the request to <http://localhost:8081/health/live> by refreshing your browser window or by using cURL. Because we defined our health check as being a liveness procedure (with `@Liveness` qualifier) the new health check procedure is now present in the checks array in [Listing 73](#).

Listing 73. Liveness JSON Result of the Number Microservice

```
{  
  "status": "UP",  
  "checks": [  
    {  
      "name": "Ping Number REST Endpoint",  
      "status": "UP"  
    }  
  ]  
}
```



Write an equivalent `ping()` method on the `BookResource` class and create a `PingBookResourceHealthCheck` class that checks that the `Book` microservice is live.

8.2.3. Adding a Readiness Health Check

We've just created a simple liveness health check procedure which states whether our application is running or not. But it's not because the application is live that it's ready. So let's create a readiness health check in the `rest-book` module which will be able to state whether our application is able to process requests.

For this, we create another health check procedure that accesses our database. If the database can be accessed, then we return the response indicating that the application is ready. As you can see in [Listing 74](#) this time we use a `@Readiness` qualifier instead of `@Liveness`.

Listing 74. Checks the Readiness of the Book Microservice

```
@Readiness
@ApplicationScoped
public class DatabaseConnectionHealthCheck implements HealthCheck {

    @Inject
    BookService bookService;

    @Override
    public HealthCheckResponse call() {
        HealthCheckResponseBuilder responseBuilder = HealthCheckResponse
            .named("Book Datasource connection health check");

        try {
            List<Book> books = bookService.findAllBooks();
            responseBuilder.withData("Number of books in the database", books.size()).up();
        } catch (IllegalStateException e) {
            responseBuilder.down();
        }

        return responseBuilder.build();
    }
}
```

If you now re-run the health check at <http://localhost:8082/health/live> the checks array contains only the previously defined `PingBookResourceHealthCheck` as it is the only check defined with the `@Liveness` qualifier. However, if you access <http://localhost:8082/health/ready> you only see the Database connection health check. That's because it's the only health check defined with the `@Readiness` qualifier as being the readiness health check procedure. If you access <http://localhost:8082/health> you will get back both checks as shown in Listing 75.

Listing 75. Array of All Health Checks

```
{  
  "status": "UP",  
  "checks": [  
    {  
      "name": "Ping Book REST Endpoint",  
      "status": "UP"  
    },  
    {  
      "name": "Book Datasource connection health check",  
      "status": "UP",  
      "data": {  
        "Number of books in the database": 102  
      }  
    }  
  ]  
}
```

8.3. Metrics

Having health checks on our microservices is very important: it quickly indicates if an instance is live and ready to process requests. But health checks do not indicate if the microservice is running at its full speed or slowing down. It doesn't indicate either if it's performing faster or slower than yesterday, for example. That's when metrics come in handy. To know if your entire microservice architecture is performing at its right speed, you need to gather metrics and be able to visualise them.

Eclipse MicroProfile Metrics provides a unified way for MicroProfile servers to export monitoring data to management agents.^[62] Metrics will also provide a common Java API for exposing their telemetry data. MicroProfile Metrics allows applications to gather various metrics and statistics that provide insights into what is happening inside the application. The metrics can be read remotely using a JSON or OpenMetrics format so that they can be processed by additional tools such as Prometheus, and stored for analysis and visualisation.

The Eclipse MicroProfile Metrics APIs and annotations are all defined under the main `org.eclipse.microprofile.metrics` package, either at the root, or under the other subpackages. Table 26 lists the main subpackages defined in Eclipse MicroProfile Metrics version 2.3 (under the root `org.eclipse.microprofile.metrics` package).^[63]

Table 26. Main org.eclipse.microprofile.metrics Subpackages

Subpackage	Description
<code>root</code>	Root package of the Metrics APIs
<code>annotation</code>	APIs for annotating methods and classes to get metrics from

Along with APIs, Metrics comes with a set of annotations. Table 27 lists a subset of the most commonly used annotations.

Table 27. Main Metrics Annotations

Annotation	Description
@Counted	Marking a method, constructor, or class invocation as counted
@Gauge	Simplest metric type that just returns a value
@Metered	Measures the rate at which a set of events occur
@Timed	Tracks the duration of an event

Importing the `smallrye-metrics` extension directly exposes a few endpoints with default metrics:

The Eclipse MicroProfile Metrics architecture consists of four endpoints:

- `/metrics/base`: Set of metrics that all MicroProfile-compliant servers have to provide.
- `/metrics/vendor`: Vendor-specific metrics on top of the basic set of required metrics.
- `/metrics/application`: Metrics provided by the application at runtime.
- `/metrics`: Aggregates all the metrics.

Now let's have metrics on all the methods of all our REST resources. For that, we need a few annotations to make sure that our desired metrics are calculated over time and can be exported for manual analysis or processing by additional tooling. The metrics that we will gather are these:

- `countCreateBook/countUpdateBook`: A counter which is increased by one each time the user creates or updates a book.
- `timeCreateBook/timeUpdateBook`: This is a timer, therefore a compound metric that benchmarks how much time the requests take.

Methods in [Listing 76](#) are annotated with Eclipse MicroProfile Metrics annotations (`@Counted` and `@Timed`) so metrics can be gathered.

Listing 76. Metrics on Methods to Create and Update a Book

```
@Operation(summary = "Creates a valid book")
@APIResponse(responseCode = "201", description = "The URI of the created book",
content = @Content(mediaType = MediaType.APPLICATION_JSON, schema = @Schema
(implementation = URI.class)))
@Counted(name = "countCreateBook", description = "Counts how many times the createBook
method has been invoked")
@Timed(name = "timeCreateBook", description = "Times how long it takes to invoke the
createBook method", unit = MetricUnits.MILLISECONDS)
@POST
public Response createBook(@RequestBody(required = true, content = @Content(mediaType
= MediaType.APPLICATION_JSON, schema = @Schema(implementation = Book.class))) @Valid
Book book, @Context UriInfo uriInfo) {
    book = service.persistBook(book);
    UriBuilder builder = uriInfo.getAbsolutePathBuilder().path(Long.toString(book.id));
    LOGGER.debug("New book created with URI " + builder.build().toString());
    return Response.created(builder.build()).build();
}

@Operation(summary = "Updates an existing book")
@APIResponse(responseCode = "200", description = "The updated book", content =
@Content(mediaType = MediaType.APPLICATION_JSON, schema = @Schema(implementation =
Book.class)))
@Counted(name = "countUpdateBook", description = "Counts how many times the updateBook
method has been invoked")
@Timed(name = "timeUpdateBook", description = "Times how long it takes to invoke the
updateBook method", unit = MetricUnits.MILLISECONDS)
@PUT
public Response updateBook(@RequestBody(required = true, content = @Content(mediaType
= MediaType.APPLICATION_JSON, schema = @Schema(implementation = Book.class))) @Valid
Book book) {
    book = service.updateBook(book);
    LOGGER.debug("Book updated with new valued " + book);
    return Response.ok(book).build();
}
```



Listing 76 shows the source code of the methods to create and update a book, but make sure to add metrics on all methods of all microservices.

8.4. Running the Application

This time, we don't need the user interface to run, just the *Number* and *Book* microservices have health checks and metrics.

8.4.1. Testing the Application

We could leave the test suite as it is. We have a nice suite of tests that make sure our business logic works, and that is the most important thing. However, we can add a few extra tests just to check

that our health check and metrics endpoints are accessible.

Testing Health Check

[Listing 77](#) adds a few extra test methods that make sure both health check endpoints are available. They just invoke an HTTP GET on both `/health/live` and `/health/ready` URIs and make sure they return a `200-OK` response. Add these tests to both the `NumberResourceTest` and `BookResourceTest` classes.

Listing 77. Testing Health Check Endpoints Availability

```
@Test
void shouldPingLiveness() {
    given().
    when()
        .get("/health/live").
    then()
        .statusCode(OK.getStatusCode());
}

@Test
void shouldPingReadiness() {
    given().
    when()
        .get("/health/ready").
    then()
        .statusCode(OK.getStatusCode());
}
```

Testing Metrics

We use the same testing approach in [Listing 78](#) to make sure the Metrics endpoint is available.

Listing 78. Testing Metrics Endpoint Availability

```
@Test
void shouldPingMetrics() {
    given()
        .header(HttpHeaders.ACCEPT, MediaType.APPLICATION_JSON).
    when()
        .get("/metrics/application").
    then()
        .statusCode(OK.getStatusCode());
}
```

Here I've just shown you the health check and metrics tests for the *Number* REST API, but you should do the same for Books.

8.4.2. Running the Infrastructure

To execute the application and get some metrics, we now need a PostgreSQL database as well as Prometheus. As usual, let's use Docker and Docker Compose to ease the installation of this infrastructure.

Listing 79. Docker Compose File With a Prometheus

```
version: "3"
services:
  database:
    image: "postgres:12.1"
    container_name: "books-database"
    ports:
      - "5432:5432"
    volumes:
      - ./db-init/initialize-databases.sql:/docker-entrypoint-initdb.d/init.sql
  monitoring:
    image: "prom/prometheus:v2.21.0"
    container_name: "books-monitoring"
    ports:
      - 9090:9090
    volumes:
      - ./monitoring/prometheus.yml:/etc/prometheus/prometheus.yml
```

At the root of the `infrastructure` directory you can execute:

- A `docker-compose -f docker-compose.yaml up -d` command to start the entire infrastructure
- and a `docker-compose -f docker-compose.yaml down` command to stop it

8.4.3. Executing the Application

Now that the tests pass and that our infrastructure is up and running, let's start our two microservices, add some load and get some metrics. Start both Quarkus instances, one for the *Book* microservice (listening on port 8082), and the other one for the *Number* microservice (listening on 8081):

```
rest-book$ mvn quarkus:dev
rest-number$ mvn quarkus:dev
```

8.4.4. Adding Load to the Application

Now that we have the microservices exposing health checks and metrics, time to add some load to our application and have a decent user interface to monitor how the system behaves. In the `load-bookstore` directory, there is an application that is NOT a Quarkus application. It's a simple Java application that simulates users interacting with the system so it generates some load.

The `BookStoreLoad` class in [Listing 80](#) is just a `main` that executes several scenarios in different

threads.

Listing 80. Main Class Executing the Load Scenarios

```
public class BookStoreLoad {  
  
    public static void main(String[] args) {  
        Thread bookScenario = new Thread(new ScenarioBook());  
        bookScenario.start();  
        Thread numberScenario = new Thread(new ScenarioNumber());  
        numberScenario.start();  
    }  
}
```

For example, if you look at the `ScenarioBook` in Listing 81, you will see that it's just a suite of HTTP calls on the Book API.

Listing 81. Book Load Scenario

```
protected List<Endpoint> getEndpoints() {  
    return Stream.of(  
        endpoint(contextRoot, "GET"),  
        endpoint(contextRoot + "/ping", "GET"),  
        endpoint(contextRoot + "/random", "GET"),  
        endpointWithTemplates(contextRoot + "/{id}", "GET", this::idParam),  
        endpointWithTemplates(contextRoot + "/{id}", "DELETE", this::idParam),  
        endpointWithEntity(contextRoot, "POST", this::createBook)  
    )  
        .collect(Collectors.unmodifiableList());  
}
```

You are all set! Time to compile and start the load application using:

```
load-bookstore$ mvn compile  
load-bookstore$ mvn exec:java
```

You will see the following logs on the `load-bookstore` project:

```

INFO: GET    - http://localhost:8082/api/books/ping    - 200
INFO: GET    - http://localhost:8081/api/numbers/book - 200
INFO: GET    - http://localhost:8082/api/books/random - 200
INFO: GET    - http://localhost:8081/api/numbers/book - 200
INFO: GET    - http://localhost:8082/api/books/1077   - 200
INFO: GET    - http://localhost:8081/api/numbers/book - 200
INFO: POST   - http://localhost:8082/api/books        - 201
INFO: DELETE - http://localhost:8082/api/books/1055   - 204
INFO: GET    - http://localhost:8082/api/books/random - 200
INFO: GET    - http://localhost:8081/api/numbers/book - 200

```

You should also see some logs appearing on the *Number* and *Book* microservices. Leave it running for a while so we have enough data to monitor.

8.4.5. Monitoring the Application

To view the metrics of the *Number* microservice in JSON format, execute `curl -H "Accept: application/json" http://localhost:8081/metrics/application`. You will receive a response similar to the one in [Listing 82](#).

Listing 82. Metrics Class

```
{
  "NumberResource.countGenerateBookNumber": 23,
  "NumberResource.timeGenerateBookNumber": {
    "p99": 2.552359,
    "min": 2.351004,
    "max": 4.142853,
    "mean": 2.4475338218611054,
    "p50": 2.459645,
    "p999": 2.552359,
    "stddev": 0.059644582615724376,
    "p95": 2.552359,
    "p98": 2.552359,
    "p75": 2.475044,
    "fiveMinRate": 0.0427305308960399,
    "fifteenMinRate": 0.018611613176138856,
    "meanRate": 0.005087646702440494,
    "count": 23,
    "oneMinRate": 0.1733913276585504
  }
}
```

Let's explain the meaning of each metric:

- `countGenerateBookNumber`: A counter which is increased by one each time the user asks for a book number.
- `timeGenerateBookNumber`: This is a timer, therefore a compound metric that benchmarks how

much time the request takes. All durations are measured in milliseconds. It consists of these values:

- `min`: The shortest duration it took to perform a request.
- `max`: The longest duration.
- `mean`: The mean value of the measured durations.
- `stddev`: The standard deviation.
- `count`: The number of observations (so it will be the same value as `countGenerateBookNumber`).
- `p50, p75, p95, p99, p999`: Percentiles of the durations. For example the value in `p95` means that 95% of the measurements were faster than this duration.
- `meanRate, oneMinRate, fiveMinRate, fifteenMinRate`: Mean throughput and one-, five-, and fifteen-minute exponentially-weighted moving average throughput.

If you prefer an OpenMetrics export rather than the JSON format, remove the `-H "Accept: application/json"` argument from your command line.^[64]

8.4.6. Collecting Metrics on Prometheus

Having a JSON representation of the metrics is ok, but we will have to have a graphical interface. That's when Prometheus comes in to play. Prometheus is an open source systems monitoring and alerting toolkit.^[65]

Configuring Prometheus

Prometheus needs to be configured to poll data from our microservices. This is made under our `infrastructure/monitoring` directory, in the `prometheus.yml` file as shown in Listing 83.

Listing 83. Prometheus YAML Configuration

```
scrape_configs:  
  - job_name: 'prometheus'  
    static_configs:  
      - targets: ['localhost:9090']  
  - job_name: 'number'  
    static_configs:  
      - targets: ['host.docker.internal:8081']  
  - job_name: 'book'  
    static_configs:  
      - targets: ['host.docker.internal:8082']
```

This file contains a basic Prometheus configuration, plus a specific `scrape_config` which instructs Prometheus to look for application metrics from our Quarkus microservices.

Adding Graphs to Prometheus

Now is the time to add some graphs to Prometheus. Figure 26 shows the Prometheus console that is accessible at <http://localhost:9090>.

The screenshot shows the Prometheus admin console interface. At the top, there are links for Prometheus, Alerts, Graph, Status, and Help. Below this is a checkbox for 'Enable query history' and a link to 'Try experimental React UI'. A search bar labeled 'Expression (press Shift+Enter for newlines)' contains the text 'Execute - insert metric at cursor'. Below the search bar are two tabs: 'Graph' (selected) and 'Console'. Under the 'Graph' tab, there is a search input field containing 'Moment' with navigation arrows (back, forward). Below this is a table with columns 'Element' and 'Value'. The table has one row with the text 'no data'. At the bottom right of the table area is a 'Remove Graph' button. A blue 'Add Graph' button is located at the bottom left.

Figure 26. Prometheus admin console

Out of the box, you get a lot of basic JVM metrics or even metrics of Prometheus itself, which are useful. But let's create new graphs with the metrics of our microservices. In the combobox shown in Figure 27, type `timeCreateBook`, select `application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_five_min_rate_per_second`, and click *Execute*.

The screenshot shows the Prometheus admin console interface. At the top, there are links for Prometheus, Alerts, Graph, Status, and Help. Below this is a checkbox for 'Enable query history' and a link to 'Try experimental React UI'. A search bar contains the text 'timeCreateBook'. A dropdown menu is open, listing various metrics starting with 'application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_fifteen_min_rate_per_second'. Other listed metrics include: application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_five_min_rate_per_second, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_five_min_rate_per_second, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_max_seconds, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_mean_seconds, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_min_seconds, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_one_min_rate_per_second, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_rate_per_second, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_seconds, application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_seconds_count, and application_org_agoncal_fascicle_quarkus_book_BookResource_timeCreateBook_stddev_seconds. At the bottom right of the dropdown menu is a 'Remove Graph' button.

Figure 27. Looking for available metrics

This will fetch the values from our metric showing the average throughput as shown in Figure 28.

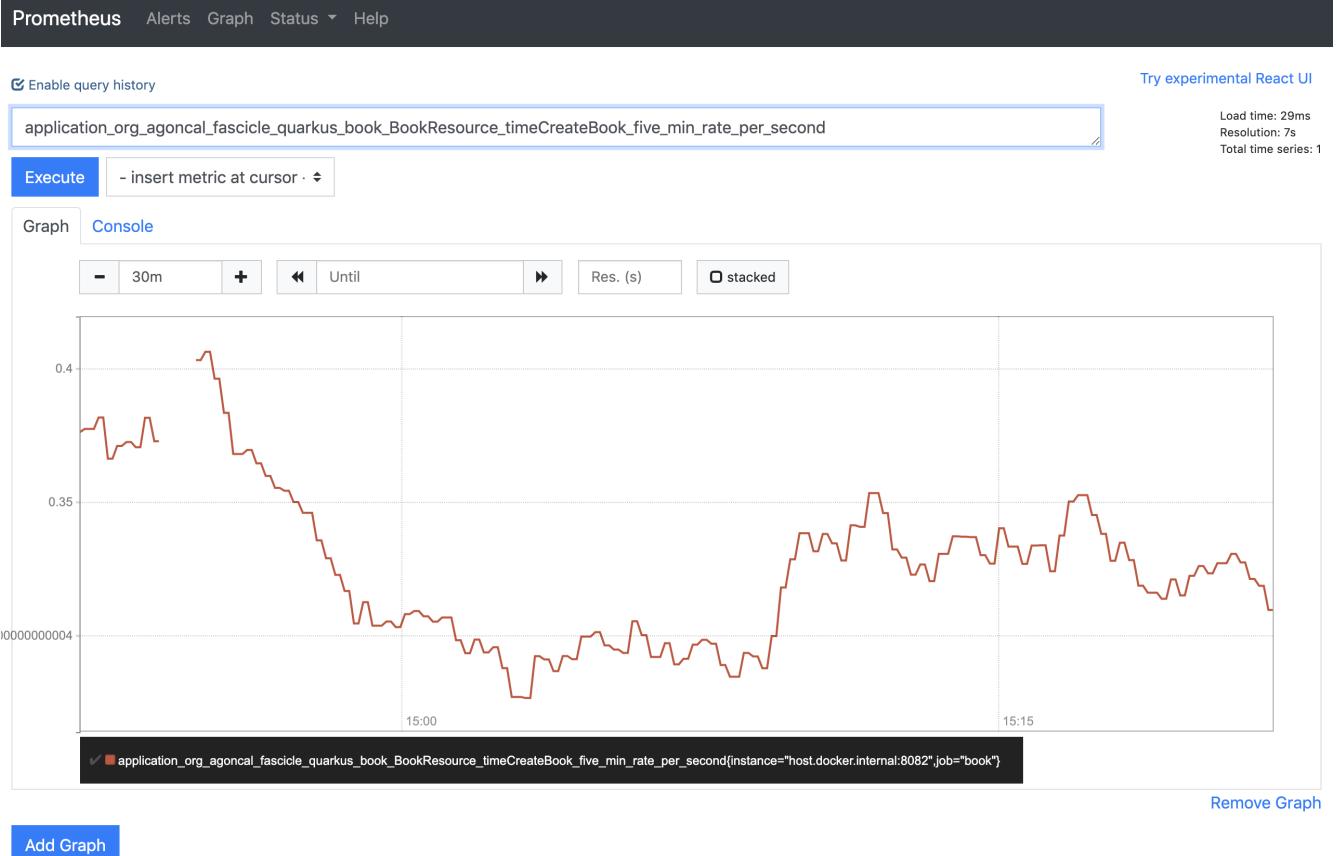


Figure 28. Metrics when creating a book

8.5. Summary

In this chapter, you've managed to monitor the microservices of our architecture. Health checks are a way to know if a microservice is alive and/or ready. This is very important in a distributed architecture where each microservice relies on others. Knowing that a process is dead or not ready allows other distributed services to adapt to the broken communication. You've implemented several health checks thanks to Eclipse MicroProfile Health.

Once a microservice is up and running, it is important to know if it responds to the incoming requests within a certain amount of time. Thanks to the Eclipse MicroProfile Metrics, you were able to add metrics to each of our microservices and monitor them with Prometheus.

In the next chapter, you will use Quarkus and GraalVM to build native executables. These executables will then be packaged as Docker images so they can be portable and executed on any server or cloud provider.

[60] Health <https://microprofile.io/project/eclipse/microprofile-health>

[61] Health GitHub <https://github.com/eclipse/microprofile-health>

[62] Metrics <https://microprofile.io/project/eclipse/microprofile-metrics>

[63] Metrics GitHub <https://github.com/eclipse/microprofile-metrics>

[64] OpenMetrics <https://openmetrics.io>

[65] Prometheus <https://prometheus.io>

Chapter 9. Creating Executables and Building Containers

Our application is finally complete: we have several microservices communicating with each other so we can create/read/update/delete books from a database using a user interface. And all of that running on several Quarkus instances, in development mode. Time to go to production! Quarkus makes it possible to easily build executable JARs and package them within containers. In this chapter, you will use Quarkus to package our microservices into executable JARs, and Docker to package them into containers and execute them.



Make sure your development environment is set up to execute the code in this chapter. You can go to [Appendix A](#) to check that you have all the required tools installed, in particular GraalVM 20.2.0 working with JDK 11.0.8.

9.1. What Will You Build in This Chapter?

In this chapter, you will:

- Try to build native executables out of our microservices,
- Package the microservices into executable JAR files,
- Package the executable JARs into Docker images,
- Execute the entire application (our microservices, the Postgres database and Prometheus) thanks to Docker Compose.

9.1.1. Overall Architecture

[Figure 29](#) shows the architecture that you will have at the end of this chapter. The *Number* and *Book* microservice will get packaged into executable JARs, and the same for the Angular application. Each of these JARs will get packaged and executed inside a Docker container.

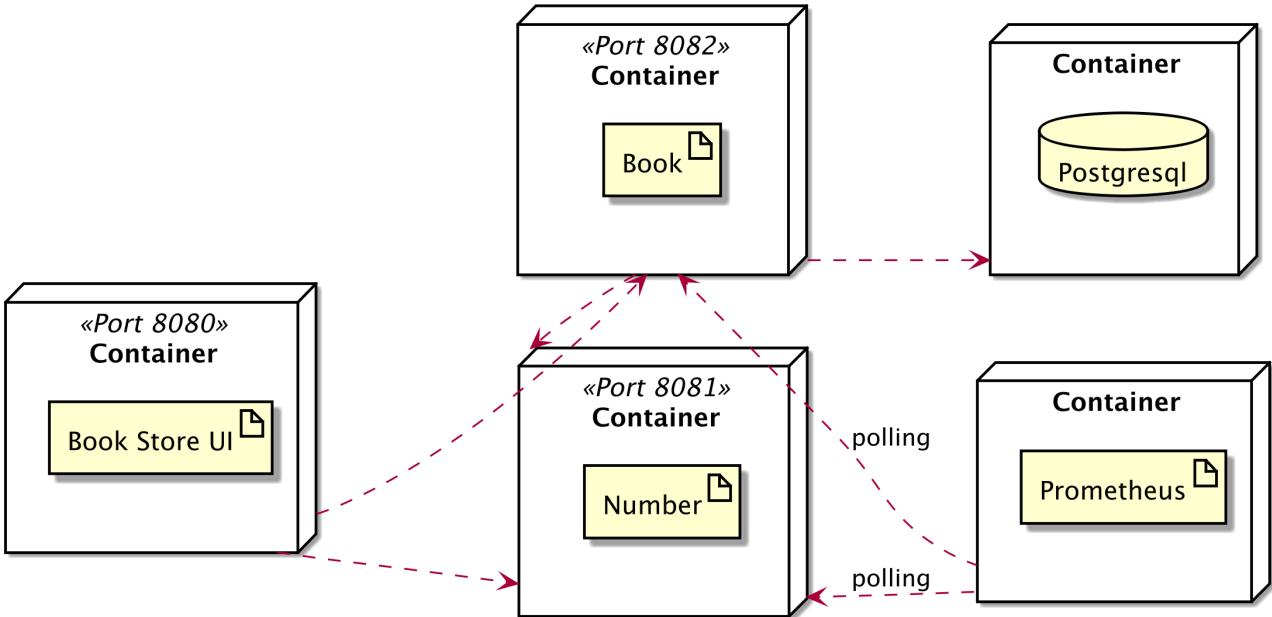


Figure 29. Overall architecture

9.1.2. Maven Dependencies

We don't need any Quarkus extension to package our microservices into executable JAR files, nor to build native executables. This is taken care of by the Quarkus plugin. But to have Quarkus generate Docker images based on Dockerfiles, we need to add the Docker extension to our `pom.xml` (see Listing 84).

Listing 84. Docker Extension

```
<dependency>
  <groupId>io.quarkus</groupId>
  <artifactId>quarkus-container-image-docker</artifactId>
</dependency>
```

Listing 85 shows the Maven profile to execute the test on the native executable. It configures the `maven-failsafe-plugin` so it runs the integration tests against the native executable.

Listing 85. Maven Profile to Test Native Images

```
<profiles>
  <profile>
    <id>native</id>
    <activation>
      <property>
        <name>native</name>
      </property>
    </activation>
    <build>
      <plugins>
        <plugin>
          <artifactId>maven-failsafe-plugin</artifactId>
          <executions>
            <execution>
              <goals>
                <goal>integration-test</goal>
                <goal>verify</goal>
              </goals>
              <configuration>
                <systemProperties>
                  <native.image.path>${project.build.directory}/${project.build.finalName}-runner</native.image.path>
                </systemProperties>
              </configuration>
            </execution>
          </executions>
        </plugin>
      </plugins>
    </build>
    <properties>
      <quarkus.package.type>native</quarkus.package.type>
    </properties>
  </profile>
</profiles>
```

9.2. Trying to Go Native

Let's now try to produce native executables for our application. Thanks to GraalVM, Quarkus is able to generate native executables. Just like Go, native executables don't need a Virtual Machine (VM) to run, they contain the whole application, like an `.exe` file on Windows. Native executables improve the startup time of the application, memory consumption, and produce a minimal disk footprint. The executable would have everything to run the application including the JVM (shrunk to be just enough to run the application), and the application.

9.2.1. Building Native Executables

Quarkus, with the help of GraalVM, can build a native executable. Therefore, make sure you have correctly setup GraalVM already. Thanks to the built-in Maven `native` profile, you can easily create a native executable using the following command.

```
rest-book$ mvn package -Pnative
```

By executing this command, you should have a similar output:

```
[rest-book-1.0-runner]  (typeflow): 12,887.14 ms
[rest-book-1.0-runner]  (objects): 22,387.32 ms
[rest-book-1.0-runner]  (features): 767.28 ms
[rest-book-1.0-runner]  analysis: 38,747.95 ms
[rest-book-1.0-runner]  (clinit): 1,216.40 ms
[rest-book-1.0-runner]  universe: 2,525.15 ms
[rest-book-1.0-runner]  (parse): 1,330.51 ms
[rest-book-1.0-runner]  (inline): 2,863.40 ms
[rest-book-1.0-runner]  (compile): 12,952.72 ms
[rest-book-1.0-runner]  compile: 19,802.63 ms
[rest-book-1.0-runner]  image: 3,567.13 ms
[rest-book-1.0-runner]  write: 1,090.45 ms
[rest-book-1.0-runner]  [total]: 77,137.84 ms
[INFO] Quarkus augmentation completed in 80641ms
```



Creating a native executable requires a lot of memory and CPU. It also takes a few minutes, even for a simple application like the *Number* microservice. Most of the time is spent during the dead-code elimination, as it traverses the whole closed-world.^[66]

In addition to the regular files, the build also produces the `rest-book-1.0-runner` (notice that there is no `.jar` file extension). And if you check the permissions of the files, you'll notice that `rest-book-1.0-runner` is executable (`x` allowing executable permissions).

```
rest-book$ ls -lh target/rest-book*
-rwxr-xr-x  62M  rest-book-1.0-runner
-rw-r--r--  575K  rest-book-1.0-runner.jar
-rw-r--r--  61K   rest-book-1.0.jar
```

Now you can simply execute the file like any other native executable with `./target/rest-book-1.0-runner`. One thing to notice when doing so is the startup time. Depending on your machine, starting the native executable is 4 to 6 times faster than executing the executable JAR. The memory footprint is also smaller.

9.2.2. Testing the Native Executable

Producing a native executable can lead to a few issues, so it's also a good idea to run some tests against the application running in the native file. This is quite easy. [Listing 86](#) shows the `NativeBookResourceIT` test class. As you can see, instead of being annotated with `@QuarkusTest`, it uses the `@NativeImageTest` test runner. We can leave it empty (or add specific tests for native code) and we just extend from our previous test.

Listing 86. Native Test

```
package org.agoncal.fascicle.quarkus.book;

import io.quarkus.test.junit.NativeImageTest;

{@NativeImageTest
public class NativeBookResourceIT extends BookResourceTest {

    // Execute the same tests but in native mode.
}}
```

To execute the native tests, invoke the `native` profile with the following command:

```
$ mvn verify -Pnative
```

This will execute the JVM mode tests, and then, the native tests. So the workflow is:

- The Surefire plugin executes the JVM mode tests (Quarkus is started in JVM mode);
- GraalVM compiles the code into a binary;
- The Failsafe plugin executes the binary (Quarkus is started in native mode);
- The Failsafe plugin runs the native tests.

But unfortunately, the native tests will not pass! In fact, there are several issues. Remember that we have created a test that pings the URL for SwaggerUI. But SwaggerUI is not available in production, so the `shouldPingSwaggerUI()` in [Listing 87](#) only makes sense in development and test, not in production. To exclude certain tests when running as a native executable we can mark them with the `@DisabledOnNativeImage` annotation in order to only run them on the JVM.

Listing 87. Excluding a Test When Running as a Native Executable

```
@Test
void shouldPingOpenAPI() {
    given()
        .header(HttpHeaders.ACCEPT, MediaType.APPLICATION_JSON).
    when()
        .get("/openapi").
    then()
        .statusCode(OK.getStatusCode());
}

@DisabledOnNativeImage
@Test
void shouldPingSwaggerUI() {
    given().
    when()
        .get("/swagger-ui").
    then()
        .statusCode(OK.getStatusCode());
}
```

Disabling the SwaggerUI test was quite easy. And if it was the only issue you should see similar traces:

```
[INFO] -----
[INFO] Building Practising Quarkus :: Numbers REST Microservice 1.0
[INFO] -----
[INFO]
[INFO] --- maven-surefire-plugin:test
[INFO]
[INFO] -----
[INFO] T E S T S
[INFO] -----
[INFO] Running NumberResourceTest
[INFO] [io.quarkus] Quarkus on JVM started in 1.772s
[INFO] [io.quarkus] Profile test activated.
[INFO] Tests run: 8, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 3.596 s - in
org.agoncal.fascicle.quarkus.number.NumberResourceTest
[INFO] [io.quarkus] Quarkus stopped in 0.029s
[INFO]
[INFO] Results:
[INFO]
[INFO] Tests run: 8, Failures: 0, Errors: 0, Skipped: 0
[INFO]
[INFO] --- quarkus-maven-plugin:build
[INFO] Building native image from rest-number/target/rest-number-1.0-native-image-
source-jar/rest-number-1.0-runner.jar
[INFO] Running Quarkus native-image plugin on GraalVM
[rest-number]    classlist:  3,955.96 ms,  1.19 GB
[rest-number]      setup:   2,928.73 ms,  1.19 GB
[rest-number]    (clinit):   947.39 ms,  5.11 GB
[rest-number]    (features):   657.81 ms,  5.11 GB
[rest-number]      (parse):  1,091.40 ms,  5.11 GB
[rest-number]     (inline):  2,587.20 ms,  6.05 GB
[rest-number]       image:   3,208.63 ms,  6.05 GB
[rest-number]      [total]: 59,936.70 ms,  6.01 GB
[INFO]
[INFO] --- maven-failsafe-plugin:integration-test
[INFO]
[INFO] -----
[INFO] T E S T S
[INFO] -----
[INFO] Running NativeNumberResourceIT
Executing target/rest-number-1.0-runner
14:01:26 INFO [i.quarkus] rest-number 1.0 native
14:01:26 INFO [i.quarkus] Profile prod activated.
[INFO]
[INFO] Results:
[INFO]
[WARNING] Tests run: 8, Failures: 0, Errors: 0, Skipped: 2
[INFO]
[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
```

But the native tests still will not pass. That's because our microservices use Java Faker. And Java Faker uses a lot of introspection, which GraalVM can't cope with. GraalVM will eliminate code from Java Faker during the dead-code elimination phase. Let's forget about native executables and package our microservices into executable JARs.

9.3. Containers

Before distributing our microservices as container images, let's package them into executable JARs. Then, once we have Docker images for all our microservices as well as our infrastructure, we will be able to run our entire application with a single command.

9.3.1. Building Executable JARs

Up to now, we've mostly used Maven to execute Quarkus in development mode with the `mvn quarkus:dev` command. But we can also build the application using a common `mvn package`. If we do so, it produces two JAR files in the `target` directory:

```
rest-book$ ls -lh target/rest-book*
-rw-r--r-- 575K  rest-book-1.0-runner.jar
-rw-r--r-- 61K   rest-book-1.0.jar
```

As you can see, these two JAR files have different sizes, and therefore their content is different:

- `rest-book-1.0.jar`: Containing just the classes and resources of the projects, it's the regular artifact produced by the Maven build.
- `rest-book-1.0-runner.jar`: Is an executable jar.

With an executable JAR, you can run the application using the following command:

```
rest-book$ java -jar target/rest-book-1.0-runner.jar
```

But be aware that `rest-book-1.0-runner.jar` is an executable JAR, not an Uber-JAR. An Uber-JAR contains both the code of our application and all its dependencies in one single JAR file. This is not the case here. Quarkus copies all the dependencies into the `target/lib` directory and `rest-book-1.0-runner.jar` depends on this `target/lib` directory. If you remove the `target/lib` and re-run the application with `java -jar target/rest-book-1.0-runner.jar` it won't work (as you will get a `ClassNotFoundException`).

Make sure you build the executables JARs for both the *Book* and the *Number* microservices:



```
rest-book$ mvn package
rest-number$ mvn package
```

9.3.2. Building Containers

Now that we have all our executable JARs under the `target` folder, we can build the containers. For that, we need the `src/main/docker/Dockerfile.jvm` *Dockerfile* (as shown in Listing 88) that build a Docker image with our code. This Dockerfile is pretty straightforward as it takes a minimal base image (`ubi-minimal`) and copies the generated executable JAR (`target/*-runner.jar`) and its dependencies (`target/lib/*`) to the `/deployments` directory.

Listing 88. Dockerfile to Package the Linux Native Image

```
FROM registry.access.redhat.com/ubi8/ubi-minimal:8.1

ARG JAVA_PACKAGE=java-11-openjdk-headless
ARG RUN_JAVA_VERSION=1.3.8

ENV LANG='en_US.UTF-8' LANGUAGE='en_US:en'

# Install java and the run-java script
# Also set up permissions for user `1001`
RUN microdnf install curl ca-certificates ${JAVA_PACKAGE} \
    && microdnf update \
    && microdnf clean all \
    && mkdir /deployments \
    && chown 1001 /deployments \
    && chmod "g+rwx" /deployments \
    && chown 1001:root /deployments \
    && curl https://repo1.maven.org/maven2/io/fabric8/run-java-
sh/${RUN_JAVA_VERSION}/run-java-sh-${RUN_JAVA_VERSION}-sh.sh -o /deployments/run-
java.sh \
    && chown 1001 /deployments/run-java.sh \
    && chmod 540 /deployments/run-java.sh \
    && echo "securerandom.source=file:/dev/urandom" >>
/etc/alternatives/jre/lib/security/java.security

# Configure the JAVA_OPTIONS, you can add -XshowSettings:vm to also display the heap
size.
ENV JAVA_OPTIONS="-Dquarkus.http.host=0.0.0.0
-Djava.util.logging.manager=org.jboss.logmanager.LogManager"

COPY target/lib/* /deployments/lib/
COPY target/*-runner.jar /deployments/app.jar

EXPOSE 8081
USER 1001

ENTRYPOINT [ "/deployments/run-java.sh" ]
```



Each of our microservices have a similar *Dockerfile*. The only thing that changes is the exposed port. We expose the port 8080 for the user interface, port 8081 for the *Number* microservice and port 8082 for the *Book* microservice.

To have Quarkus build Docker images based on the Dockerfiles located under `src/main/docker` we need to set the configuration property `quarkus.container-image.build` to `true`. To build the containers, use the following commands for all our microservices:

```
rest-number$ mvn package -Dquarkus.container-image.build=true  
rest-book$ mvn package -Dquarkus.container-image.build=true  
ui-bookstore$ mvn package -Dquarkus.container-image.build=true
```

Then you can check the built images with a `docker image ls` command:

```
$ docker image ls "agoncal/*"  
  
REPOSITORY          TAG      SIZE  
agoncal/rest-book  1.0      528MB  
agoncal/rest-number 1.0      510MB  
agoncal/ui-bookstore 1.0      504MB
```

9.3.3. Running Containers

You could then start each image with a `docker container run` command. But this would be cumbersome as each microservice needs some configuration. The easiest is to use the Docker compose file `docker-compose-app.yaml` in Listing 89, located under the `infrastructure` directory.

Listing 89. Docker Compose File Defining the Entire Application

```
version: "3"
services:
  ui-bookstore:
    image: "agoncal/ui-bookstore:1.0"
    container_name: "ui-bookstore"
    ports:
      - "8080:8080"
    depends_on:
      - rest-number
      - rest-book
  rest-number:
    image: "agoncal/rest-number:1.0"
    container_name: "rest-number"
    ports:
      - "8081:8081"
  rest-book:
    image: "agoncal/rest-book:1.0"
    container_name: "rest-book"
    ports:
      - "8082:8082"
    depends_on:
      database:
        condition: service_healthy
    environment:
      - QUARKUS_DATASOURCE_JDBC_URL=jdbc:postgresql://database:5432/books_database
      - ORG_AGONCAL_FASCICLE_QUARKUS_BOOK_CLIENT_NUMBERPROXY_MP_REST_URL=http://rest-number:8081
    database:
      image: "postgres:12.1"
      container_name: "books-database"
      ports:
        - "5432:5432"
      volumes:
        - ./db-init/initialize-databases.sql:/docker-entrypoint-initdb.d/init.sql
    healthcheck:
      test: ["CMD-SHELL", "pg_isready -U postgres"]
      interval: 5s
      timeout: 5s
      retries: 5
  monitoring:
    image: "prom/prometheus:v2.21.0"
    container_name: "books-monitoring"
    ports:
      - 9090:9090
    volumes:
      - ./monitoring/prometheus.yml:/etc/prometheus/prometheus.yml
```

The Docker compose defines the following components:

- `ui-bookstore` is our user interface, listens on port 8080 and depends on both *Number* and *Book* microservices.
- `rest-number` is our *Number* microservice and it listens on port 8081.
- `rest-book` is our *Book* microservice it listens on port 8082, and it needs the Postgres database up and running before it starts. Also notice that we override the URL of the database (using the URI `database:5432` instead of the default `localhost:5432` defined in the `application.properties`). We also override the URL of the *Number* microservice.
- `database` is our Postgres database.
- `monitoring` is Prometheus listening on port 9090.

To run all the components of our application, it's just a matter of executing the following command:

```
$ docker-compose -f infrastructure/docker-compose-app.yaml up -d

Creating network "infrastructure_default" with the default driver
Creating books-database    ... done
Creating rest-number       ... done
Creating books-monitoring ... done
Creating rest-book         ... done
Creating ui-bookstore      ... done
```

You can now access the different URLs that we have seen so far:

- Open your browser at <http://localhost:8080/ui-bookstore> to access the user interface
- Generate some ISBN numbers invoking the *Number* microservice with `curl -H "Accept: application/json" http://localhost:8081/api/numbers/book | jq`
- Get the list of all the books from the database invoking the *Book* microservice at `curl -H "Accept: application/json" http://localhost:8082/api/book | jq`
- You can create a new book with `curl -X POST -d '{"title":"Practising Quarkus", "author":"Antonio Goncalves", "yearOfPublication":"2020"}' -H "Content-Type: application/json" http://localhost:8082/api/books -v`
- Remember to check Prometheus at <http://localhost:9090/graph>

While you are browsing the user interface and Prometheus, remember to add some load to our application with the following command:

```
load-bookstore$ mvn exec:java

INFO: GET    - http://localhost:8082/api/books/1077    - 200
INFO: GET    - http://localhost:8081/api/numbers/book - 200
INFO: POST   - http://localhost:8082/api/books          - 201
INFO: DELETE - http://localhost:8082/api/books/1055    - 204
INFO: GET    - http://localhost:8082/api/books/random - 200
INFO: GET    - http://localhost:8081/api/numbers/book - 200
```

Once you are finished and you want to shutdown the entire system, you can do it with a single Docker compose command:

```
$ docker-compose -f infrastructure/docker-compose-app.yaml down

Stopping ui-bookstore    ... done
Stopping rest-book       ... done
Stopping books-database  ... done
Stopping books-monitoring ... done
Stopping rest-number     ... done
Removing ui-bookstore    ... done
Removing rest-book       ... done
Removing books-database  ... done
Removing books-monitoring ... done
Removing rest-number     ... done
Removing network infrastructure_default
```

9.4. Summary

In this chapter, you didn't develop any new component for our distributed architecture. Instead, you used the Quarkus Maven plugin to package each microservice into an executable JAR. The *Number* and *Book* microservices became executable JARs, as well as the Angular application as it is bundled within Quarkus. These executable JARs start way faster than when developing with Quarkus in development mode.

Thanks to Docker, it is easy to package these JARs into container images and execute them. This enhances the portability of the components of our architecture which can now be deployed in any in-house or cloud server supporting containers.

[66] Closed-World Assumption <https://www.graalvm.org/community/opensource>

Chapter 10. Summary

[Chapter 2, Understanding Quarkus](#) started with some very brief terminology to help you in understanding some concepts around Quarkus. If you find it was too short and need more details on Quarkus, Microservices, MicroProfile, Cloud Native, or GraalVM, make sure you read my other Quarkus book entitled *Understanding Quarkus* (see [Appendix E](#) for references).

Then, thanks to [Chapter 3, Getting Started](#), you made sure your environment was ready to develop the application.

[Chapter 4, Developing the REST Number Microservice](#) and [Chapter 5, Developing the REST Book Microservice](#) focused on developing two isolated JAX-RS microservices. The *Number* microservice returns a few book numbers in JSON, while the *Book* microservice stores, deletes and retrieves books from a relational database with the help of JPA, Panache and JTA.

In [Chapter 6, Installing the Vintage Store User Interface](#) you installed an already coded Angular application on another instance of Quarkus. At this stage, the Angular application couldn't access the microservices because of CORS issues that we quickly fixed.

In [Chapter 7, Adding Communication and Fault Tolerance](#) we made the two microservices communicate with each other thanks to Eclipse MicroProfile REST Client. But HTTP related technologies usually use synchronous communication and therefore need to deal with invocation failure. With Eclipse MicroProfile Fault Tolerance, it was just a matter of using a few annotations and we can get some fallback when the communication fails.

When there are many microservices, observability becomes mandatory. In [Chapter 8, Monitoring the Microservices](#) we added some metrics to our microservices.

Then, comes production time. In [Chapter 9, Creating Executables and Building Containers](#), we built executable JARs and packaged our microservices into Docker containers.

This is the end of the *Practising Quarkus* fascicle. I hope you liked it, learnt a few things, and more importantly, will be able to take this knowledge back to your projects.

Remember that you can find all the code for this fascicle at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/tree/1.0>. If some parts were not clear enough, or if you found something missing, a bug, or you just want to leave a note or suggestion, please use the GitHub issue tracker at <https://github.com/agoncal/agoncal-fascicle-quarkus-pract/issues>.

If you liked the format of this fascicle, you might want to read others that I have written. Check [Appendix E](#) for the full list of fascicles.

Appendix A: Setting up the Development Environment on macOS

This appendix focuses on setting up your development environment so you can do the hands-on work by following the code snippets listed in the previous chapters. Being a *Practising* fascicle, each chapter asks you to develop, build or package the components of our microservice architecture. You need to install the required software in order to develop, compile, deploy, execute and test the components.

Bear in mind that I run all of these tools on macOS. So, this appendix gives you all of the installation guidelines for the macOS operating system. If your machine runs on Linux or Windows, check online to know how to install the following tools on your platform.

A.1. Homebrew

One of the pre-requisites is that you have *Homebrew* installed. *Homebrew* is a package manager for macOS.^[67]

A.1.1. A Brief History of Homebrew

The name *Homebrew* is intended to suggest the idea of building software on the Mac depending on the user's taste. It was written by Max Howell in 2009 in Ruby.^[68] On September 2016, Homebrew version 1.0.0 was released. In January 2019, Linuxbrew was merged back into Homebrew, adding beta support for Linux and the Windows Subsystem for Linux to Homebrew's feature set. On February 2, 2019, Homebrew version 2.0.0 was released.

A.1.2. Installing Homebrew on macOS

To install Homebrew, just execute the following command:

```
$ /bin/bash -c "$(curl -fsSL  
https://raw.githubusercontent.com/Homebrew/install/master/install.sh)"
```

You also need *Homebrew Cask* which extends Homebrew and brings installation and management of GUI macOS applications.^[69] Install it by running:

```
$ brew tap homebrew/cask
```

A.1.3. Checking for Homebrew Installation

Now you should be able to execute a few Homebrew commands:

```
$ brew --version  
  
Homebrew 2.4.13  
Homebrew/homebrew-core  
Homebrew/homebrew-cask
```

A.1.4. Some Homebrew Commands

- `brew commands`: Lists the built-in and external commands.
- `brew help`: Displays help.
- `brew doctor`: Checks for potential problems.
- `brew install`: Installs a formula.
- `brew uninstall`: Uninstalls a formula.
- `brew list`: Lists all installed formulae.
- `brew upgrade`: Upgrades outdated casks and formulae.
- `brew update`: Fetches the newest version of Homebrew.
- `brew cask help`: Displays Homebrew Cask help.
- `brew cask install`: Installs a cask.
- `brew cask uninstall`: Uninstalls a cask.
- `brew cask list`: Lists installed casks.
- `brew cask upgrade`: Upgrades all outdated casks (or the specified casks).

A.2. Java 11

Essential for the development and execution of the examples in the fascicle is the *Java Development Kit* (JDK).^[70] The JDK includes several tools such as a compiler (`javac`), a virtual machine, a documentation generator (`javadoc`), monitoring tools (Visual VM) and so on.^[71] The code in this fascicle uses Java 11 (JDK 11.0.8).

A.2.1. Architecture

One design goal of Java is portability, which means that programs written for the Java platform must run similarly on any combination of hardware and operating system with adequate run time support. This is achieved by compiling the Java language code to an intermediate representation called *bytecode*, instead of directly to a specific machine code. This bytecode is then analysed, interpreted and executed on the *Java Virtual Machine* (JVM).

The *Interpreter* is the one interpreting the bytecode. It does it quickly, but executes slowly. The disadvantage of the interpreter is that, when one method is called multiple times, a new interpretation is required every time. That's when the *Just In Time* (JIT) compiler kicks in. JIT is basically the component that translates the JVM bytecode (generated by your `javac` command) into machine code which is the language that your underlying execution environment (i.e. your

processor) can understand—and all that happens dynamically at runtime! When the JIT finds repeated code, it compiles the bytecode and changes it to native code. This native code will then be used directly for repeated method calls, which improves the performance of the system. This JIT is also called the *Java HotSpot* (a.k.a. Java HotSpot Performance Engine, or HotSpot VM).^[72] Then, the *Garbage Collector* will collect and remove unreferenced objects.

When using GraalVM you have the choice of doing just-in-time or ahead-of-time compilation. GraalVM includes a high performance Java compiler, itself called Graal, which can be used in the HotSpot VM.

A.2.2. A Brief History of Java

James Gosling, Mike Sheridan, and Patrick Naughton initiated the Java language project in June 1991. Java was originally designed for interactive television, but it was too advanced for the digital cable television industry at the time. The language was initially called Oak after an oak tree that stood outside Gosling's office. Later, the project went by the name Green and was finally renamed Java, from Java coffee. Gosling designed Java with a C/C++-style syntax that system and application programmers would find familiar. Sun Microsystems released the first public implementation as Java 1.0 in 1996. Following Oracle Corporation's acquisition of Sun Microsystems in 2009–10, Oracle has described itself as the "*steward of Java technology*" since then.^[73]

A.2.3. Installing the JDK on macOS

To install the JDK 11.0.8, go to the official website, select the appropriate platform and language, and download the distribution.^[74] For example, on macOS, download the file `jdk-11.0.8_osx-x64_bin.dmg` shown in Figure 30 (you should check out the *Accept License Agreement* check box before hitting the download link to let the download start). If you are not on Mac, the download steps are still pretty similar.

Java SE Development Kit 11.0.8

This software is licensed under the [Oracle Technology Network License Agreement for Oracle Java SE](#)

Product / File Description	File Size	Download
Linux Debian Package	148.77 MB	 jdk-11.0.8_linux-x64_bin.deb
Linux RPM Package	155.45 MB	 jdk-11.0.8_linux-x64_bin.rpm
Linux Compressed Archive	172.66 MB	 jdk-11.0.8_linux-x64_bin.tar.gz
macOS Installer	166.84 MB	 jdk-11.0.8_osx-x64_bin.dmg
macOS Compressed Archive	167.23 MB	 jdk-11.0.8_osx-x64_bin.tar.gz
Solaris SPARC Compressed Archive	186.49 MB	 jdk-11.0.8_solaris-sparcv9_bin.tar.gz
Windows x64 Installer	151.73 MB	 jdk-11.0.8_windows-x64_bin.exe

Figure 30. Downloading the JDK distribution

Double-click on the file `jdk-11.0.8_osx-x64_bin.dmg`. This will bring up a pop-up screen (see Figure 31), asking you to start the installation.

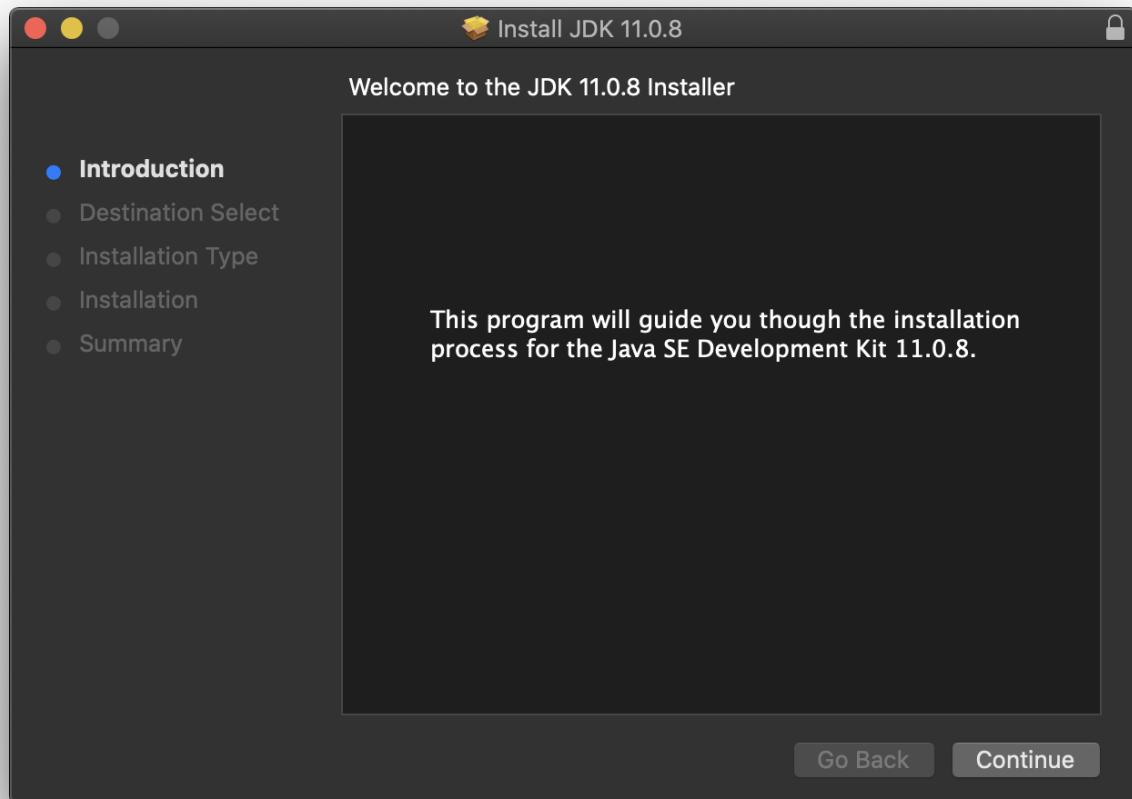


Figure 31. Installation pop-up screen

The wizard invites you to accept the licence for the software and install the JDK successfully (see [Figure 32](#)).

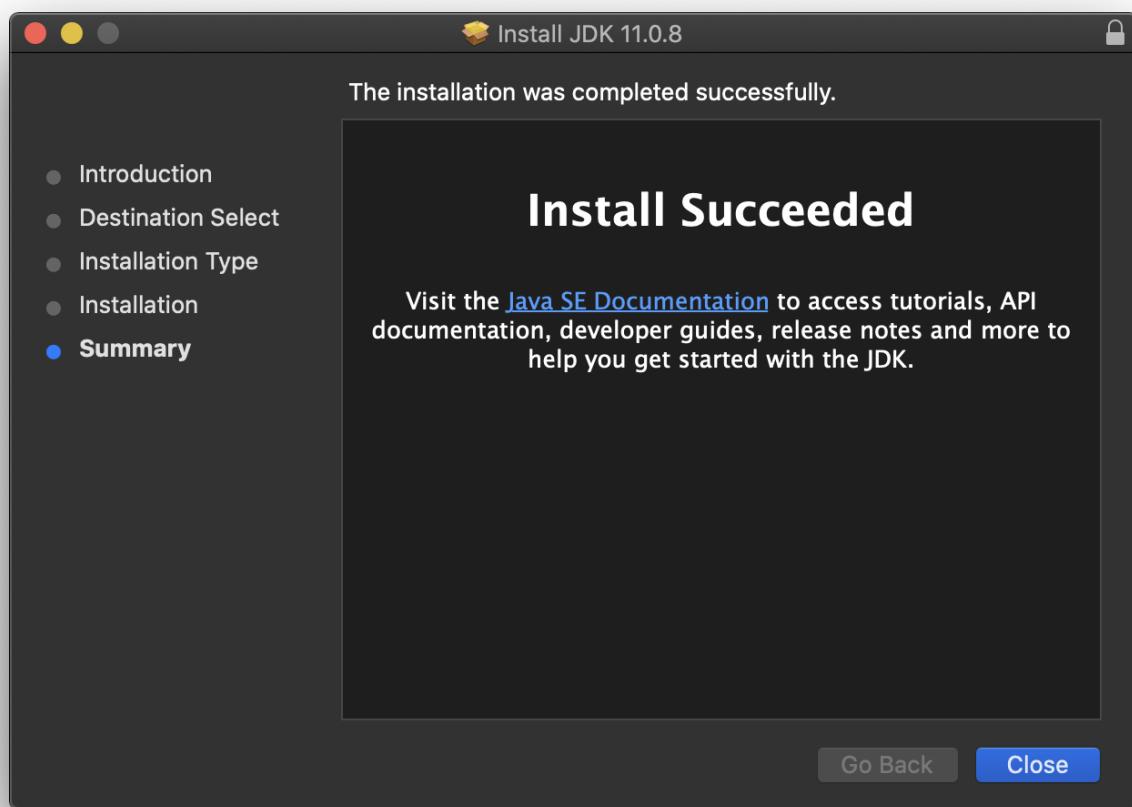


Figure 32. Successful JDK installation

There is also an easier way to install Java using Homebrew. First of all, check if you already have the Java formula installed on your machine:

```
$ brew cask list java11
Error: Cask 'java11' is not installed.
```

If the Java formula is not installed, execute the following Homebrew commands to install it:

```
$ brew tap homebrew/cask-versions
$ brew cask install java11
...
java11 was successfully installed!
```

A.2.4. Checking for Java Installation

Once the installation is complete, it is necessary to set the `JAVA_HOME` variable and the `$JAVA_HOME/bin` directory to the `PATH` variable. Check that your system recognises Java by entering `java -version` as well as the Java compiler with `javac -version`.

```

$ java -version
java version "11.0.8" 2020-07-14 LTS
Java(TM) SE Runtime Environment 18.9 (build 11.0.8+10-LTS)
Java HotSpot(TM) 64-Bit Server VM 18.9 (build 11.0.8+10-LTS, mixed mode)

$ javac -version
javac 11.0.8

```

Notice that, in the previous output, the HotSpot build is displayed. This is one easy way to know that you are using the HotSpot VM instead of the Graal VM.

A.3. GraalVM 20.2.0

GraalVM is an extension of the *Java Virtual Machine* (JVM) to support more languages and several execution modes.^[75] It is itself implemented in Java. GraalVM supports a large set of languages: Java, of course, other JVM-based languages (such as Groovy, Kotlin etc.) but also JavaScript, Ruby, Python, R and C/C++.

But it also includes a new high performance Java compiler, itself called *Graal*. Running your application inside a JVM comes with startup and footprint costs. GraalVM has a feature to create *native images* for existing JVM-based applications. The image generation process employs static analysis to find any code reachable from the main Java method and then performs full *Ahead-Of-Time* (AOT) compilation on the Substrate VM.^[76] The resulting native binary contains the whole program in machine code form for its immediate execution. This improves the performance of Java to match the performance of native languages for fast startup and low memory footprint.

HotSpot's execution engine has a *Just-in-Time* (JIT) compiler. HotSpot starts interpreting the code, the methods are compiled at the client compilation level and then finally move to the server compilation level. Even with the improvements in the compilation levels, HotSpot still starts interpreting its bytecode and then moves on to JIT-ing it.

On the other hand, the *Ahead-of-Time* (AOT) compilation improves the startup time by loading pre-compiled classes.^[77] This helps avoid running those classes in the interpreted mode or at a sub-optimised compilation level.

A.3.1. Architecture

The major differentiators of GraalVM compared to the base JDK are:

- *Sulong*: Guarantees memory safety for C/C++ and other LLVM-based languages (e.g. Fortran).
- *Truffle Framework*: A language implementation framework for creating languages and instrumentations for GraalVM (e.g. R, Ruby, Python, NodeJS, etc.).
- *Graal Compiler*: Written in Java and supports both dynamic and static compilation.
- *JVM Compiler Interface* (JVMCI): Is part of the regular JDK and allows us to plug-in additional Java compilers (such as Graal) to the JVM.
- *Java HotSpot VM*: Runtime with the GraalVM compiler enabled as the top tier JIT compiler for

JVM-based languages.

- *Substrate VM*: Allows AOT compilation for applications written in various languages.

Figure 33 depicts a high-level view of the GraalVM stack. The *Graal Compiler* is a high performance JIT compiler written in Java. It accepts the JVM bytecode and produces the machine code. It uses the new *JVM Compiler Interface* (JVMCI) to communicate with the *Java HotSpot VM*.^[78] On top of all that, you will find the *Truffle* framework that enables you to build interpreters and implementations for other languages except JVM-based languages (such as Java, Groovy or Scala). If you want to run a new programming language, you will just have to integrate it with Truffle and the framework will produce the optimised machine code for you. As you can see, there are already language implementations for R, Ruby, or JavaScript. For LLVM-based languages (e.g. C/C++, Fortran), *Sulong* guarantees memory safety.

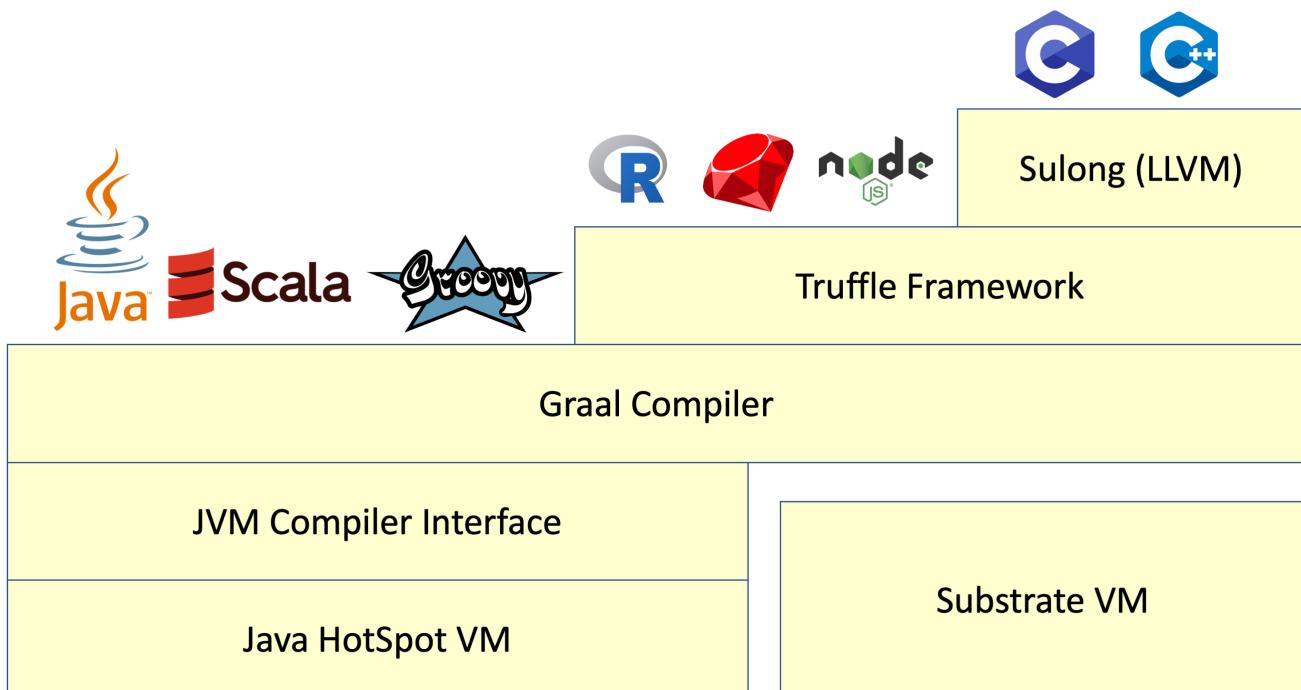


Figure 33. GraalVM architecture

GraalVM allows you to ahead-of-time compile Java code to a standalone executable, called a *native image*. This executable includes the application classes, classes from its dependencies, runtime library classes from the JDK and statically linked native code from the JDK. It does not run on the Java VM, but includes necessary components like memory management and thread scheduling from a different virtual machine, called *Substrate VM*. Substrate VM is the name for the runtime components.

A.3.2. A Brief History of GraalVM

The history of Graal dates back to the research works on *MaxineVM* in 2013, also known as a *meta-circular virtual machine* because this JVM is actually written in Java itself.^[79] Oracle invested in this research project and then released it under the name of GraalVM. GraalVM is a production-ready software and is available as a *Community Edition* (open source license) and as an *Enterprise Edition* (OTN License). Oracle Corporation announced the release of Oracle GraalVM Enterprise Edition in May 2019.

A.3.3. Installing GraalVM on macOS

GraalVM can be installed from the GraalVM web site.^[80] As shown in Figure 34, it shows two versions of GraalVM:

- *Community Edition*: Available for free for any use and built from the GraalVM sources available on GitHub.
- *Enterprise Edition*: Provides additional performance, security, and scalability relevant for running applications in production.

The screenshot shows the official GraalVM website. At the top, there is a navigation bar with links for Start, Learn, Download (which is highlighted in orange), Contribute, and social media icons for GitHub and Twitter. A GitHub star count of 13,668 is also displayed. Below the navigation bar, a brief introduction to GraalVM is provided, mentioning it's a high-performance runtime for Java, JavaScript, LLVM-based languages, and other dynamic languages, with a link to learn more.

Below this, there are three tabs: Current Release (which is selected and underlined), Annual Release, and Nightly Builds.

The main content area is divided into two sections: **GraalVM Community 20.2.0** on the left and **GraalVM Enterprise 20.2.0** on the right.

GraalVM Community 20.2.0 features:

- Details →
- Free for all purposes
- Runs any program that runs on GraalVM Enterprise
- Based on OpenJDK 8u262 and 11.0.8

DOWNLOAD FROM GITHUB button

Operating system icons for macOS, Linux, and Windows.

Release Notes → **Documentation →**

GraalVM Enterprise 20.2.0 features:

- Free for evaluation and development
- Additional performance, scalability and security
- Based on Oracle JDK 8u261 and 11.0.8

TRY FROM OTN and **BUY FROM ORACLE STORE** buttons

Operating system icons for macOS, Linux, and Windows.

Release Notes → **Documentation →**

Figure 34. Community and enterprise edition of GraalVM

Using the community edition is enough. So you will be redirected to the GitHub account of GraalVM (see Figure 35) where you can download the latest versions.^[81] Make sure you pick up version 20.2.0 and download the GraalVM file specific to your OS platform. For example, on macOS, download the file `graalvm-ce-java11-darwin-amd64-20.2.0.tar.gz` shown in Figure 35. If you are not on Mac, the download steps are still pretty similar.

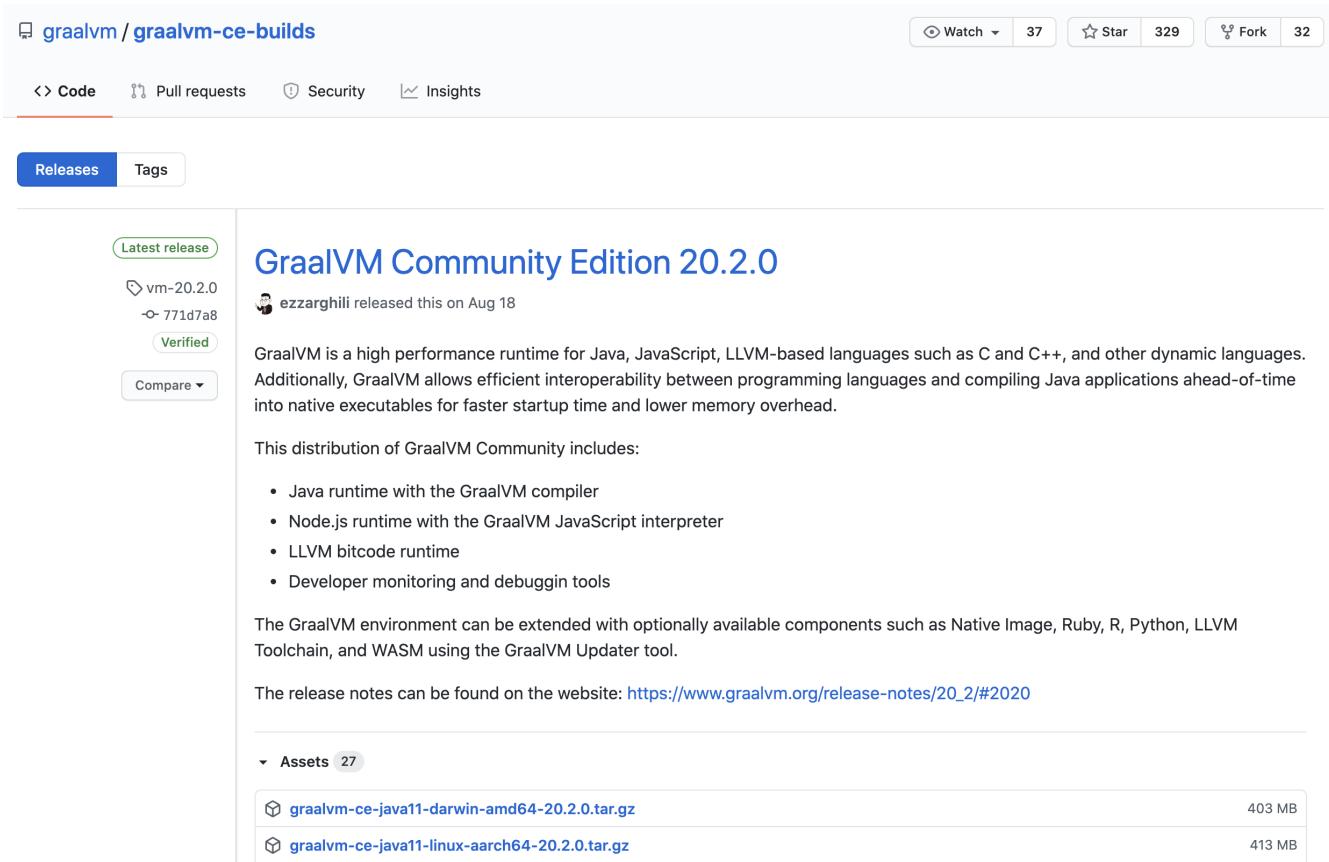


Figure 35. Download GraalVM

Double-click on the file `graalvm-ce-java11-darwin-amd64-20.2.0.tar.gz` and this will install GraalVM. Once installed, configure the `GRAALVM_HOME` environment variable to point to the directory where GraalVM is installed (e.g. on macOS it will be `/Library/Java/JavaVirtualMachines/graalvm-ce-java11-20.2.0/Contents/Home`).

A.3.4. Installing the Native Image Generator

The Native Image Generator, or `native-image`, is a utility that processes all the classes of your application and their dependencies, including those from the JDK.^[82] It statically analyses these classes to determine which classes and methods are reachable and used during application execution (a.k.a *closed-world*). Then it passes all this reachable code as the input to the GraalVM compiler which ahead-of-time compiles it to the native binary.

So we need to install the `native-image` tool. This can be done by running the following command from your GraalVM directory (inside the `bin` directory).

```
$GRAALVM_HOME/bin $ ./gu install native-image
```

A.3.5. Checking for GraalVM Installation

Once installed and setup, you should be able to run the following command and get the following output.

```
$ $GRAALVM_HOME/bin/native-image --version  
GraalVM Version 20.2.0 (Java Version 11.0.8)
```

A.4. Maven 3.6.x

All the examples of this fascicle are built and tested using Maven.^[83] Maven offers a building solution, shared libraries, and a plugin platform for your projects, allowing you to do quality control, documentation, teamwork and so forth. Based on the "*convention over configuration*" principle, Maven brings a standard project description and a number of conventions such as a standard directory structure. With an extensible architecture based on plugins, Maven can offer many different services.

A.4.1. A Brief History of Maven

Maven, created by Jason van Zyl, began as a subproject of Apache Turbine in 2002. In 2003, it was voted on and accepted as a top-level Apache Software Foundation project. In July 2004, Maven's release was the critical first milestone, v1.0. Maven 2 was declared v2.0 in October 2005 after about six months in beta cycles. Maven 3.0 was released in October 2010, being mostly backwards compatible with Maven 2.^[84]

A.4.2. Project Descriptor

Maven is based on the fact that a majority of Java projects face similar requirements when building applications. A Maven project needs to follow some standards as well as define specific features in a project descriptor, or *Project Object Model* (POM). The POM is an XML file (`pom.xml`) placed at the root of the project and contains all the metadata of the project. As shown in Listing 90, the minimum required information to describe the identity of a project is the `groupId`, the `artifactId`, the `version`, and the `packaging` type.

Listing 90. Header of a Maven Project Descriptor

```
<?xml version="1.0" encoding="UTF-8"?>  
<project xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"  
         xmlns="http://maven.apache.org/POM/4.0.0"  
         xsi:schemaLocation="http://maven.apache.org/POM/4.0.0  
                           http://maven.apache.org/xsd/maven-4.0.0.xsd">  
  
    <modelVersion>4.0.0</modelVersion>  
    <groupId>org.agoncal.fascicle</groupId>  
    <artifactId>chapter01</artifactId>  
    <version>1.0-SNAPSHOT</version>  
    <packaging>jar</packaging>  
</project>
```

A project is often divided into different artifacts. These artifacts are then grouped under the same `groupId` (similar to packages in Java) and uniquely identified by the `artifactId`. Packaging allows Maven to produce each artifact following a standard format (jar, war, ear etc.). Finally, the version

allows the identifying of an artifact during its lifetime (version 1.1, 1.2, 1.2.1 etc.). Maven imposes versioning so that a team can manage the life of its project development. Maven also introduces the concept of **SNAPSHOT** versions (the version number ends with the string **-SNAPSHOT**) to identify an artifact that is being developed and is not released yet.

The POM defines much more information about your project. Some aspects are purely descriptive (name, description etc.), while others concern the application execution such as the list of external libraries used, and so on. Moreover, the **pom.xml** defines environmental information to build the project (versioning tool, continuous integration server, artifact repositories), and any other specific process to build your project.

A.4.3. Managing Artifacts

Maven goes beyond building artifacts; it also offers a genuine approach to archive and share these artifacts. Maven uses a local repository on your hard drive (by default in **~/.m2/repository**) where it stores all the artifacts that the project's descriptor references. The local repository is filled either by the local developer's artifacts (e.g. **myProject-1.1.jar**) or by external ones (e.g. **javax.annotation-api-1.2.jar**) that Maven downloads from remote repositories.

A Maven project can reference a specific artifact including the artifact's dependencies in the POM using **groupId**, **artifactId**, **version** and **scope** in a declarative way as shown in Listing 91. If necessary, Maven will download them to the local repository from remote repositories. Moreover, using the POM descriptors of these external artifacts, Maven will also download the artifacts they need (so-called "*transitive dependencies*"). Therefore, the development team doesn't have to manually add the project dependencies to the classpath. Maven automatically adds the necessary libraries.

Listing 91. Maven Dependencies

```
<dependencies>
  <dependency>
    <groupId>org.eclipse.persistence</groupId>
    <artifactId>javax.persistence</artifactId>
    <version>2.1</version>
    <scope>provided</scope>
  </dependency>
  <dependency>
    <groupId>org.glassfish</groupId>
    <artifactId>javax.ejb</artifactId>
    <version>3.2</version>
    <scope>provided</scope>
  </dependency>
</dependencies>
```

Dependencies may have limited visibility (called scope):

- **test**: The library is used to compile and run test classes but is not packaged in the produced artifact (e.g. war file).
- **provided**: The library is provided by the environment (persistence provider, application server

etc.) and is only used to compile the code.

- **compile**: The library is necessary for compilation and execution. Therefore, it will be packaged as part of the produced artifact too.
- **runtime**: The library is only required for execution but is excluded from the compilation (e.g. Servlets).

A.4.4. Installing Maven on macOS

The examples of this fascicle have been developed with Apache Maven 3.6.x. Once you have installed the JDK 11.0.8, make sure the `JAVA_HOME` environment variable is set. Then, check if you already have the Maven formula installed on your machine:

```
$ brew list maven  
Error: No such keg: /usr/local/Cellar/maven
```

If the Maven formula is not installed, execute the following Homebrew command to install it:

```
$ brew install maven  
...  
maven was successfully installed!
```

You should now see the Maven formula in Homebrew:

```
$ brew list maven  
/usr/local/Cellar/maven/3.6.3_1/bin/mvn  
/usr/local/Cellar/maven/3.6.3_1/bin/mvnDebug  
/usr/local/Cellar/maven/3.6.3_1/bin/mvnyjp
```

A.4.5. Checking for Maven Installation

Once you've got Maven installed, open a command line and enter `mvn -version` to validate your installation. Maven should print its version and the JDK version it uses (which is handy as you might have different JDK versions installed on the same machine).

```
$ mvn -version  
  
Apache Maven 3.6.3  
Maven home: /usr/local/Cellar/maven/3.6.3_1/libexec
```

Be aware that Maven needs Internet access so it can download plugins and project dependencies from the Maven Central and/or other remote repositories.^[85] If you are behind a proxy, see the documentation to configure your settings.

A.4.6. Some Maven Commands

Maven is a command line utility where you can use several parameters and options to build, test or package your code. To get some help on the commands you can type, use the following command:

```
$ mvn --help  
usage: mvn [options] [<goal(s)>] [<phase(s)>]
```

Here are some commands that you will be using to run the examples in the fascicle. Each invokes a different phase of the project life cycle (clean, compile, install etc.) and uses the `pom.xml` to download libraries, customise the compilation, or extend some behaviours using plugins:

- `mvn clean`: Deletes all generated files (compiled classes, generated code, artifacts etc.).
- `mvn compile`: Compiles the main Java classes.
- `mvn test-compile`: Compiles the test classes.
- `mvn test`: Compiles the main Java classes as well as the test classes and executes the tests.
- `mvn package`: Compiles, executes the tests and packages the code into an archive (e.g. a war file).
- `mvn install`: Builds and installs the artifacts in your local repository.
- `mvn clean install`: Cleans and installs (note that you can add several commands separated by spaces, like `mvn clean compile test`).



Maven allows you to compile, run, and package the examples of this fascicle. It decouples the fact that you need to write your code (within an IDE) and build it. To develop you need an *Integrated Development Environment* (IDE). I use IntelliJ IDEA from JetBrains, but you can use any IDE you like because this fascicle only relies on Maven and not on specific IntelliJ IDEA features.

A.5. Testing Frameworks

A.5.1. JUnit 5.x

All the examples of this fascicle are tested using JUnit 5.x. JUnit is an open source framework to write and run repeatable tests.^[86] JUnit features include: assertions for testing expected results, fixtures for sharing common test data, and runners for running tests.

JUnit is the de facto standard testing library for the Java language, and it stands in a single jar file that you can download from <https://junit.org/junit5> (or use Maven dependency management, which we do in this fascicle). The library contains a complete API to help you write your unit tests and execute them. Unit and integration tests help your code to be more robust, bug free, and reliable. Coming up, we will go through the above features with some examples but before that, let's have a quick overview of JUnit's history.



The code in this appendix can be found at <https://github.com/agoncal/agoncal-fascicle-commons/tree/master/junit>

A Brief History of JUnit

JUnit was originally written by Erich Gamma and Kent Beck in 1998. It was inspired by Smalltalk's SUnit test framework, also written by Kent Beck. It quickly became one of the most popular frameworks in the Java world. JUnit took an important step in achieving test-driven development (TDD). Let's see some of the JUnit features through a simple example.

Writing Tests

[Listing 92](#) represents a `Customer` POJO. It has some attributes, including a date of birth, constructors, getters, and setters. It also provides two utility methods to clear the date of birth and to calculate the age of the customer (`calculateAge()`).

Listing 92. A Customer Class

```
public class Customer {  
  
    private Long id;  
    private String firstName;  
    private String lastName;  
    private String email;  
    private String phoneNumber;  
    private LocalDate dateOfBirth;  
    private Integer age;  
  
    // Constructors, getters, setters  
  
    public void calculateAge() {  
        if (dateOfBirth == null) {  
            age = null;  
            return;  
        }  
  
        age = Period.between(dateOfBirth, LocalDate.now()).getYears();  
    }  
  
    public void clear() {  
        this.dateOfBirth = null;  
    }  
}
```

The `calculateAge()` method uses the `dateOfBirth` attribute to set the customer's age. It has some business logic and we want to make sure the algorithm calculates the age accurately. We want to test this business logic. For that, we need a test class with some JUnit test methods and assertions.

Test Class

In JUnit, test classes do not have to extend anything. To be executed as a test case, a JUnit class needs at least one method annotated with `@Test`. If you write a class without at least one `@Test` method, you will get an error when trying to execute it (`java.lang.Exception: No runnable methods`). Listing 93 shows the `CustomerTest` class that initialises the `Customer` object.

Listing 93. A Unit Test Class for Customer

```
public class CustomerTest {  
  
    private Customer customer = new Customer();
```

Fixtures

Fixtures are methods to initialise and release any common object during tests. JUnit uses `@BeforeEach` and `@AfterEach` annotations to execute code before or after each test. These methods can be given any name (`clearCustomer()` in Listing 94), and you can have multiple methods in one test class. JUnit uses `@BeforeAll` and `@AfterAll` annotations to execute specific code only once, before or after the test suite is executed. These methods must be unique and static. `@BeforeAll` and `@AfterAll` can be very useful if you need to allocate and release expensive resources.

Listing 94. Fixture Executed Before Each Test

```
@BeforeEach  
public void clearCustomer() {  
    customer.clear();  
}
```

Test Methods

A test method must use the `@Test` annotation, return `void`, and take no parameters. This is controlled at runtime and throws an exception if not respected. In Listing 95, the test method `ageShouldBeGreater ThanZero` creates a new `Customer` and sets a specific date of birth. Then, using the assertion mechanism of JUnit (explained in the next section), it checks that the calculated age is greater than zero.

Listing 95. Method Testing Age Calculation

```
@Test  
public void ageShouldBeGreater ThanZero() {  
    customer = new Customer("Rita", "Navalhas", "rnavalhas@gmail.com");  
    customer.setDateOfBirth(LocalDate.of(1975, 5, 27));  
  
    customer.calculateAge();  
  
    assertTrue(customer.getAge() >= 0);  
}
```

JUnit also allows us to check for exceptions. In [Listing 96](#), we are trying to calculate the age of a null customer object so the call to the `calculateAge()` method should throw a `NullPointerException`. If it does, then the test succeeds. If it doesn't, or if it throws a different type of exception than the one declared, the test fails.

Listing 96. Method Testing Nullity

```
@Test  
public void shouldThrowAnExceptionCauseDateOfBirthIsNull() {  
  
    customer = null;  
    assertThrows(NullPointerException.class, () -> {  
        customer.calculateAge();  
    });  
}
```

[Listing 97](#) does not implement the `shouldCalculateOldAge` method. However, you don't want the test to fail; you just want to ignore it. You can add the `@Disable` annotation next to the `@Test` annotation. JUnit will report the number of disabled tests, along with the number of tests that succeeded and failed. Note that `@Disable` takes an optional parameter (a `String`) in case you want to record why a test is being disabled.

Listing 97. Disabling a Method for Testing

```
@Test  
@Disabled("Test is not ready yet")  
public void shouldCalculateOldAge() {  
    // some work to do  
}
```

JUnit Assertions

Test cases must assert that objects conform to an expected result such as in [Listing 95](#) where we assert that the age is greater than zero. For that, JUnit has an `Assertions` class that contains several methods. In order to use different assertions, you can either use the prefixed syntax (e.g. `Assertions.assertEquals()`) or import the `Assertions` class statically. [Listing 98](#) shows a simplified subset of the methods defined in the `Assertions` class.

Listing 98. Subset of JUnit Assertions

```
public class Assertions {  
  
    void assertTrue(boolean condition) { }  
    void assertFalse(boolean condition) { }  
  
    void assertNull(Object actual) { }  
    void assertNotNull(Object actual) { }  
  
    void assertEquals(Object expected, Object actual) { }  
    void assertNotEquals(Object unexpected, Object actual) { }  
  
    void assertArrayEquals(Object[] expected, Object[] actual) { }  
    void assertLinesMatch(List<String> expectedLines, List<String> actualLines) { }  
  
    void assertSame(Object expected, Object actual) { }  
    void assertNotSame(Object unexpected, Object actual) { }  
    void assertAll(Collection<Executable> executables) { }  
    void assertTimeout(Duration timeout, Executable executable) { }  
  
    <T extends Throwable> T assertThrows(Class<T> expectedType, Executable exec) { }  
}
```

Executing Tests

JUnit is very well integrated with most IDEs (IntelliJ IDEA, Eclipse, NetBeans etc.). When working with these IDEs, in most cases, JUnit highlights in green to indicate successful tests and in red to indicate failures. Most IDEs also provide facilities to create test classes.

JUnit is also integrated with Maven through the Surefire plugin used during the test phase of the build life cycle.^[87] It executes the JUnit test classes of an application and generates reports in XML and text file formats. That's mostly how we will be using JUnit in this fascicle: through Maven. To integrate JUnit in Maven, you just need the JUnit dependency and make sure to declare the Surefire plugin in the `pom.xml` as shown in Listing 99.

Listing 99. JUnit Dependencies in a Maven pom.xml

```
<dependencies>
  <dependency>
    <groupId>org.junit.jupiter</groupId>
    <artifactId>junit-jupiter-engine</artifactId>
    <version>5.6.0</version>
    <scope>test</scope>
  </dependency>
</dependencies>

<build>
  <plugins>
    <plugin>
      <groupId>org.apache.maven.plugins</groupId>
      <artifactId>maven-surefire-plugin</artifactId>
      <version>2.22.2</version>
    </plugin>
  </plugins>
</build>
```

The following Maven command runs the JUnit tests through the Surefire plugin:

```
$ mvn test
```

Then JUnit executes the tests and gives the number of executed tests, the number of failures and the number of disabled tests (through warnings).

```
[INFO] -----
[INFO] Building Commons :: JUnit
[INFO] -----
[INFO]
[INFO] --- maven-compiler-plugin:3.7.0:compile (default-compile)
[INFO]
[INFO] --- maven-surefire-plugin:2.22.2:test (default-test)
[INFO]
[INFO] -----
[INFO] T E S T S
[INFO] -----
[INFO] Running org.agoncal.fascicle.common.junit.CustomerTest
[WARNING] Tests run: 3, Failures: 0, Errors: 0, Skipped: 1, Time elapsed: 0.032 s
[INFO]
[INFO] Results:
[INFO]
[WARNING] Tests run: 3, Failures: 0, Errors: 0, Skipped: 1
[INFO]
[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
[INFO] Total time: 1.824 s
[INFO] Finished at: 2020-03-04T11:51:34+01:00
[INFO] -----
```

A.5.2. REST Assured 4.1.x

All the examples of this fascicle containing REST resources are tested using REST Assured 4.1.x. REST Assured is an open source Java library that provides a *Domain Specific Language* (DSL) for writing powerful and maintainable tests for RESTful APIs.^[88] It supports POST, GET, PUT, DELETE, OPTIONS, PATCH and HEAD requests and can be used to validate and verify the response of these requests.

[Listing 100](#) uses REST Assured to execute an HTTP GET on a resource and check that the return code is 200.

Listing 100. Simple HTTP GET Test

```
given().
when()
    .get("/customers").
then()
    .statusCode(200);
```

[Listing 101](#) and [Listing 100](#) are quite similar. [Listing 101](#) uses the REST Assured DSL to pass certain parameters to the HTTP GET such as the **ACCEPT** header.

Listing 101. HTTP GET Test Given Certain Parameters

```
given()
    .baseUri("http://localhost:8081")
    .header(ACCEPT, APPLICATION_JSON).
when()
    .get("/customers").
then()
    .statusCode(200);
```

As you can see in [Listing 102](#), REST Assured can then help to easily make the GET request and verify the response as well as its content (thanks to the `body()` method).

Listing 102. HTTP GET Test Checking Response Body

```
given()
    .pathParam("id", 1L).
when()
    .get("/customers/{id}").
then()
    .statusCode(200)
    .contentType(APPLICATION_JSON)
    .body("first-name", is("John"))
    .body("last-name", is("Lennon"));
```

[Listing 103](#) shows how to invoke an HTTP POST passing a `Customer` object and then check that the response code is a `201` (created).

Listing 103. HTTP POST Test Passing a Body

```
Customer customer = new Customer().firstName("John").lastName("Lennon");

given()
    .body(customer)
    .header(CONTENT_TYPE, APPLICATION_JSON)
    .header(ACCEPT, APPLICATION_JSON).
when()
    .post("/customers").
then()
    .statusCode(201);
```

A.5.3. Hamcrest 2.2.x

Hamcrest is a framework for writing matcher objects allowing "match" rules to be defined declaratively.^[89] When writing tests it is sometimes difficult to get the balance right between overspecifying the test, and not specifying enough. Hamcrest allows you to pick out precisely the aspect being tested and to describe the values it should have.

[Listing 104](#) shows a very simple JUnit test. Instead of using JUnit's `assertEquals()` methods, we use

Hamcrest's `assertThat` construct and the standard set of matchers, both of which we statically import.

Listing 104. Simple Hamcrest Assertion

```
import static org.hamcrest.MatcherAssert.assertThat;
import static org.hamcrest.Matchers.equalTo;

class BookTest {

    @Test
    public void shouldTestEquals() {
        Book oneBook = new Book("H2G2");
        Book anotherBook = new Book("H2G2");
        assertThat(oneBook, equalTo(anotherBook));
    }
}
```

The `assertThat()` method is a stylized sentence for making a test assertion. You can write simple assertions that are easy to read such as:

```
assertThat(book.getTitle(), equalTo("H2G2"));
assertThat(book.getYearOfPublication(), equalTo(1979));
assertThat(book, equalTo(anotherBook));
```

If you want to be even more expressive, you can use some sugar syntax. For example, Hamcrest has a `is` matcher that doesn't add any extra behaviour to the underlying matcher. So the following assertions are equivalent to the previous ones:

```
assertThat(book.getTitle(), is(equalTo("H2G2")));
assertThat(book.getYearOfPublication(), is(equalTo(1979)));
assertThat(book, is(anotherBook));
assertThat(book.getTitle(), is(not(nullValue())));
assertThat(book.getIsbn10(), is(nullValue()));
assertThat(book.getNbOfPages(), is(greaterThan(100)));
```

Hamcrest comes with a library of useful matchers. [Table 28](#) shows some of the most important ones.

Table 28. Main Hamcrest Matchers

Matchers	Description
<code>anything</code>	Always matches, useful if you don't care what the object under test is
<code>is</code>	Decorator to improve readability
<code>allOf</code>	Matches if all matchers match (like Java <code>&&</code>)

Matchers	Description
<code>anyOf</code>	Matches if any matchers match (like Java <code> </code>)
<code>not</code>	Matches if the wrapped matcher doesn't match and vice versa
<code>equalTo</code>	Tests object equality using <code>Object.equals()</code>
<code>notNullValue, nullValue</code>	Tests for null
<code>greaterThan,</code> <code>greaterThanOrEqualTo, lessThan,</code> <code>lessThanOrEqualTo</code>	Tests ordering
<code>equalToIgnoringCase</code>	Tests string equality ignoring case
<code>equalToIgnoringWhiteSpace</code>	Tests string equality ignoring differences in runs of whitespace
<code>containsString, endsWith,</code> <code>startsWith</code>	Tests string matching

A.5.4. TestContainers 1.13.x

TestContainers is a Java library that supports JUnit tests, providing lightweight, throwaway instances of common Docker images.^[90] It allows us to use Docker containers within our tests. For example, it can use a containerized instance of a PostgreSQL database to test a data access layer but without requiring a complex setup on the developer's machine. The pre-requisites of using TestContainers are to have Docker installed and to use a supported JVM testing framework (such as JUnit or TestNG).

Let's say our application uses PostgreSQL as a relational database and we want to run some tests with a running PostgreSQL. With TestContainers it's easy to make such a test. As you can see in Listing 105, JUnit integration is provided by means of the `@Testcontainers` annotation. This extension finds all fields that are annotated with `@Container` and calls their container life cycle methods. Containers declared as static fields will be shared between test methods. They will be started only once before any test method is executed and stopped after the last test method has executed. Containers declared as instance fields will be started and stopped for every test method.

Listing 105. PostgreSQL TestContainer Test

```
@Testcontainers
public class PingPostgreSQLTest {

    @Container
    public static PostgreSQLContainer pg = new PostgreSQLContainer<>("postgres:12.4")
        .withDatabaseName("vintageStoreDB")
        .withUsername("vintage")
        .withPassword("vintage")
        .withExposedPorts(5432);

    @Test
    public void shouldPingPostgreSQL() throws Exception {
        pg.start();

        try (Connection con = DriverManager.getConnection(pg.getJdbcUrl(), pg.getUsername(),
            pg.getPassword());
            Statement st = con.createStatement();
            ResultSet rs = st.executeQuery("SELECT VERSION())) {
            if (rs.next()) {
                assertTrue(rs.getString(1).contains("PostgreSQL 12"));
            } else {
                throw new Exception();
            }
        }

        pg.stop();
    }
}
```

Testcontainers will try to connect to a Docker daemon. So, to execute the test in [Listing 105](#), make sure Docker is up and running. If that's not the case, you will get the following exception:

```
IllegalStateException: Could not find a valid Docker environment.
```

With Docker up and running, TestContainers will first download the PostgreSQL image from Docker Hub if not available locally on your machine. Then, it starts the PostgreSQL container, executes the test, and stops the PostgreSQL container.^[91] The output looks like this:

```
INFO --- maven-surefire-plugin:test @ testcontainers ---
-----
T E S T S
-----
Running org.agoncal.fascicle.PingPostgreSQLTest

INFO Accessing docker with local Unix socket
INFO Found Docker environment with local Unix socket
INFO Docker host IP address is localhost
INFO Connected to docker:
INFO Checking the system...

INFO [postgres] - Pulling docker image: postgres. Please be patient;
INFO [postgres] - Starting to pull image
INFO [postgres] - Pulling image layers: 0 pending, 0 downloaded, 0 extracted
INFO [postgres] - Pulling image layers: 13 pending, 1 downloaded, 0 extracted
INFO [postgres] - Pulling image layers: 10 pending, 4 downloaded, 0 extracted
INFO [postgres] - Pulling image layers: 7 pending, 7 downloaded, 2 extracted
INFO [postgres] - Pulling image layers: 6 pending, 8 downloaded, 3 extracted

INFO [postgres] - Creating container for image: postgres
INFO [postgres] - Starting container with ID: 77a1669fe4bb3f7f
INFO [postgres] - Container postgres is starting: 77a1669fe4bb3f7f
INFO [postgres] - Container postgres started

Tests run: 1, Failures: 0, Errors: 0, Skipped: 0
INFO -----
INFO BUILD SUCCESS
INFO -----
```

A.6. cURL 7.x

To invoke the REST Web Services described in this fascicle, we often use cURL.

cURL is a command-line tool for transferring files with url syntax via protocols such as HTTP, FTP, SFTP, SCP, and many more.^[92] It is free, open source (available under the MIT Licence) and has been ported to several operating systems. You can send HTTP commands, change HTTP headers, and so on. It is a good tool for simulating a user's actions at a web browser.

A.6.1. A Brief History of cURL

cURL was first released in 1997. The name stands for *Client URL*, that's why you can stumble on the spelling *cURL* instead of *Curl* or *CURL*. The original author and lead developer is the Swedish developer Daniel Stenberg.^[93]

A.6.2. Installing cURL on macOS

Usually macOS already provides cURL and installing another version in parallel can cause all kinds

of trouble. So first, double check if cURL is already installed just by executing the following cURL command:

```
$ curl --version
```

If cURL is not installed, then it is just a matter of installing it with a single Homebrew command:

```
$ brew install curl
```

A.6.3. Checking for cURL Installation

Once installed, check for cURL by running `curl --version` in the terminal. It should display cURL version:

```
$ curl --version
```

```
curl 7.54.0 (x86_64-apple-darwin18.0) libcurl/7.54.0 LibreSSL/2.6.5 zlib/1.2.11
nghttp2/1.24.1
Protocols: dict file ftp ftps gopher http https imap imaps ldap ldaps pop3 pop3s rtsp
smb smbs smtp smtps telnet tftp
Features: AsynchDNS IPv6 Largefile GSS-API Kerberos SPNEGO NTLM NTLM_WB SSL libz HTTP2
UnixSockets HTTPS-proxy
```

A.6.4. Some cURL Commands

cURL is a command line utility where you can use several parameters and options to invoke URLs. You invoke `curl` with zero, one or several command lines and a URL (or set of URLs) to which the data should be transferred. cURL supports over two hundred different options and I would recommend reading the documentation for more help.^[94] To get some help on the commands and options, you can use the following command:

```
$ curl --help
```

```
Usage: curl [options...] <url>
```

You can also opt to use `curl --manual` which will output the entire man page for cURL plus an appended tutorial for the most common use cases.

Here are some sample cURL commands that you will be using to invoke the RESTful web service examples in this fascicle.

- `curl http://localhost:8080/authors`: HTTP GET on a given URL.
- `curl -X GET http://localhost:8080/authors`: Same effect as the previous command, an HTTP GET on a given URL.

- `curl -v http://localhost:8080/authors`: HTTP GET on a given URL with verbose mode on.
- `curl -H 'Content-Type: application/json' http://localhost:8080/authors`: HTTP GET on a given URL passing the JSON Content Type in the HTTP Header.
- `curl -X DELETE http://localhost:8080/authors/1`: HTTP DELETE on a given URL.

A.6.5. Formatting the cURL JSON Output with JQ

Very often when using cURL to invoke a RESTful web service, we get some JSON payload in reply. cURL does not format this JSON, so you will get a flat String such as:

```
$ curl http://localhost:8080/vintage-store/artists
[{"id": "1", "firstName": "John", "lastName": "Lennon"}, {"id": "2", "firstName": "Paul", "lastName": "McCartney"}, {"id": "3", "firstName": "George", "lastName": "Harrison"}, {"id": "4", "firstName": "Ringo", "lastName": "Starr"}]
```

But what we really want is to format the JSON payload to make it easier to read. For that, there is a neat utility tool called jq. It is a tool for processing JSON inputs, applying the given filter on them and producing the filtered results as JSON on standard output.^[95] You can install it on macOS with a simple `brew install jq`. Once installed, it's just a matter of piping the cURL output to jq like this:

```
$ curl http://localhost:8080/vintage-store/artists | jq
[
  {
    "id": "1",
    "firstName": "John",
    "lastName": "Lennon"
  },
  {
    "id": "2",
    "firstName": "Paul",
    "lastName": "McCartney"
  },
  {
    "id": "3",
    "firstName": "George",
    "lastName": "Harrison"
  },
  {
    "id": "4",
    "firstName": "Ringo",
    "lastName": "Starr"
  }
]
```

A.7. Docker

Docker is a set of platform-as-a-service (PaaS) products that use OS-level virtualisation to deliver software.^[96] It makes it easier to create, deploy and run applications by using containers. Containers are isolated from one another and bundle their own software, libraries and configuration files; they can communicate with each other through well-defined channels. Containers allow developers to package an application with all its dependencies and ship it all out as one package.

A.7.1. A Brief History of Docker

Docker was founded by Solomon Hykes and Sebastien Pahl during the Y Combinator Summer 2010 startup incubator group and launched in 2011.^[97] Hykes started the Docker project in France as an internal project within dotCloud (a Platform-as-a-Service company). Docker debuted to the public in Santa Clara at PyCon in 2013. It was released as open source in March 2013. At the time, it used LXC as its default execution environment. One year later, with the release of version 0.9, Docker replaced LXC with its own component, which was written in the Go programming language.

A.7.2. Installing Docker on macOS

The infrastructure in this fascicle uses Docker to ease the installation of the different technical services (database, monitoring...). So for this, we need to install `docker` and `docker-compose`. First of all, check if you already have the Docker formula installed on your machine:

```
$ brew cask list docker  
Error: Cask 'docker' is not installed.
```

If the Docker formula is not installed, execute the following Homebrew command to install it:

```
$ brew cask install docker  
...  
docker was successfully installed!
```

You should now see the Docker formula in Homebrew:

```
$ brew cask list docker  
==> App  
/Applications/Docker.app
```

A.7.3. Checking for Docker Installation

After installing Docker, you should have both `docker` and `docker-compose` available in your `PATH`. But the command `docker` should not be able to connect to the Docker daemon. You should have the following error:

```
$ docker version
```

```
Cannot connect to the Docker daemon at unix:///var/run/docker.sock.  
Is the docker daemon running?
```

That's because you need to launch the Docker Desktop application. To do that, you can either click on the Docker.app icon located under [/Applications](#), launch it using Spotlight or execute the following command:

```
$ open -a Docker
```

On your Mac top menu bar you should see the logo of a whale. Click on it and you should see a menu that looks like [Figure 36](#).

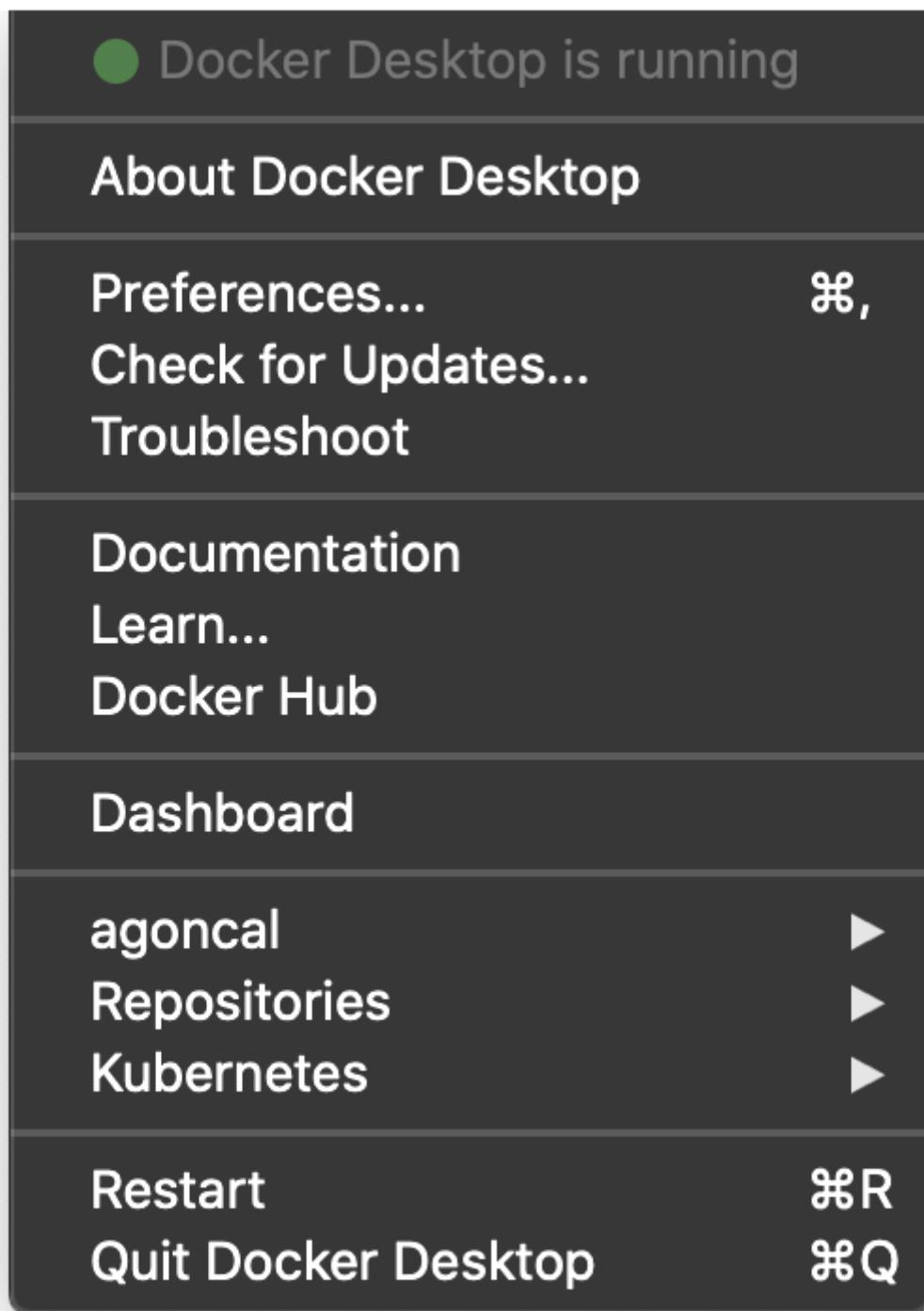


Figure 36. Docker icon on the menu bar

Click on the *About* menu, a window that looks like Figure 37 should give you the versions of the installed Docker tools.



Figure 37. About Docker desktop

Now, if you type the same Docker command, it should connect to the daemon:

```
$ docker version

Client: Docker Engine - Community
 Version:           19.03.12
 API version:        1.40
 Go version:         go1.13.10
 Git commit:         48a66213fe
 Built:              Mon Jun 22 15:41:33 2020
 OS/Arch:            darwin/amd64
 Experimental:       false

Server: Docker Engine - Community
Engine:
 Version:           19.03.12
 API version:        1.40 (minimum version 1.12)
 Go version:         go1.13.10
 Git commit:         48a66213fe
 Built:              Mon Jun 22 15:49:27 2020
 OS/Arch:            linux/amd64
 Experimental:       true
containerd:
 Version:           v1.2.13
 GitCommit:          7ad184331fa3e55e52b890ea95e65ba581ae3429
runc:
 Version:           1.0.0-rc10
 GitCommit:          dc9208a3303feef5b3839f4323d9beb36df0a9dd
docker-init:
 Version:           0.18.0
 GitCommit:          fec3683
```

You can check that Docker Compose is also working:

```
$ docker-compose version

docker-compose version 1.26.2, build eefe0d31
docker-py version: 4.2.2
CPython version: 3.7.7
OpenSSL version: OpenSSL 1.1.1g  21 Apr 2020
```

Finally, you can run your first container. The `docker container run` command will execute a container that is located on your computer. If not, it will pull the image from the Docker Hub registry and then execute it.^[98] That's what happens when you execute an image for the very first time.

Below, the `docker container run` method wants to execute the Docker image called `hello-world`. It doesn't find it locally, therefore it pulls the image from the default Docker Hub registry: https://hub.docker.com/_/hello-world. Then it executes it:

```
$ docker container run hello-world  
  
Unable to find image 'hello-world:latest' locally  
latest: Pulling from library/hello-world  
Pull complete  
Status: Downloaded newer image for hello-world:latest  
  
Hello from Docker!  
This message shows that your installation appears to be working correctly.  
  
To generate this message, Docker took the following steps:  
1. The Docker client contacted the Docker daemon.  
2. The Docker daemon pulled the "hello-world" image from the Docker Hub.  
3. The Docker daemon created a new container from that image which runs the  
   executable that produces the output you are currently reading.  
4. The Docker daemon streamed that output to the Docker client, which sent it  
   to your terminal.  
  
To try something more ambitious, you can run an Ubuntu container with:  
$ docker run -it ubuntu bash  
  
Share images, automate workflows, and more with a free Docker ID:  
https://hub.docker.com/  
  
For more examples and ideas, visit:  
https://docs.docker.com/get-started/
```

A.7.4. Building, Running, Pushing and Pulling Images

Let's now see the typical flow on how to get started on using docker images and containers. Basically you create a Dockerfile, build it into a local Docker image and run it inside a container. To make your local image available to others (external team developers but also tools such as Kubernetes), push the image to a remote Docker registry (the default one being Docker Hub). Then, if your local image has been removed, just pull it from the remote repository and execute it again.

But first, you need to create an account on a remote Docker repository. Let's take the default one: Docker Hub.

Remote Docker Repository

Docker Hub is a service provided by Docker for finding and sharing container images.^[99] It will be used to push and pull our Docker images.

To create a Docker account, sign up on <https://hub.docker.com/signup>. The name of the account is very important as it will be used to name the Docker images so they can be pushed to your remote repository (the image name and account name have to be the same). Figure 38 shows a Docker hub account called **agoncal** (you should have your own).

The screenshot shows the Docker Hub user profile for 'agoncal'. At the top, there's a navigation bar with links for 'Explore', 'Repositories', 'Organizations', 'Get Help', and a user icon. Below the navigation is a search bar with placeholder text 'Search for great content (e.g., mysql)'. The main area displays the user's profile picture, name 'agoncal', and status 'User Joined November 13, 2014'. A breadcrumb navigation 'Billing > Plan' is visible above the profile.

Figure 38. Docker hub account

Now back to your local computer. You should be able to login to your newly created Docker hub account with the following command:

```
$ docker login  
Login with your Docker ID to push and pull images from Docker Hub.  
Username: agoncal  
Password:  
Login Succeeded
```

Dockerfile

Now, let's create a very simple Dockerfile. The Dockerfile below is based on the Alpine image which is a very lightweight Linux (only 5 MB in size). Then, it uses the `echo` command to display the message *Hello Fascicle*. Take any text editor, create a file called `Dockerfile` and add the following:

```
FROM alpine  
CMD echo "Hello Fascicle"
```

This is a very simple Dockerfile that only uses two commands: `FROM` and `CMD`. But a Dockerfile is usually much richer than that and uses more commands. [Table 29](#) shows a subset of Dockerfile commands that can be used.

Table 29. Some Docker Commands

Command	Description
<code>ADD</code>	Defines files to copy from the Host file system onto the container
<code>CMD</code>	This is the command that will run when the container starts
<code>ENTRYPOINT</code>	Sets the default application used every time a container is created from the image
<code>ENV</code>	Set/modify the environment variables within containers created from the image
<code>EXPOSE</code>	Define which container ports to expose
<code>FROM</code>	Select the base image to build the new image on top of

Command	Description
USER	Define the default user all commands will be run as within any container created from your image
WORKDIR	Define the default working directory for the command defined in the <code>ENTRYPOINT</code> or <code>CMD</code> instructions

Building the Docker Image

Now, using this Dockerfile, build the Docker image using the following command:

```
$ docker image build -t agoncal/hello-fascicle .

Sending build context to Docker daemon 2.048kB
Step 1/2 : FROM alpine
Step 2/2 : CMD echo "Hello Fascicle"
Successfully built a896f9983057
Successfully tagged agoncal/hello-fascicle:latest
```

The last message of the trace indicates that the Docker image has been successfully built and is called `agoncal/hello-fascicle:latest`. Notice that the prefix `agoncal` is the name of the Docker hub account (change it accordingly to yours). To check that this image is now locally installed, type the following command:

```
$ docker image ls --filter "reference=agoncal/hello-fascicle"

REPOSITORY          TAG      IMAGE ID      SIZE
agoncal/hello-fascicle    latest    d036b3b86cd4  5.57MB
```

Running the Docker Image

Now that the image is available locally, let's execute it. The following command executes our image which echoes a message to the console:

```
$ docker container run agoncal/hello-fascicle

Hello Fascicle
```

Pushing to a Docker Registry

Now that we know that our image runs as expected, let's make it available to others by pushing it to the remote Docker registry. This is done with a simple `push` command. For consuming existing public images from Docker Hub, you don't need to be authenticated. But for publishing your own images, you need to be authenticated. The `docker image push` command assumes that you've already authenticated with the remote registry (otherwise execute `docker login` before hand):

```
$ docker image push agoncal/hello-fascicle
```

```
The push refers to repository [docker.io/agoncal/hello-fascicle]  
50644c29ef5a: Mounted from library/alpine  
latest: digest: sha256:608aa60a8d32b6b3 size: 528
```

Go back to the Docker Hub website to see the newly-pushed image. It should look like the repository shown in [Figure 39](#).

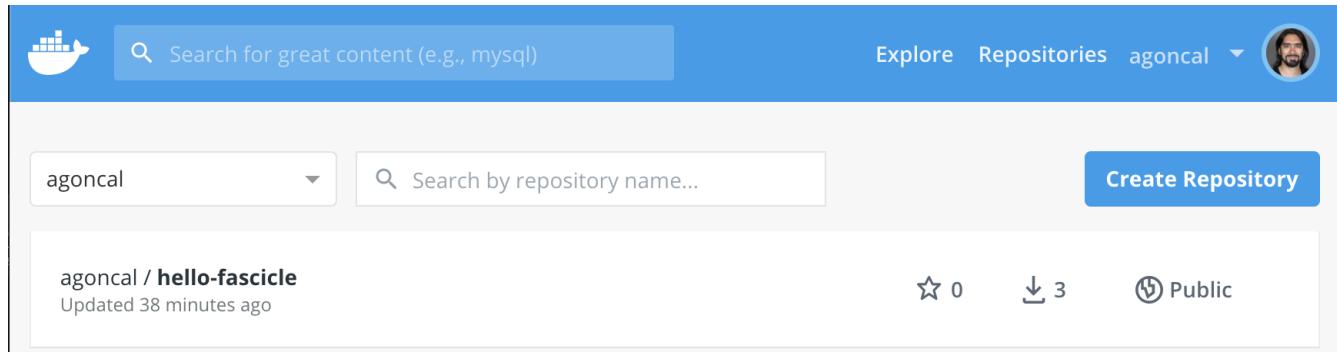


Figure 39. Docker image available on Docker Hub

Pulling from a Docker Registry

Now let's remove our image on our local system:

```
$ docker image rm agoncal/hello-fascicle -f
```

```
Untagged: agoncal/hello-fascicle:latest
Untagged: agoncal/hello-fascicle@sha256:608aa60a8d32b6b3
Deleted: sha256:d036b3b86cd4a2a82234202dac26ebbf39f8aae2
```

```
$ docker image ls --filter "reference=agoncal/hello-fascicle"
REPOSITORY          TAG           IMAGE ID      SIZE
```

The `docker image ls` command confirms that the `rm` command has been successful and that the image `agoncal/hello-fascicle` has been removed. This means that we can't execute our image anymore. Well, this is not exactly true. If we run our image again, Docker automatically downloads (pulls) the images that don't yet exist locally, creates a container, and starts it.

```
$ docker container run agoncal/hello-fascicle
```

```
Unable to find image 'agoncal/hello-fascicle:latest' locally
latest: Pulling from agoncal/hello-fascicle
df20fa9351a1: Already exists
Digest: sha256:608aa60a8d32b6b36ef595e1bf81c046bcf3504b06da787d1cbfe848e31da8db
Status: Downloaded newer image for agoncal/hello-fascicle:latest
```

```
Hello Fascicle
```

This has exactly the same effect as pulling the image first, and executing it after:

```
$ docker image pull agoncal/hello-fascicle

Using default tag: latest
latest: Pulling from agoncal/hello-fascicle
df20fa9351a1: Already exists
Digest: sha256:608aa60a8d32b6b36ef595e1bf81c046bcf3504b06da787d1cbfe848e31da8db
Status: Downloaded newer image for agoncal/hello-fascicle:latest
docker.io/agoncal/hello-fascicle:latest

$ docker container run agoncal/hello-fascicle

Hello Fascicle
```

A.7.5. Some Docker Commands

Docker is a command line utility where you can use several parameters and options to start/stop a container. You invoke `docker` with zero, one or several command-line options with the container or image ID you want to work with. Docker comes with several options that are described in the documentation if you need more help.^[100] To get some help on the commands and options, you can use the following command:

```
$ docker help

Usage: docker [OPTIONS] COMMAND

$ docker help attach

Usage: docker attach [OPTIONS] CONTAINER

Attach local standard input, output, and error streams to a running container
```

Here are some commands that you will be using to start/stop containers in this workshop.

- `docker login`: Logs into to a Docker registry.
- `docker image ls`: Lists images.
- `docker image push`: Pushes a local Docker image to the remote Docker repository.
- `docker image pull`: Pulls a Docker image from the remote Docker repository to the local repository.
- `docker container ls`: Lists containers.
- `docker container run <CONTAINER>`: Starts one or more stopped containers.
- `docker container stop <CONTAINER>`: Stops one or more running containers.
- `docker-compose -f docker-compose.yaml up -d`: Starts all containers defined in a Docker Compose file.

- `docker-compose -f docker-compose.yaml down`: Stops all containers defined in a Docker Compose file.

A.8. Git

Git is a free and open source distributed version control system designed for tracking changes in computer files and coordinating work on those files among multiple people.^[101] It is primarily used for source code management in software development, but it can be used to keep track of changes in any set of files. Git was created by Linus Torvalds in 2005 for the development of the Linux kernel, with other kernel developers contributing to its initial development.

Git is not really needed to run the samples in this fascicle. Even if the code is hosted on a public Git repository (<https://github.com/agoncal/agoncal-fascicle-quarkus-pract/tree/1.0>), you can either download the code as a zip file, or clone the repository. Only if you clone the repository will you need to have Git installed.

A.8.1. A Brief History of Git

Git development began in April 2005, after many developers in the Linux kernel gave up access to BitKeeper, a proprietary source-control management (SCM). Linus Torvalds wanted a distributed system that he could use, like BitKeeper, but none of the available free systems met his needs. So, Linus started the development of Git on 3rd April 2005, announced the project on 6th April and the first merge of multiple branches took place on 18th April. On 29th April, the nascent Git was benchmarked, recording patches to the Linux kernel tree at the rate of 6.7 patches per second.^[102]

A.8.2. Installing Git on macOS

On macOS, if you have installed Homebrew, then installing Git is just a matter of a single command.
^[103] Open your terminal and install Git with the following command:

```
$ brew install git
```

A.8.3. Checking for Git Installation

Once installed, check for Git by running `git --version` in the terminal. It should display the git version:

```
$ git --version
git version 2.25.0
```

A.8.4. Cloning Repository

Once Git is installed, you can clone the code of the repository with a `git clone` on <https://github.com/agoncal/agoncal-fascicle-quarkus-pract.git>.

[67] Homebrew <https://brew.sh>

- [68] Homebrew History [https://en.wikipedia.org/wiki/Homebrew_\(package_manager\)#History](https://en.wikipedia.org/wiki/Homebrew_(package_manager)#History)
- [69] Homebrew Cask <https://github.com/Homebrew/homebrew-cask>
- [70] Java <http://www.oracle.com/technetwork/java/javase>
- [71] Visual VM <https://visualvm.github.io>
- [72] The Java HotSpot Performance Engine Architecture <https://www.oracle.com/technetwork/java/whitepaper-135217.html>
- [73] Java History [https://en.wikipedia.org/wiki/Java_\(programming_language\)#History](https://en.wikipedia.org/wiki/Java_(programming_language)#History)
- [74] Java Website <http://www.oracle.com/technetwork/java/javase/downloads/index.html>
- [75] GraalVM <https://www.graalvm.org>
- [76] SubstrateVM <https://github.com/oracle/graal/tree/master/substratevm>
- [77] AOT JEP 295 <https://openjdk.java.net/jeps/295>
- [78] JVM Compiler Interface <https://openjdk.java.net/jeps/243>
- [79] MaxineVM <https://dl.acm.org/doi/10.1145/2400682.2400689>
- [80] GraalVM Download <https://www.graalvm.org/downloads>
- [81] GraalVM GitHub <https://github.com/graalvm/graalvm-ce-builds/tags>
- [82] Native Image <https://www.graalvm.org/docs/reference-manual/native-image>
- [83] Maven <https://maven.apache.org>
- [84] Maven History https://en.wikipedia.org/wiki/Apache_Maven#History
- [85] Maven Central <https://search.maven.org>
- [86] JUnit <https://junit.org/junit5>
- [87] Maven Surefire Plugin <https://maven.apache.org/surefire/maven-surefire-plugin>
- [88] REST Assured <http://rest-assured.io>
- [89] Hamcrest <http://hamcrest.org/JavaHamcrest>
- [90] TestContainers <https://www.testcontainers.org>
- [91] Docker Hub <https://hub.docker.com>
- [92] cURL <https://curl.haxx.se>
- [93] Daniel Stenberg https://en.wikipedia.org/wiki/Daniel_Stenberg
- [94] cURL commands <https://ec.haxx.se/cmdline.html>
- [95] jq <https://stedolan.github.io/jq>
- [96] Docker <https://www.docker.com>
- [97] Docker History [https://en.wikipedia.org/wiki/Docker_\(software\)#History](https://en.wikipedia.org/wiki/Docker_(software)#History)
- [98] <https://hub.docker.com>
- [99] Docker Hub <https://hub.docker.com>
- [100] Docker commands <https://docs.docker.com/engine/reference/commandline/cli>
- [101] Git <https://git-scm.com>
- [102] History of Git <https://en.wikipedia.org/wiki/Git#History>
- [103] Homebrew <https://brew.sh>

Appendix B: Quarkus Versions

Quarkus evolves at a fast pace. Below you will find a short recap of the latest major versions and their content. If you want to have more details on each release, you can browse the GitHub account. [\[104\]](#)

B.1. Quarkus 1.8 (*September 2020*)

Quarkus 1.8 comes with bug fixes, improvements, as well as some notable new features: [\[105\]](#)

- Multiple persistence units support for the Hibernate ORM extension
- A new Micrometer extension
- jbang integration for easy Quarkus-based scripting
- An update to GraalVM 20.2

B.2. Quarkus 1.7 (*August 2020*)

Quarkus 1.7, with more than 300 pull requests merged, was released with Elasticsearch and Redis clients, Reactive routes and Funqy improvements. [\[106\]](#) The most prominent new features are:

- New extensions for the low-level and high level Elasticsearch REST clients
- An extension for the Vert.x Redis client
- An Hibernate Envers extension
- Support for the JDBC Db2 driver
- A lot of improvements to the Reactive routes feature
- The Funqy serverless framework got some interesting new features

B.3. Quarkus 1.6 (*July 2020*)

Quarkus 1.6 released with AppCDS, Google Cloud Functions, GraalVM 20.1.0 and more. [\[107\]](#)

- Integrated generation of AppCDS archives to improve startup time in JVM mode
- Support for Google Cloud Functions - joining the existing Amazon Lambda and Azure Functions support
- Reactive IBM Db2 client (the Db2 JDBC driver is coming in 1.7)
- An Apache Cassandra client
- WebJars locator extension and Spring `@Scheduled` support
- Better tools to troubleshoot your applications
- Upgrade to GraalVM 20.1.0

B.4. Quarkus 1.5 (June 2020)

Quarkus 1.5 introduces the fast-jar packaging as an option.^[108]

- New fast-jar packaging format to bring faster startup times
- Quarkus 1.4 introduced command mode and 1.5 added a Picocli extension^[109]
- Adds gRPC extension
- Implements Eclipse MicroProfile GraphQL extension
- Supports more Amazon Services (DynamoDB, KMS, S3, SES, SNS, SQS)
- Hibernate ORM REST Data with Panache extension
- Spring Cache compatibility layer

B.5. Quarkus 1.4 (April 2020)

Quarkus 1.4 brings some major updates.^[110]

- Deprecates support for Java 8 as Java 11 is recommended
- Introduces *Command mode* (how to build command line applications with Quarkus)
- Introduces *Funqy*, the new FaaS framework, to improve function front (AWS Lambdas and Azure Functions)
- Adds support for HTTP/2
- Quarkus Security 1.1.0.Final
- Moves the Security API to Mutiny
- Improved mocking (add support for `@InjectMock` and Mockito)
- Adds support for SmallRye Reactive Messaging 2.0
- Update to SmallRye Health 2.2.0

B.6. Quarkus 1.3 (March 2020)

Quarkus 1.3 passed the TCKs of all Eclipse MicroProfile 3.3 specifications.^[111] MicroProfile 3.3 includes the following specification updates:

- Config 1.4
- Fault Tolerance 2.1
- Health 2.2
- Metrics 2.3
- REST Client 1.4

In addition to the specifications within the MicroProfile platform, Quarkus also includes implementations of Reactive Streams Operators, Reactive Messaging, and Context Propagation. This version also brings GraalVM 20.0 support and a new class loader infrastructure.^[112]

B.7. Quarkus 1.2 (*January 2020*)

Quarkus 1.2 was released with GraalVM 19.3.1 support, Metrics, Cache extension, and much more. [\[103\]](#)

- Supports three flavors of GraalVM:
 - GraalVM 19.2.1 - JDK 8
 - GraalVM 19.3.1 - JDK 8
 - GraalVM 19.3.1 - JDK 11
- Adds a brand new Cache extension
- Adds metrics for Agroal (the database connection pool) and Hibernate ORM
- New SmallRye Fault Tolerance v4.0.0 that replaces Hystrix

B.8. Quarkus 1.1 (*December 2019*)

Quarkus 1.1 released with a template engine and YAML configuration. [\[114\]](#)

- Adds Qute template engine
- YAML support for configuration file
- Adds health checks for Kafka, Kafka Streams, MongoDB, Neo4j and Artemis
- Adds Quartz extension

B.9. Quarkus 1.0 (*November 2019*)

First final version of Quarkus. [\[115\]](#)

- Creation of a Platform BOM
- Upgrades SmallRye OpenAPI and Swagger UI
- Updates to GraalVM SDK 19.2.1
- Replace usage of java.util.logging by JBoss logging
- Upgrade to Hibernate ORM 5.4.9.Final
- Quarkus HTTP 3.0.0.Final
- Quarkus Security 1.0.0.Final

B.10. Quarkus 0.0.1 (*November 2018*)

Very first commit of the Quarkus code. [\[116\]](#) Tag 0.0.1 was created. [\[117\]](#)

[104] Quarkus Releases <https://github.com/quarkusio/quarkus/releases>

[105] Quarkus 1.8 <https://quarkus.io/blog/quarkus-1-8-0-final-released>

[106] Quarkus 1.7 <https://quarkus.io/blog/quarkus-1-7-0-final-released>

[107] Quarkus 1.6 <https://quarkus.io/blog/quarkus-1-6-0-final-released>

[108] Quarkus 1.5 <https://quarkus.io/blog/quarkus-1-5-final-released>

- [109] Picocli <https://picocli.info>
- [110] Quarkus 1.4 <https://quarkus.io/blog/quarkus-1-4-final-released>
- [111] Quarkus 1.3 <https://quarkus.io/blog/quarkus-eclipse-micropattern-3-3>
- [112] Quarkus Class Loader <https://quarkus.io/guides/class-loading-reference>
- [113] Quarkus 1.2 <https://quarkus.io/blog/quarkus-1-2-0-final-released>
- [114] Quarkus 1.1 <https://quarkus.io/blog/quarkus-1-1-0-final-released>
- [115] Quarkus 1.0 <https://quarkus.io/blog/quarkus-1-0-0-Final-bits-are-here>
- [116] Quarkus 1st commit <https://github.com/quarkusio/quarkus/commit/161cfa303b4ea366dbd07e54bf4fe5a67ddec497>
- [117] Quarkus Tag 0.0.1 <https://github.com/quarkusio/quarkus/commits/0.0.1?after=1200367b8ddbe5605d8219c4994205f6c1d7af50+1084>

Appendix C: Eclipse MicroProfile Specification Versions

The MicroProfile specification evolves at a fast pace. Below you will find a short recap of the latest versions and which sub-specification has been updated for a specific version. If you want to have more details on each specification, you can browse the GitHub account.^[118]

C.1. MicroProfile 3.3 (*February 2020*)

MicroProfile 3.3 is an incremental release.^[119] It includes an update to:

- Configuration 1.4
- Fault Tolerance 2.1
- Health 2.2
- Metrics 2.3
- REST Client 1.4

C.2. MicroProfile 3.2 (*November 2019*)

MicroProfile 3.2 is an incremental release.^[120] It includes an update to:

- Metrics 2.2
- Health 2.1

C.3. MicroProfile 3.1 (*October 2019*)

MicroProfile 3.1 is an incremental release.^[121] It includes an update to:

- Health 2.1
- Metrics 2.1

C.4. MicroProfile 3.0 (*June 2019*)

MicroProfile 3.0 is a major release.^[122] It consists of:

- Eclipse MicroProfile Configuration 1.3
- Eclipse MicroProfile Fault Tolerance 2.0
- Eclipse MicroProfile Health 2.0
- Eclipse MicroProfile JWT Auth 1.1
- Eclipse MicroProfile Metrics 2.0
- Eclipse MicroProfile OpenAPI 1.1

- Eclipse MicroProfile OpenTracing 1.3
- Eclipse MicroProfile REST Client 1.3
- Context and Dependency Injection 2.0
- Common Annotations 1.3
- Java API for RESTful Web Services 2.1
- JSON Binding 1.0
- JSON Processing 1.1

C.5. MicroProfile 2.2 (*February 2019*)

MicroProfile 2.2 is an incremental release.^[123] It includes an update to:

- Fault Tolerance 2.0
- OpenAPI 1.1
- OpenTracing 1.3
- REST Client 1.2

C.6. MicroProfile 2.1 (*October 2018*)

MicroProfile 2.1 is an incremental release.^[124] It includes an update to:

- OpenTracing 1.2

C.7. MicroProfile 2.0.1 (*July 2018*)

MicroProfile 2.0.1 is a patch release to correct an issue with the JSON-B maven dependency in the `pom.xml`.^[125] The defined content for MicroProfile 2.0 did not change.

C.8. MicroProfile 2.0 (*June 2018*)

MicroProfile 2.0 is a major release since the subset of Java EE dependencies are now based on Java EE 8.^[126] It consists of:

- Eclipse MicroProfile Configuration 1.3
- Eclipse MicroProfile Fault Tolerance 1.1
- Eclipse MicroProfile Health 1.0
- Eclipse MicroProfile JWT Auth 1.1
- Eclipse MicroProfile Metrics 1.1
- Eclipse MicroProfile OpenAPI 1.0
- Eclipse MicroProfile OpenTracing 1.1
- Eclipse MicroProfile REST Client 1.1

- Context and Dependency Injection 2.0
- Common Annotations 1.3
- Java API for RESTful Web Services 2.1
- JSON Binding 1.0
- JSON Processing 1.1

C.9. MicroProfile 1.4 (*June 2018*)

MicroProfile 1.4 is an incremental release.^[127] It includes an update to:

- Configuration 1.3
- Fault Tolerance 1.1
- JWT 1.1
- OpenTracing 1.1
- REST Client 1.1

C.10. MicroProfile 1.3 (*January 2018*)

MicroProfile 1.3 is an incremental release.^[128] It includes an update to:

- Configuration 1.2
- Metrics 1.1

It adds:

- OpenAPI 1.0
- OpenTracing 1.0
- REST Client 1.0

C.11. MicroProfile 1.2 (*September 2017*)

MicroProfile 1.2 is an incremental release.^[129] It includes an update to:

- Common Annotations 1.2
- Configuration 1.1

It adds:

- Fault Tolerance 1.0
- Health 1.0
- Metrics 1.0
- JWT 1.0

C.12. MicroProfile 1.1 (August 2017)

MicroProfile 1.1 is an incremental release.^[130] It adds:

- Configuration 1.0

C.13. MicroProfile 1.0

MicroProfile 1.0 is the first major release and is based on Java EE 7 specifications. It consists of:

- Context and Dependency Injection 1.2
- Java API for RESTful Web Services 2.0
- JSON Processing 1.0

[118] MicroProfile Releases <https://github.com/eclipse/microprofile/releases>

[119] MicroProfile 3.3 <https://github.com/eclipse/microprofile/releases/tag/3.3>

[120] MicroProfile 3.2 <https://github.com/eclipse/microprofile/releases/tag/3.2>

[121] MicroProfile 3.1 <https://github.com/eclipse/microprofile/releases/tag/3.1>

[122] MicroProfile 3.0 <https://github.com/eclipse/microprofile/releases/tag/3.0>

[123] MicroProfile 2.2 <https://github.com/eclipse/microprofile/releases/tag/2.2>

[124] MicroProfile 2.1 <https://github.com/eclipse/microprofile/releases/tag/2.1>

[125] MicroProfile 2.0.1 <https://github.com/eclipse/microprofile/releases/tag/2.0.1>

[126] MicroProfile 2.0 <https://github.com/eclipse/microprofile/releases/tag/2.0>

[127] MicroProfile 1.4 <https://github.com/eclipse/microprofile/releases/tag/1.4>

[128] MicroProfile 1.3 <https://github.com/eclipse/microprofile-bom/releases/tag/1.3>

[129] MicroProfile 1.2 <https://github.com/eclipse/microprofile-bom/releases/tag/1.2>

[130] MicroProfile 1.1 <https://github.com/eclipse/microprofile-bom/releases/tag/1.1>

Appendix D: References

- Quarkus <https://quarkus.io>
- Quarkus developers' guides <https://quarkus.io/guides>
- Quarkus Super Hero Workshop <https://quarkus.io/quarkus-workshops/super-heroes>
- SmallRye <https://github.com/smallrye>
- MicroProfile <https://microprofile.io>
 - Config <https://github.com/eclipse/microprofile-config>
 - Fault Tolerance <https://github.com/eclipse/microprofile-fault-tolerance>
 - Health <https://github.com/eclipse/microprofile-health>
 - JWT <https://github.com/eclipse/microprofile-jwt-auth>
 - Metrics <https://github.com/eclipse/microprofile-metrics>
 - OpenApi <https://github.com/eclipse/microprofile-open-api>
 - OpenTracing <https://github.com/eclipse/microprofile-opentracing>
 - Reactive Messaging <https://github.com/eclipse/microprofile-reactive-messaging>
 - Reactive Streams Operators <https://github.com/eclipse/microprofile-reactive-streams-operators>
 - REST-Client <https://github.com/eclipse/microprofile-rest-client>

Appendix E: Fascicles by the Same Author

The *agoncal fascicle* series contains two types of fascicles. The *Understanding* collection is about fascicles that dive into a specific technology, explain it, and show different aspects of it as well as integrating it with other external technologies. On the other hand, the *Practising* collection is all about coding. So you are supposed to already know a little bit of this technology and be ready to code in order to build a specific application.

E.1. Understanding Bean Validation 2.0

Validating data is a common task that Java developers have to do and it is spread throughout all layers (from client to database) of an application. This common practice is time-consuming, error prone, and hard to maintain in the long run. Besides, some of these constraints are so frequently used that they could be considered standard (checking for a null value, size, range, etc.). It would be good to be able to centralise these constraints in one place and share them across layers.

That's when Quarkus comes into play.

In this fascicle, you will learn Quarkus and use its different APIs to apply constraints on a bean, validate all sorts of constraints, write your own constraints and a few advanced topics such as integrating Bean Validation with other frameworks (JPA, JAX-RS, CDI, Spring).

ISBN: 9781980399025 | ASIN B07B2KJ41R

E.2. Understanding JPA 2.2

Applications are made up of business logic, interaction with other systems, user interfaces etc. and data. Most of the data that our applications manipulate have to be stored in datastores, retrieved, processed and analysed. If this datastore is a relational database and you use an object-oriented programming language such as Java, then you might want to use an Object-Relational Mapping tool.

That's when Quarkus comes into play.

In this fascicle, you will learn Quarkus, the standard ORM that maps Java objects to relational databases. You will discover its annotations for mapping entities, as well as the Java Persistence Query Language, entity life cycle and a few advanced topics such as integrating JPA with other frameworks (Bean Validation, JTA, CDI, Spring).

ISBN: 9781093918977 | ASIN B07RWPXPS6

E.3. Understanding Quarkus

Microservices is an architectural style that structures an application as a collection of distributed services. Microservices are certainly appealing but there are many questions that should be asked prior to diving into this architectural style: How do I deal with an unreliable network in a distributed architecture? How do I test my services? How do I monitor them? How do I package and execute them?

That's when Quarkus comes into play.

In this fascicle, you will learn Quarkus but also its ecosystem. You will discover Quarkus internals and how you can use it to build REST and reactive microservices, bind and process JSON or access datastores in a transactional way. With Cloud Native and GraalVM in mind, Quarkus makes packaging and orchestrating your microservices with Docker and Kubernetes easy.

This fascicle has a good mix of theory and practical examples. It is the companion book of *Practising Quarkus* where you learn how to develop an entire microservice architecture.

E.4. Practising Quarkus

Microservices is an architectural style that structures an application as a collection of distributed services. Microservices are certainly appealing but there are many questions that should be asked prior to diving into this architectural style: How do I deal with an unreliable network in a distributed architecture? How do I test my services? How do I monitor them? How do I package and execute them?

That's when Quarkus comes into play.

In this fascicle you will develop an entire microservice application using Quarkus as well as MicroProfile. You will expose REST endpoints using JAX-RS and OpenAPI, customise the JSON output thanks to JSON-B and deal with persistence and transaction with Hibernate ORM with Panache and JTA. Having distributed microservices, you will implement health checks and add some metrics so you can monitor your microservice architecture. Finally, thanks to GraalVM you will build native executables, and package and execute them with Docker.

This fascicle is very practical. It is the companion book of the more theoretical *Understanding Quarkus* where you'll learn more about Quarkus, MicroProfile, REST and reactive microservices, as well as Cloud Native and GraalVM.

Appendix F: Printed Back Cover

This fascicle *Practising Quarkus* also has a printed version (with ISBN number 9798629562115). This is what's written on the back cover:

Antonio Goncalves is a senior software architect and Java Champion. Having been focused on Java development since the late 1990s, his career has taken him to many different countries and companies. For the last few years, Antonio has given talks at international conferences, mainly on Java, distributed systems and microservices. This fascicle stems from his extensive experience in writing books, blogs and articles.

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