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ASP.NET Core IN ACTION

SECOND EDITION

MEAP

Andrew Lock

MEAP Edition
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ASP.NET Core in Action

Second Edition

Version 5

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welcome

Thanks for purchasing the MEAP for *ASP.NET Core in Action, Second Edition*. This book has been written to take a moderately experienced C# developer, without web development experience, to being a well-round ASP.NET Core developer, ready to build your first web applications.

The genesis of ASP.NET Core goes back several years, but I first really started paying attention shortly before the release of ASP.NET Core RC2. As an ASP.NET developer for many years, the new direction and approach to development Microsoft were embracing was a breath of fresh air. No longer are Visual Studio and Windows mandated. You are now free to build and run cross-platform .NET applications on any OS, with any IDE, and using the tools that you choose.

Along with that, the entire framework is open-source, and developed with many contributions from the community. It was this aspect that drew me in initially. The ability to wade through the framework code and see how features were implemented was such a revelation (compared to the dubious documentation of old) that I was hooked!

ASP.NET Core has grown massively since its release in 2016—.NET Core 3, released in 2019, was the fastest adopted version of .NET ever. *ASP.NET Core in Action* is my attempt to get you started and productive with the latest version of the framework as soon as possible. In the first half of the book, you will work through the basics of a typical ASP.NET Core application, focusing on how to create basic web pages using Razor Pages and Web APIs using MVC controllers.

In the second half, you will build on this core knowledge, looking at more advanced requirements and how to add extra features to your application. You will learn how to secure your application behind a login screen, how to handle configuration and dependency injection, and how to deploy your application to production. In the last part of the book you will look in depth at further bending the framework to your will by creating custom components.

There’s already a lot of ground to cover in such a big framework, so I won’t be covering Blazor in this book, but I will be updating the book to cover .NET 5 before final publication. Your feedback is essential to creating the best book possible, so please be sure to post any comments, questions or suggestions you have about the book in the liveBook discussion forum. I appreciate knowing where to make improvements to ensure you can get the most out of it!

Dr Andrew Lock

brief contents

APPENDIXES

Part 1

Getting started with ASP.NET Core

Web applications are everywhere these days, from social media web apps and news sites, to the apps on your phone. Behind the scenes, there is almost always a server running a web application or an HTTP API. Web applications are expected to be infinitely scalable, deployed to the cloud, and highly performant. Getting started can be overwhelming at the best of times and doing so with such high expectations can be even more of a challenge.

The good news for you as readers is that ASP.NET Core was designed to meet those requirements. Whether you need a simple website, a complex e-commerce web app, or a distributed web of microservices, you can use your knowledge of ASP.NET Core to build lean web apps that fit your needs. ASP.NET Core lets you build and run web apps on Windows, Linux, or macOS. It's highly modular, so you only use the components you need, keeping your app as compact and performant as possible.

In part 1, you'll go from a standing start all the way to building your first web applications and APIs. Chapter 1 gives a high-level overview of ASP.NET Core, which you'll find especially useful if you're new to web development in general. You'll get your first glimpse of a full ASP.NET Core application in chapter 2, in which we look at each component of the app in turn and see how they work together to generate a response.

Chapter 3 looks in detail at the middleware pipeline, which defines how incoming web requests are processed and how a response is generated. We look at several standard pieces of middleware and see how the Razor Pages framework fits in to the pipeline. In Chapters 4 through 8 we focus on Razor Pages, which is the main approach to generate responses in ASP.NET Core apps. In chapters 4 through 6 we examine the behavior of the Razor Pages framework itself, routing, and model binding. In Chapters 7 and 8, we look at how to build the UI for your application using the Razor syntax and Tag Helpers, so that users can navigate and interact with your app. Finally, in chapter 9, we explore specific features of ASP.NET Core that let you build Web APIs, and how that differs from building UI-based applications.

There's a lot of content in part 1, but by the end, you'll be well on your way to building simple applications with ASP.NET Core. Inevitably, I gloss over some of the more complex configuration aspects of the framework, but you should get a good understanding of the Razor Pages framework and how you can use it to build dynamic web apps. In later parts of this book, we'll dive deeper into the ASP.NET Core framework, where you'll learn how to configure your application and add extra features, such as user profiles.

1

Getting started with ASP.NET Core

This chapter covers

- **What is ASP.NET Core?**
- **Things you can build with ASP.NET Core**
- **The advantages and limitations of .NET Core**
- **How ASP.NET Core works**

Choosing to learn and develop with a new framework is a big investment, so it's important to establish early on whether it's right for you. In this chapter, I provide some background about ASP.NET Core, what it is, how it works, and why you should consider it for building your web applications.

If you're new to .NET development, this chapter will help you to understand the .NET landscape. For existing .NET developers, I provide guidance on whether now is the right time to consider moving your focus to .NET Core, and the advantages ASP.NET Core can bring over previous versions of ASP.NET.

By the end of this chapter, you should have a good overview of the .NET landscape, the role of .NET Core, and the basic mechanics of how ASP.NET Core works—so without further ado, let's dive in!

1.1 An introduction to ASP.NET Core

ASP.NET Core is the latest evolution of Microsoft’s popular ASP.NET web framework, released in June 2016. Previous versions of ASP.NET have seen many incremental updates, focusing on high developer productivity and prioritizing backwards compatibility. ASP.NET Core bucks that trend by making significant architectural changes that rethink the way the web framework is designed and built.

ASP.NET Core owes a lot to its ASP.NET heritage and many features have been carried forward from before, but ASP.NET Core is a new framework. The whole technology stack has been rewritten, including both the web framework and the underlying platform.

At the heart of the changes is the philosophy that ASP.NET should be able to hold its head high when measured against other modern frameworks, but that existing .NET developers should continue to be left with a sense of familiarity. In this section I cover

- The reasons for using a web framework
- The previous ASP.NET framework’s benefits and limitations
- What ASP.NET Core is and its motivations

At the end of this section you should have a good sense of why ASP.NET Core was created, its design goals, and why you might want to use it

1.1.1 Using a web framework

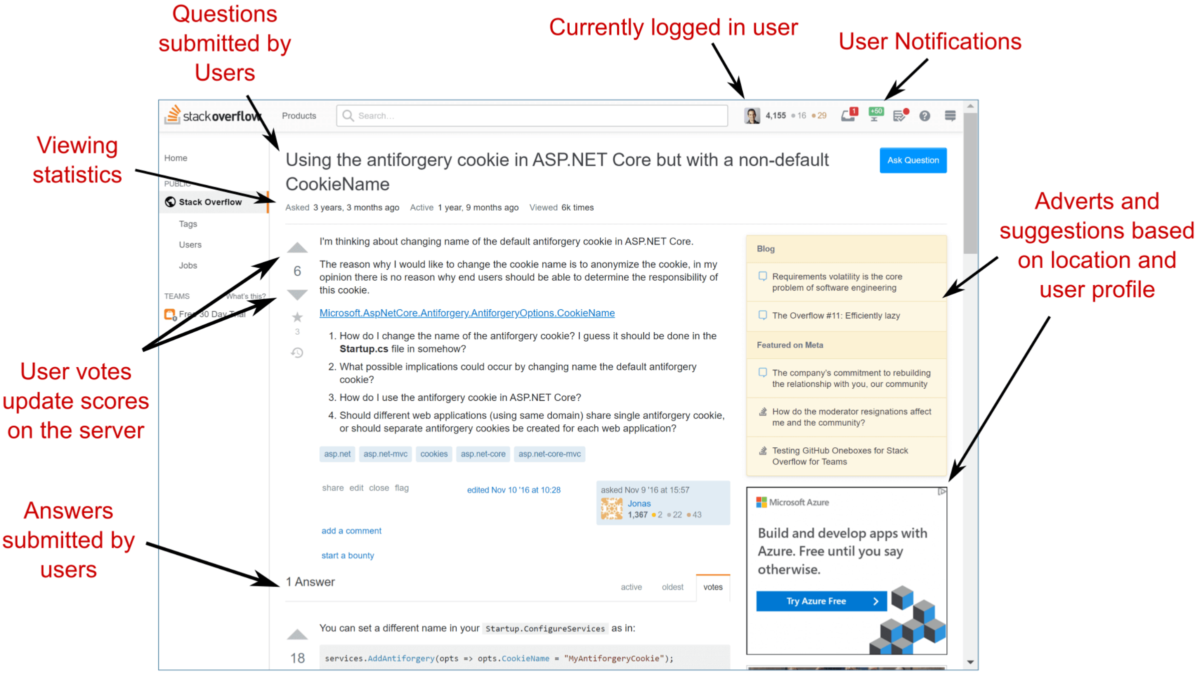
If you’re new to web development, it can be daunting moving into an area with so many buzzwords and a plethora of ever-changing products. You may be wondering if they’re all necessary—how hard can it be to return a file from a server?

Well, it’s perfectly possible to build a static web application without the use of a web framework, but its capabilities will be limited. As soon as you want to provide any kind of security or dynamism, you’ll likely run into difficulties, and the original simplicity that enticed you will fade before your eyes!

Just as you may have used desktop or mobile development frameworks for building native applications, ASP.NET Core makes writing web applications faster, easier, and more secure than trying to build everything from scratch. It contains libraries for common things like

- Creating dynamically changing web pages
- Letting users log in to your web app
- Letting users use their Facebook account to log in to your web app using OAuth
- Providing a common structure to build maintainable applications
- Reading configuration files
- Serving image files
- Logging requests made to your web app

The key to any modern web application is the ability to generate dynamic web pages. A *dynamic web page* displays different data depending on the current logged-in user, for example, or it could display content submitted by users. Without a dynamic framework, it wouldn’t be possible to log in to websites or to have any sort of personalized data displayed on a page. In short, websites like Amazon, eBay, and Stack Overflow (seen in figure 1.1) wouldn’t be possible.



Using the antiforgery cookie in ASP.NET Core but with a non-default CookieName

Asked 3 years, 3 months ago Active 1 year, 9 months ago Viewed 6k times

I'm thinking about changing name of the default antiforgery cookie in ASP.NET Core.

The reason why I would like to change the cookie name is to anonymize the cookie, in my opinion there is no reason why end users should be able to determine the responsibility of this cookie.

Microsoft.AspNetCore.Antiforgery.AntiforgeryOptions.CookieName

1. How do I change the name of the antiforgery cookie? I guess it should be done in the **Startup.cs** file in somehow?
2. What possible implications could occur by changing name the default antiforgery cookie?
3. How do I use the antiforgery cookie in ASP.NET Core?
4. Should different web applications (using same domain) share single antiforgery cookie, or should separate antiforgery cookies be created for each web application?

edited Nov 10 '16 at 10:28

asked Nov 9 '16 at 15:57
Jonas
1,367 ● 2 ● 22 ● 43

1 Answer

You can set a different name in your `Startup.ConfigureServices` as in:

```
services.AddAntiforgery(opts => opts.CookieName = "MyAntiforgeryCookie");
```

Blog

- Requirements volatility is the core problem of software engineering
- The Overflow #11: Efficiently lazy

Featured on Meta

- The company’s commitment to rebuilding the relationship with you, our community
- How do the moderator resignations affect me and the community?
- Testing GitHub Oneboxes for Stack Overflow for Teams

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The Stack Overflow website (https://stackoverflow.com) is built using ASP.NET and is almost entirely dynamic content.

1.1.2 The benefits and limitations of ASP.NET

To understand *why* Microsoft decided to build a new framework, it’s important to understand the benefits and limitations of the previous ASP.NET web framework.

The first version of ASP.NET was released in 2002 as part of .NET Framework 1.0, in response to the then conventional scripting environments of classic ASP and PHP. ASP.NET Web Forms allowed developers to rapidly create web applications using a graphical designer and a simple event model that mirrored desktop application-building techniques.

The ASP.NET framework allowed developers to quickly create new applications, but over time, the web development ecosystem changed. It became apparent that ASP.NET Web Forms suffered from many issues, especially when building larger applications. In particular, a lack of testability, a complex stateful model, and limited influence over the generated HTML (making client-side development difficult) led developers to evaluate other options.

In response, Microsoft released the first version of ASP.NET MVC in 2009, based on the Model-View-Controller pattern, a common web design pattern used in other frameworks such as Ruby on Rails, Django, and Java Spring. This framework allowed you to separate UI elements from application logic, made testing easier, and provided tighter control over the HTML-generation process.

ASP.NET MVC has been through four more iterations since its first release, but they have all been built on the same underlying framework provided by the System.Web.dll file. This library is part of .NET Framework, so it comes pre-installed with all versions of Windows. It contains all the core code that ASP.NET uses when you build a web application.

This dependency brings both advantages and disadvantages. On the one hand, the ASP.NET framework is a reliable, battle-tested platform that's fine for building web applications on Windows. It provides a wide range of features, which have seen many years in production, and is well known by virtually all Windows web developers.

On the other hand, this reliance is limiting—changes to the underlying System.Web.dll are far-reaching and, consequently, slow to roll out. This limits the extent to which ASP.NET is free to evolve and results in release cycles only happening every few years. There's also an explicit coupling with the Windows web host, Internet Information Service (IIS), which precludes its use on non-Windows platforms.

> **NOTE** More recently, Microsoft have declared .NET Framework to be "done". It won't be being removed or replaced, but it also won't be receiving any new features. Consequently ASP.NET based on System.Web.dll will not receive new features or updates either.

In recent years, many web developers have started looking at cross-platform web frameworks that can run on Windows, as well as Linux and macOS. Microsoft felt the time had come to create a framework that was no longer tied to its Windows legacy, thus ASP.NET Core was born.

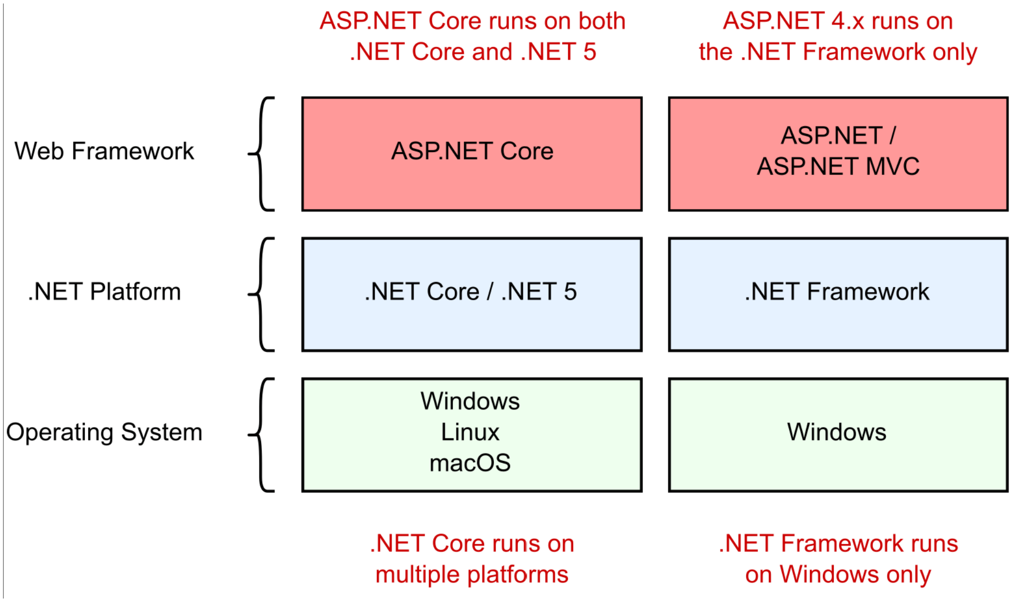
1.1.3 What is ASP.NET Core?

The development of ASP.NET Core was motivated by the desire to create a web framework with four main goals:

- To be run and developed cross-platform
- To have a modular architecture for easier maintenance
- To be developed completely as open source software
- To be applicable to current trends in web development, such as client-side applications and deploying to cloud environments

In order to achieve all these goals, Microsoft needed a platform that could provide underlying libraries for creating basic objects such as lists and dictionaries, and performing, for example, simple file operations. Up to this point, ASP.NET development had always been focused, and dependent, on the Windows-only .NET Framework. For ASP.NET Core, Microsoft created a lightweight platform that runs on Windows, Linux, and macOS called .NET Core (and subsequently .NET 5), as shown in figure 1.2.

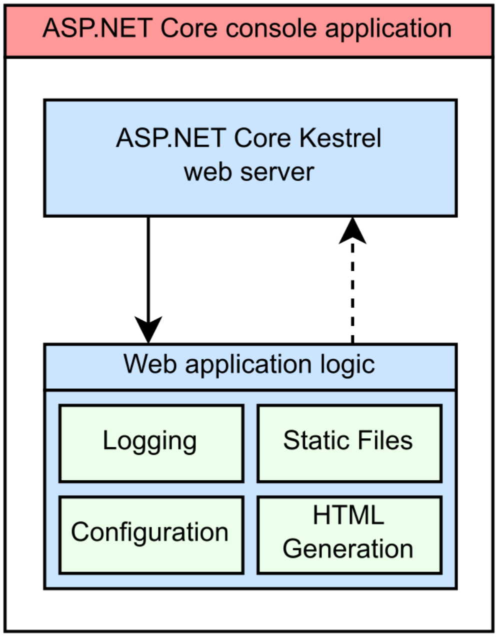
> **DEFINITION** .NET 5 is the next version of .NET Core after 3.1. It represents a unification of .NET Core and other .NET platforms into a single runtime and framework. The terms .NET Core and .NET 5 are often used interchangeably, but for consistency, I use the term .NET Core throughout this book.


ASP.NET Core runs on both .NET Core and .NET 5
ASP.NET 4.x runs on the .NET Framework only
Web Framework
ASP.NET Core
ASP.NET / ASP.NET MVC
.NET Platform
.NET Core / .NET 5
.NET Framework
Operating System
Windows
Linux
macOS
Windows
.NET Core runs on multiple platforms
.NET Framework runs on Windows only

The relationship between ASP.NET Core, ASP.NET, .NET Core, and .NET Framework. ASP.NET Core runs on .NET Core, so it can run cross-platform. Conversely, ASP.NET runs on .NET Framework only, so is tied to the Windows OS.

.NET Core shares many of the same APIs as .NET Framework, but it’s more modular, and only implements a subset of the features .NET Framework provides, with the goal of providing a simpler implementation and programming model. It’s a completely separate platform, rather than a fork of .NET Framework, though it uses similar code for many of its APIs.

With .NET Core alone, it’s possible to build console applications that run cross-platform. Microsoft created ASP.NET Core to be an additional layer on top of console applications, such that converting to a web application involves adding and composing libraries, as shown in figure 1.3.



You write a .NET Core console app that starts up an instance of an ASP.NET Core web server.

Microsoft provides a cross-platform web server by default, called Kestrel.

Your web application logic is run by Kestrel. You'll use various libraries to enable features such as logging and HTML generation as required.

The ASP.NET Core application model. The .NET Core platform provides a base console application model for running command-line apps. Adding a web server library converts this into an ASP.NET Core web app. Additional features, such as configuration and logging, are added by way of additional libraries.

By adding an ASP.NET Core web server to your .NET Core app, your application can run as a web application. ASP.NET Core is composed of many small libraries that you can choose from to provide your application with different features. You'll rarely need all the libraries available to you and you only add what you need. Some of the libraries are common and will appear in virtually every application you create, such as the ones for reading configuration files or performing logging. Other libraries build on top of these base capabilities to provide application-specific functionality, such as third-party logging-in via Facebook or Google.

Most of the libraries you'll use in ASP.NET Core can be found on GitHub, in the Microsoft ASP.NET Core organization repositories at https://github.com/dotnet/aspnetcore. You can find the core libraries here, such as the authentication and logging libraries, as well as many more peripheral libraries, such as the third-party authentication libraries.

All ASP.NET Core applications will follow a similar design for basic configuration, as suggested by the common libraries, but in general the framework is flexible, leaving you free to create your own code conventions. These common libraries, the extension libraries that build on them, and the design conventions they promote make up the somewhat nebulous term ASP.NET Core.

1.2 When to choose ASP.NET Core

Hopefully, you now have a general grasp of what ASP.NET Core is and how it was designed. But the question remains: should you use it? Microsoft is recommending that all new .NET web development should use ASP.NET Core, but switching to or learning a new web stack is a big ask for any developer or company. In this section I cover

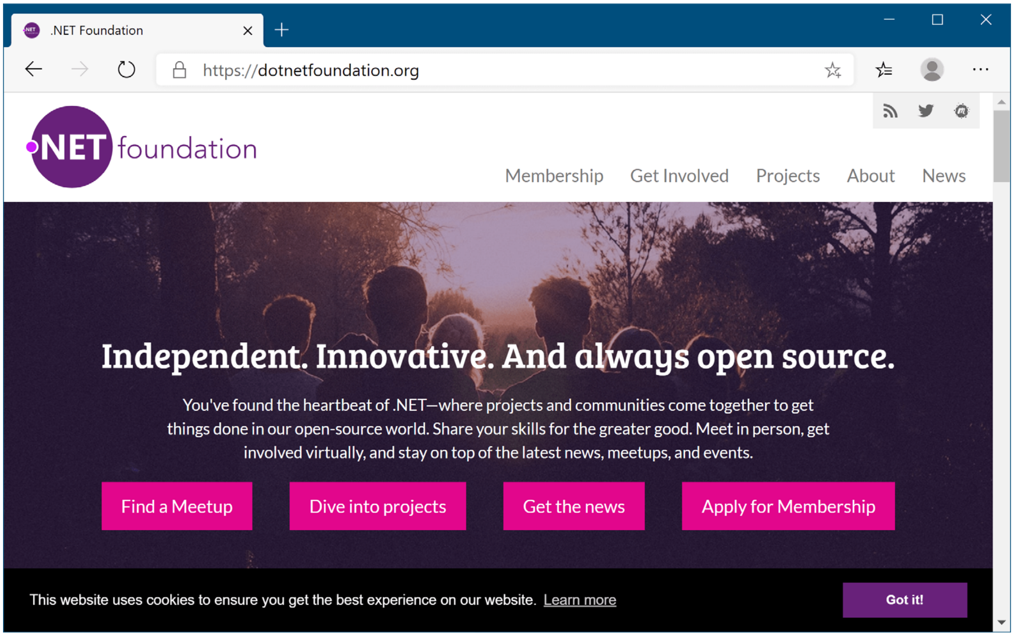
- What sort of applications you can build with ASP.NET Core
- Some of the highlights of ASP.NET Core
- Why you should consider using ASP.NET Core for new applications
- Things to consider before converting existing ASP.NET applications to ASP.NET Core

1.2.1 What type of applications can you build?

ASP.NET Core provides a generalized web framework that can be used for a variety of applications. It can most obviously be used for building rich, dynamic websites, whether they're e-commerce sites, content-based sites, or large n-tier applications—much the same as the previous version of ASP.NET.

When .NET Core was originally released, there were few third-party libraries available for building these types of complex applications. After several years of active development, that's no longer the case. Many developers have updated their libraries to work with ASP.NET Core, and many other libraries have been created to target ASP.NET Core specifically. For example, the open source content management system (CMS), Orchard[1] has been redeveloped as Orchard Core[2] to run on ASP.NET Core. In contrast, the cloudscribe[3] CMS project (figure 1.4) was written specifically for ASP.NET Core from its inception.

[1] The Orchard project (www.orchardproject.net/). Source code at https://github.com/OrchardCMS/.
[2] Orchard Core (https://www.orchardcore.net/). Source code at https://github.com/OrchardCMS/OrchardCore
[3] The cloudscribe project (https://www.cloudscribe.com/). Source code at https://github.com/cloudscribe



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You've found the heartbeat of .NET—where projects and communities come together to get things done in our open-source world. Share your skills for the greater good. Meet in person, get involved virtually, and stay on top of the latest news, meetups, and events.

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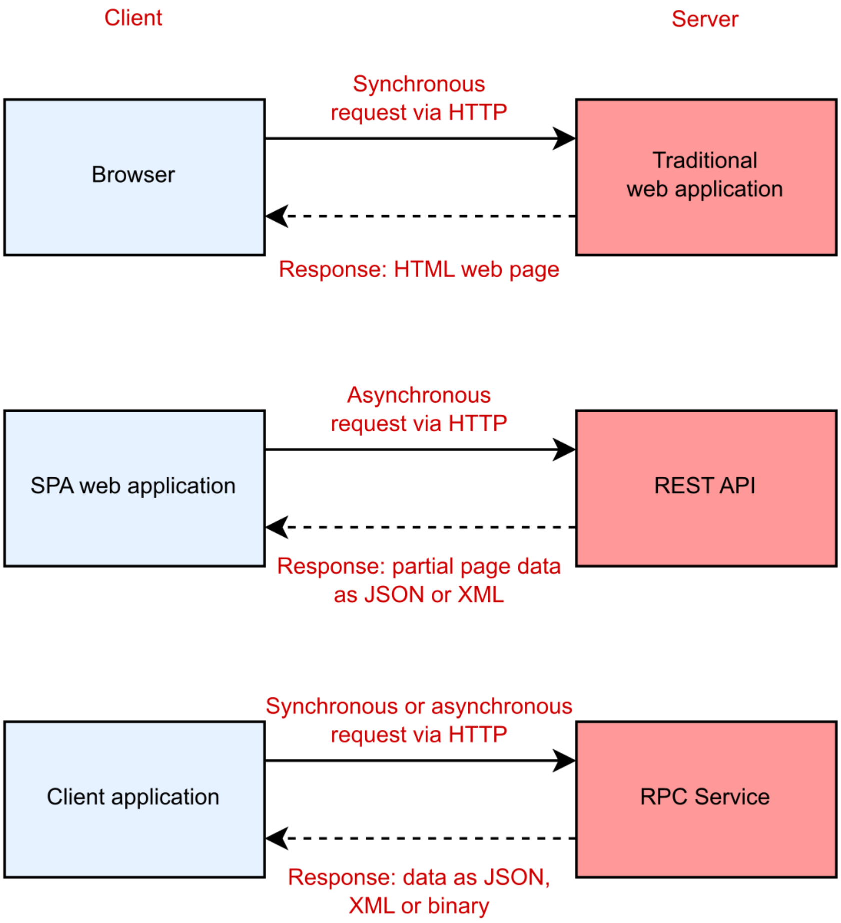
The .NET Foundation website (https://dotnetfoundation.org/) is build using the cloudscribe CMS and ASP.NET Core.

Traditional, page-based server-side-rendered web applications are the bread and butter of ASP.NET development, both with the previous version of ASP.NET and with ASP.NET Core. Additionally, single-page applications (SPAs), which use a client-side framework that commonly talks to a REST server, are easy to create with ASP.NET Core. Whether you’re using Angular, Vue, React, or some other client-side framework, it’s easy to create an ASP.NET Core application to act as the server-side API.

> **DEFINITION** ***REST*** **stands for REpresentational State Transfer. RESTful applications typically use lightweight and stateless HTTP calls to read, post (create/update), and delete data.**

ASP.NET Core isn’t restricted to creating RESTful services. It’s easy to create a web service or remote procedure call (RPC)-style service for your application, depending on your requirements, as shown in figure 1.5. In the simplest case, your application might expose only a single endpoint, narrowing its scope to become a microservice. ASP.NET Core is perfectly designed for building simple services thanks to its cross-platform support and lightweight design.



ASP.NET Core can act as the server-side application for a variety of different clients: it can serve HTML pages for traditional web applications, it can act as a REST API for client-side SPA applications, or it can act as an ad-hoc RPC service for client applications.

You should consider multiple factors when choosing a platform, not all of which are technical. One such factor is the level of support you can expect to receive from its creators. For some organizations, this can be one of the main obstacles to adopting open source software. Luckily, Microsoft has pledged[4] to provide full support for Long Term Support (LTS) versions of .NET Core and ASP.NET Core for at least three years from the time of their release. And as all

[4] View the support policy at https://dotnet.microsoft.com/platform/support/policy/dotnet-core.

development takes place in the open, you can sometimes get answers to your questions from the general community, as well as from Microsoft directly.

When deciding whether to use ASP.NET Core, you have two primary dimensions to consider: whether you're already a .NET developer, and whether you're creating a new application or looking to convert an existing one.

1.2.2 If you're new to .NET development

If you're new to .NET development and are considering ASP.NET Core, then welcome! Microsoft is pushing ASP.NET Core as an attractive option for web development beginners, but taking .NET cross-platform means it's competing with many other frameworks on their own turf. ASP.NET Core has many selling points when compared to other cross-platform web frameworks:

- It's a modern, high-performance, open source web framework.
- It uses familiar design patterns and paradigms.
- C# is a great language (or you can use VB.NET or F# if you prefer).
- You can build and run on any platform.

ASP.NET Core is a re-imagining of the ASP.NET framework, built with modern software design principles on top of the new .NET Core platform. Although new in one sense, .NET Core has several years of widespread production use, and has drawn significantly from the mature, stable, and reliable .NET Framework, which has been used for nearly two decades. You can rest easy knowing that by choosing ASP.NET Core and .NET Core, you'll be getting a dependable platform as well as a fully-featured web framework.

Many of the web frameworks available today use similar, well-established design patterns, and ASP.NET Core is no different. For example, Ruby on Rails is known for its use of the Model-View-Controller (MVC) pattern; Node.js is known for the way it processes requests using small discrete modules (called a pipeline); and dependency injection is found in a wide variety of frameworks. If these techniques are familiar to you, you should find it easy to transfer them across to ASP.NET Core; if they're new to you, then you can look forward to using industry best practices!

NOTE You'll encounter a pipeline in chapter 3, MVC in chapter 4, and dependency injection in chapter 10.

The primary language of .NET development, and ASP.NET Core in particular, is C#. This language has a huge following, and for good reason! As an object-oriented C-based language, it provides a sense of familiarity to those used to C, Java, and many other languages. In addition, it has many powerful features, such as Language Integrated Query (LINQ), closures, and asynchronous programming constructs. The C# language is also designed in the open on GitHub, as is Microsoft's C# compiler, codenamed Roslyn.[5]

NOTE I use C# throughout this book and will highlight some of the newer features it provides, but I won't be teaching the language from scratch. If you want to learn C#, I recommend *C# in Depth, fourth edition* by Jon Skeet (Manning, 2019), and *Code like a Pro in C#*, by Jort Rodenburg (Manning, 2021).

One of the major selling points of ASP.NET Core and .NET Core is the ability to develop and run on any platform. Whether you're using a Mac, Windows, or Linux, you can run the same ASP.NET Core apps and develop across multiple environments. As a Linux user, a wide range of distributions are supported (RHEL, Ubuntu, Debian, Cent-OS, Fedora, and openSUSE, to name a few), so you can be confident your operating system of choice will be a viable option. ASP.NET Core even runs on the tiny Alpine distribution, for truly compact deployments to containers.

Built with containers in mind

Traditionally, web applications were deployed directly to a server, or more recently, to a virtual machine. Virtual machines allow operating systems to be installed in a layer of virtual hardware, abstracting away the underlying hardware. This has several advantages over direct installation, such as easy maintenance, deployment, and recovery. Unfortunately, they're also heavy both in terms of file size and resource use.

This is where containers come in. Containers are far more lightweight and don't have the overhead of virtual machines. They're built in a series of layers and don't require you to boot a new operating system when starting a new one. That means they're quick to start and are great for quick provisioning. Containers, and Docker in particular, are quickly becoming the go-to platform for building large, scalable systems.

Containers have never been a particularly attractive option for ASP.NET applications, but with ASP.NET Core, .NET Core, and Docker for Windows, that's all changing. A lightweight ASP.NET Core application running on the cross-platform .NET Core framework is perfect for thin container deployments. You can learn more about your deployment options in chapter 16.

As well as running on each platform, one of the selling points of .NET is the ability to write and compile only once. Your application is compiled to Intermediate Language (IL) code, which is a platform-independent format. If a target system has the .NET Core platform installed, then you can run compiled IL from any platform. That means you can, for example, develop on a Mac or a Windows machine and deploy *the exact same files* to your production Linux machines. This compile-once, run-anywhere promise has finally been realized with ASP.NET Core and .NET Core.

[5] The C# language and .NET Compiler Platform GitHub source code repository can be found at https:// github.com/dotnet/roslyn.

1.2.3 If you’re a .NET Framework developer creating a new application

If you’re a .NET developer, then the choice of whether to invest in ASP.NET Core for new applications has largely been a question of timing. Early versions of .NET Core were lacking in some features that made it hard to adopt. With the release of .NET Core 3.1 and .NET 5, that is no longer a problem; Microsoft now explicitly advises that all new .NET applications should use .NET Core. Microsoft has pledged to provide bug and security fixes for the older ASP.NET framework, but it won’t receive any more feature updates. .NET Framework isn’t being removed, so your old applications will continue to work, but you shouldn’t use it for new development.

The main benefits of ASP.NET Core over the previous ASP.NET framework are:

- Cross-platform development and deployment
- A focus on performance as a feature
- A simplified hosting model
- Regular releases with a shorter release cycle
- Open source
- Modular features

As a .NET developer, if you aren’t using any Windows-specific constructs, such as the Registry, then the ability to build and deploy applications cross-platform opens the door to a whole new avenue of applications: take advantage of cheaper Linux VM hosting in the cloud, use Docker containers for repeatable continuous integration, or write .NET code on your Mac without needing to run a Windows virtual machine. ASP.NET Core, in combination with .NET Core, makes all this possible.

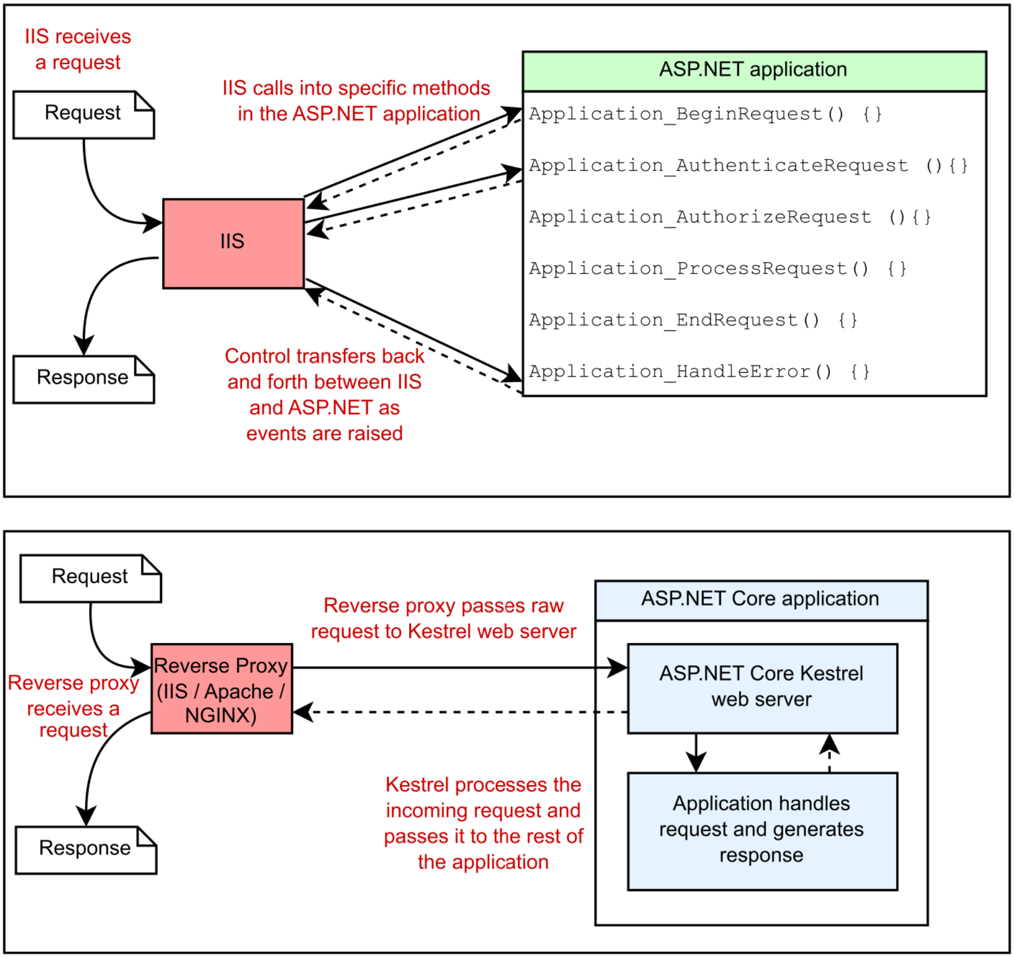
.NET Core is inherently cross-platform, but you can still use platform-specific features if you need to. For example, Windows-specific features like the Registry or Directory Services can be enabled with a compatibility pack[6] that makes these APIs available in .NET Core. They’re only available when running .NET Core on Windows, not on Linux or macOS, so you need to take care that such applications only run in a Windows environment, or account for the potential missing APIs.

The hosting model for the previous ASP.NET framework was a relatively complex one, relying on Windows IIS to provide the web server hosting. In a cross-platform environment, this kind of symbiotic relationship isn’t possible, so an alternative hosting model has been adopted, one which separates web applications from the underlying host. This opportunity has led to the development of Kestrel: a fast, cross-platform HTTP server on which ASP.NET Core can run.

Instead of the previous design, whereby IIS calls into specific points of your application, ASP.NET Core applications are console applications that self-host a web server and handle

[6] The Windows Compatibility Pack is designed to help port code from .NET Framework to .NET Core. See http://mng.bz/50hu.

requests directly, as shown in figure 1.6. This hosting model is conceptually much simpler and allows you to test and debug your applications from the command line, though it doesn't remove the need to run IIS (or equivalent) in production, as you'll see in section 1.3.


IIS receives a request
Request
IIS
Response
IIS calls into specific methods in the ASP.NET application
Control transfers back and forth between IIS and ASP.NET as events are raised
ASP.NET application
Application_BeginRequest() {}
Application_AuthenticateRequest (){}
Application_AuthorizeRequest (){}
Application_ProcessRequest() {}
Application_EndRequest() {}
Application_HandleError() {}
Request
Reverse proxy receives a request
Reverse Proxy (IIS / Apache / NGINX)
Response
Reverse proxy passes raw request to Kestrel web server
ASP.NET Core application
ASP.NET Core Kestrel web server
Application handles request and generates response
Kestrel processes the incoming request and passes it to the rest of the application

The difference between hosting models in ASP.NET (top) and ASP.NET Core (bottom). With the previous version of ASP.NET, IIS is tightly coupled with the application. The hosting model in ASP.NET Core is simpler; IIS hands off the request to a self-hosted web server in the ASP.NET Core application and receives the response, but has no deeper knowledge of the application.

Changing the hosting model to use a built-in HTTP web server has created another opportunity. Performance has been somewhat of a sore point for ASP.NET applications in the past. It's certainly possible to build high-performing applications—Stack Overflow (https://stackoverflow.com) is testament to that—but the web framework itself isn't designed with performance as a priority, so it can end up being somewhat of an obstacle.

To be competitive cross-platform, the ASP.NET team have focused on making the Kestrel HTTP server as fast as possible. TechEmpower (www.techempower.com/benchmarks) has been running benchmarks on a whole range of web frameworks from various languages for several years now. In Round 19 of the plain text benchmarks, TechEmpower announced that ASP.NET Core with Kestrel was the fastest of over 400 frameworks tested![7]

Web servers: naming things is hard

One of the difficult aspects of programming for the web is the confusing array of often conflicting terminology. For example, if you've used IIS in the past, you may have described it as a web server, or possibly a web host. Conversely, if you've ever built an application using Node.js, you may have also referred to that application as a web server. Alternatively, you may have called the physical machine on which your application runs a web server!

Similarly, you may have built an application for the internet and called it a website or a web application, probably somewhat arbitrarily based on the level of dynamism it displayed.

In this book, when I say "web server" in the context of ASP.NET Core, I am referring to the HTTP server that runs as part of your ASP.NET Core application. By default, this is the Kestrel web server, but that's not a requirement. It would be possible to write a replacement web server and substitute it for Kestrel if you desired.

The web server is responsible for receiving HTTP requests and generating responses. In the previous version of ASP.NET, IIS took this role, but in ASP.NET Core, Kestrel is the web server.

I will only use the term web application to describe ASP.NET Core applications in this book, regardless of whether they contain only static content or are completely dynamic. Either way, they're applications that are accessed via the web, so that name seems the most appropriate!

Many of the performance improvements made to Kestrel did not come from the ASP.NET team themselves, but from contributors to the open source project on GitHub.[8] Developing in the open means you typically see fixes and features make their way to production faster than you would for the previous version of ASP.NET, which was dependent on .NET Framework and Windows and, as such, had long release cycles.

In contrast, .NET Core, and hence ASP.NET Core, is designed to be released in small increments. Major versions will be released on a predictable cadence, with a new version every year, and a new Long Term Support (LTS) version released every two years[9]. In addition, bug fixes and minor updates can be released as and when they're needed. Additional functionality is provided as NuGet packages, independent of the underlying .NET Core platform.

[7] As always in web development, technology is in a constant state of flux, so these benchmarks will evolve over time. Although ASP.NET Core may not maintain its top ten slot, you can be sure that performance is one of the key focal points of the ASP.NET Core team.

[8] The Kestrel HTTP server GitHub project can be found in the ASP.NET Core repository at https://github.com/dotnet/aspnetcore.

[9] The release schedule for .NET 5 and beyond: https://devblogs.microsoft.com/dotnet/introducing-net-5/

NOTE NuGet is a package manager for .NET that enables importing libraries into your projects. It's equivalent to Ruby Gems, npm for JavaScript, or Maven for Java.

To enable this, ASP.NET Core is highly modular, with as little coupling to other features as possible. This modularity lends itself to a pay-for-play approach to dependencies, where you start from a bare-bones application and only add the additional libraries you require, as opposed to the kitchen-sink approach of previous ASP.NET applications. Even MVC is an optional package! But don't worry, this approach doesn't mean that ASP.NET Core is lacking in features; it means you need to opt in to them. Some of the key infrastructure improvements include

- Middleware "pipeline" for defining your application's behavior
- Built-in support for dependency injection
- Combined UI (MVC) and API (Web API) infrastructure
- Highly extensible configuration system
- Scalable for cloud platforms by default using asynchronous programming

Each of these features was possible in the previous version of ASP.NET but required a fair amount of additional work to set up. With ASP.NET Core, they're all there, ready, and waiting to be connected!

Microsoft fully supports ASP.NET Core, so if you have a new system you want to build, then there's no significant reason not to. The largest obstacle you're likely to come across is when you want to use programming models that are no longer supported in ASP.NET Core, such as Web Forms or WCF server, as I'll discuss in the next section.

Hopefully, this section has whetted your appetite with some of the many reasons to use ASP.NET Core for building new applications. But if you're an existing ASP.NET developer considering whether to convert an existing ASP.NET application to ASP.NET Core, that's another question entirely.

1.2.4 Converting an existing ASP.NET application to ASP.NET Core

In contrast with new applications, an existing application is presumably already providing value, so there should always be a tangible benefit to performing what may amount to a significant rewrite in converting from ASP.NET to ASP.NET Core. The advantages of adopting ASP.NET Core are much the same as for new applications: cross-platform deployment, modular features, and a focus on performance. Determining whether the benefits are sufficient will depend largely on the particulars of your application, but there are some characteristics that are clear indicators *against* conversion:

- Your application uses ASP.NET Web Forms
- Your application is built using WCF
- Your application is large, with many "advanced" MVC features

If you have an ASP.NET Web Forms application, then attempting to convert it to ASP.NET Core isn't advisable. Web Forms is inextricably tied to System.Web.dll, and as such will likely never be available in ASP.NET Core. Converting an application to ASP.NET Core would effectively involve rewriting the application from scratch, not only shifting frameworks but also shifting design paradigms. A better approach would be to slowly introduce Web API concepts and try to reduce the reliance on legacy Web Forms constructs such as ViewData. You can find many resources online to help you with this approach, in particular, the www.asp.net/web-api website.

Windows Communication Foundation (WCF) is only partially supported in ASP.NET Core.[10] It's possible to consume some WCF services, but support is spotty at best. There's no supported way to host a WCF service from an ASP.NET Core application, so if you absolutely must support WCF, then ASP.NET Core may be best avoided for now.

> **TIP** If you like WCFs RPC-style of programming, but don't have a hard requirement on WCF itself, then consider using gRPC instead. gRPC is a modern RPC framework with many similar concepts as WCF and is supported by ASP.NET Core out-of-the-box[11].

If your existing application is complex and makes extensive use of the previous MVC or Web API extensibility points or message handlers, then porting your application to ASP.NET Core may be more difficult. ASP.NET Core is built with many similar features to the previous version of ASP.NET MVC, but the underlying architecture is different. Several of the previous features don't have direct replacements, and so will require rethinking.

The larger the application, the greater the difficulty you're likely to have converting your application to ASP.NET Core. Microsoft itself suggests that porting an application from ASP.NET MVC to ASP.NET Core is at least as big a rewrite as porting from ASP.NET Web Forms to ASP.NET MVC. If that doesn't scare you, then nothing will!

If an application is rarely used, isn't part of your core business, or won't need significant development in the near term, then I strongly suggest you *don't* try to convert it to ASP.NET Core. Microsoft will support .NET Framework for the foreseeable future (Windows itself depends on it!) and the payoff in converting these "fringe" applications is unlikely to be worth the effort.

So, when *should* you port an application to ASP.NET Core? As I've already mentioned, the best opportunity for getting started is on small, green-field, new projects instead of existing applications. That said, if the existing application in question is small, or will need significant future development, then porting may be a good option. It is always best to work in small iterations where possible, rather than attempting to convert the entire application at once. But if your application consists primarily of MVC or Web API controllers and associated Razor views, then moving to ASP.NET Core may well be a good choice.

[10] You can find the client libraries for using WCF with .NET Core at https://github.com/dotnet/wcf.

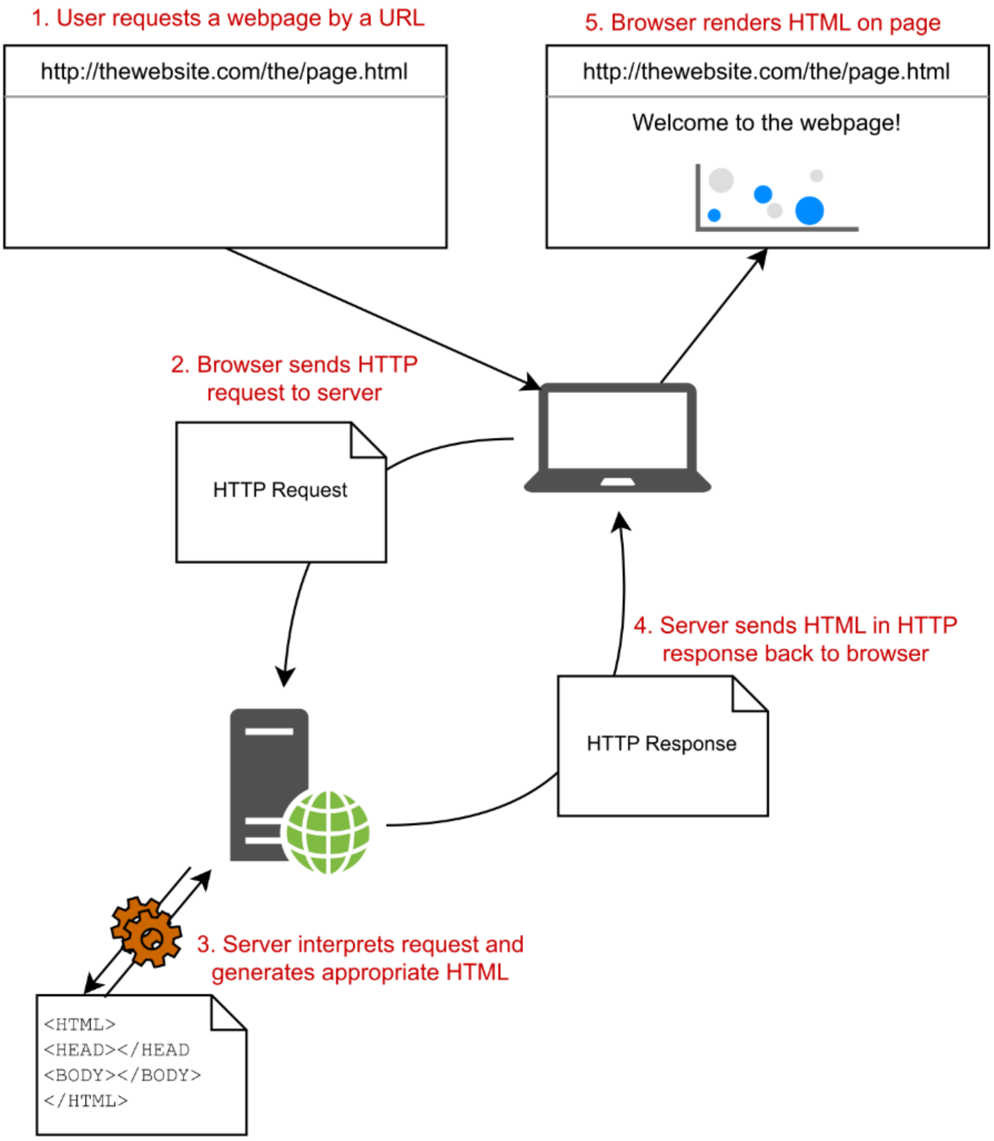
[11] You can find an eBook from Microsoft on gRPC for WCF developers at https://docs.microsoft.com/en-us/dotnet/architecture/grpc-for-wcf-developers/.

1.3 How does ASP.NET Core work?

By now, you should have a good idea of what ASP.NET Core is and the sort of applications you should use it for. In this section, you'll see how an application built with ASP.NET Core works, from the user requesting a URL, to a page being displayed on the browser. To get there, first you'll see how an HTTP request works for any web server, and then you'll see how ASP.NET Core extends the process to create dynamic web pages.

1.3.1 How does an HTTP web request work?

As you know, ASP.NET Core is a framework for building web applications that serve data from a server. One of the most common scenarios for web developers is building a web app that you can view in a web browser. The high-level process you can expect from any web server is shown in figure 1.7.


1. User requests a webpage by a URL
http://thewebsite.com/the/page.html
5. Browser renders HTML on page
http://thewebsite.com/the/page.html
Welcome to the webpage!
2. Browser sends HTTP request to server
HTTP Request
4. Server sends HTML in HTTP response back to browser
HTTP Response
3. Server interprets request and generates appropriate HTML
<HTML>
<HEAD></HEAD
<BODY></BODY>
</HTML>

Requesting a web page. The user starts by requesting a web page, which causes an HTTP request to be sent to the server. The server interprets the request, generates the necessary HTML, and sends it back in an HTTP response. The browser can then display the web page.

The process begins when a user navigates to a website or types a URL in their browser. The URL or web address consists of a *hostname* and a *path* to some resource on the web app.

Navigating to the address in your browser sends a request from the user's computer to the server on which the web app is hosted, using the HTTP protocol.

> **DEFINITION** The *hostname* of a website uniquely identifies its location on the internet by mapping via the Domain Name Service (DNS) to an IP Address. Examples include microsoft.com, www.google.co.uk, and facebook.com.

The request passes through the internet, potentially to the other side of the world, until it finally makes its way to the server associated with the given hostname on which the web app is running. The request is potentially received and rebroadcast at multiple routers along the way, but it's only when it reaches the server associated with the hostname that the request is processed.

Once the server receives the request, it will check that it makes sense, and if it does, will generate an HTTP response. Depending on the request, this response could be a web page, an image, a JavaScript file, or a simple acknowledgment. For this example, I'll assume the user has reached the homepage of a web app, and so the server responds with some HTML. The HTML is added to the HTTP response, which is then sent back across the internet to the browser that made the request.

As soon as the user's browser begins receiving the HTTP response, it can start displaying content on the screen, but the HTML page may also reference other pages and links on the server. To display the complete web page, instead of a static, colorless, raw HTML file, the browser must repeat the request process, fetching every referenced file. HTML, images, CSS for styling, and JavaScript files for extra behavior are all fetched using the exact same HTTP request process.

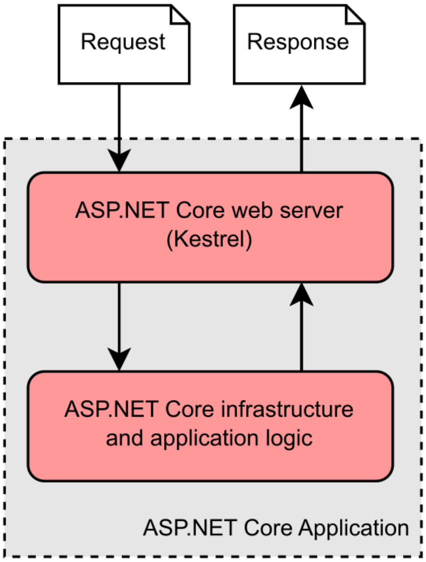
Pretty much all interactions that take place on the internet are a facade over this same basic process. A basic web page may only require a few simple requests to fully render, whereas a modern, large web page may take hundreds. The Amazon.com homepage (www.amazon.com), for example, makes 606 requests, including 3 CSS files, 12 JavaScript files, and 402 image files!

Now you have a feel for the process, let's see how ASP.NET Core dynamically generates the response on the server.

1.3.2 How does ASP.NET Core process a request?

When you build a web application with ASP.NET Core, browsers will still be using the same HTTP protocol as before to communicate with your application. ASP.NET Core itself encompasses everything that takes place on the server to handle a request, including verifying the request is valid, handling login details, and generating HTML.

Just as with the generic web page example, the request process starts when a user's browser sends an HTTP request to the server, as shown in figure 1.8.


Request
Response
ASP.NET Core web server (Kestrel)
ASP.NET Core infrastructure and application logic
ASP.NET Core Application

1. HTTP request is made to the server and is received by ASP.NET Core web server.

2. ASP.NET Core web server receives the HTTP request and passes it to Middleware.

3. Request is processed by the application which generates a response.

4. Response passes through middleware back to web server.

5. Web server sends response to browser.

How an ASP.NET Core application processes a request. A request is received by the ASP.NET Core application, which runs a self-hosted web server. The web server processes the request and passes it to the body of the application, which generates a response and returns it to the web server. The web server sends this response to the browser.

The request is received from the network by your ASP.NET Core application. Every ASP.NET Core application has a built-in web server, Kestrel by default, which is responsible for receiving raw requests and constructing an internal representation of the data, an `HttpContext` object, which can be used by the rest of the application.

From this representation, your application should have all the details it needs to create an appropriate response to the request. It can use the details stored in `HttpContext` to generate an appropriate response, which may be to generate some HTML, to return an "access denied" message, or to send an email, all depending on your application's requirements.

Once the application has finished processing the request, it will return the response to the web server. The ASP.NET Core web server will convert the representation into a raw HTTP response and send it to the network, which will forward it to the user's browser.

To the user, this process appears to be the same as for the generic HTTP request shown in figure 1.7—the user sent an HTTP request and received an HTTP response. All the differences are server-side, within our application.

ASP.NET Core and Reverse Proxies

You can expose ASP.NET Core applications directly to the internet, so that Kestrel receives requests directly from the network. However, it's more common to use a reverse proxy between the raw network and your application. In Windows, the reverse-proxy server will typically be IIS, and on Linux or macOS it might be NGINX, HAProxy or Apache.

A *reverse proxy* is software responsible for receiving requests and forwarding them to the appropriate web server. The reverse proxy is exposed directly to the internet, whereas the underlying web server is exposed only to the proxy. This setup has several benefits, primarily security and performance for the web servers.

You may be thinking that having a reverse proxy *and* a web server is somewhat redundant. Why not have one or the other? Well, one of the benefits is the decoupling of your application from the underlying operating system. The same ASP.NET Core web server, Kestrel, can be cross-platform and used behind a variety of proxies without putting any constraints on a particular implementation. Alternatively, if you wrote a new ASP.NET Core web server, you could use that in place of Kestrel without needing to change anything else about your application.

Another benefit of a reverse proxy is that it can be hardened against potential threats from the public internet. They're often responsible for additional aspects, such as restarting a process that has crashed. Kestrel can stay as a simple HTTP server without having to worry about these extra features when it's used behind a reverse proxy. Think of it as a simple separation of concerns: Kestrel is concerned with generating HTTP responses; a reverse proxy is concerned with handling the connection to the internet.

You've seen how requests and responses find their way to and from an ASP.NET Core application, but I haven't yet touched on how the response is generated. In part 1 of this book, we'll look at the components that make up a typical ASP.NET Core application and how they all fit together. A lot goes into generating a response in ASP.NET Core, typically all within a fraction of a second, but over the course of the book we'll step through an application slowly, covering each of the components in detail.

1.4 What you will learn in this book

This book takes you on an in-depth tour of the ASP.NET Core framework. To benefit from the book, you should be familiar with C# or a similar objected-oriented language. Basic familiarity with web concepts like HTML and JavaScript will also be beneficial. You will learn:

- How to create page-based applications with Razor Pages.
- Key ASP.NET Core concepts like model-binding, validation, and routing.
- How to generate HTML for web pages using Razor syntax and Tag Helpers.
- To use features like dependency injection, configuration, and logging as your applications grow more complex.
- How to protect your application using security best practices.

Throughout the book we'll use a variety of examples to learn and explore concepts. The examples are generally small and self-contained, so we can focus on a single feature at a time.

I'll be using Visual Studio for most of the examples in this book, but you'll be able to follow along using your favorite editor or IDE.

TIP You can install .NET Core from https://get.asp.net/. Appendix A contains further details on how to configure your development environment for working with .NET Core.

In the next chapter, you'll create your first application from a template and run it. We'll walk through each of the main components that make up your application and see how they all work together to render a web page.

1.5 Summary

- ASP.NET Core is a new web framework built with modern software architecture practices and modularization as its focus.
- It's best used for new, "green-field" projects.
- Legacy technologies such as WCF Server and Web Forms can't be used with ASP.NET Core.
- ASP.NET Core runs on the cross-platform .NET Core platform. You can access Windows-specific features such as the Windows Registry by using the Windows Compatibility Pack.
- Fetching a web page involves sending an HTTP request and receiving an HTTP response.
- ASP.NET Core allows dynamically building responses to a given request.
- An ASP.NET Core application contains a web server, which serves as the entry-point for a request.
- ASP.NET Core apps are typically protected from the internet by a reverse-proxy server, which forwards requests to the application.

2

Your first application

This chapter covers

- **Creating your first ASP.NET Core web application**
- **Running your application**
- **Understanding the components of your application**

After reading chapter 1, you should have a general idea of how ASP.NET Core applications work and when you should use them. You should have also set up a development environment to start building applications. In this chapter, you'll dive right in by creating your first web app. You'll get to kick the tires and poke around a little to get a feel for how it works, and in later chapters, I'll show how you go about customizing and building your own applications.

As you work through this chapter, you should begin to get a grasp of the various components that make up an ASP.NET Core application, as well as an understanding of the general application-building process. Most applications you create will start from a similar *template*, so it's a good idea to get familiar with the setup as soon as possible.

> **DEFINITION** A *template* provides the basic code required to build an application. You can use a template as the starting point for building your own apps.

I'll start by showing how to create a basic ASP.NET Core application using one of the Visual Studio templates. If you're using other tooling, such as the .NET CLI, then you'll have similar templates available. I use Visual Studio 2019 and ASP.NET Core 3.1 in this chapter, but I also provide tips for working with the .NET CLI.

> **TIP** You can view the application code for this chapter in the GitHub repository for the book at https://github.com/andrewlock/asp-dot-net-core-in-action-2e.

Once you've created your application, I'll show you how to restore all the necessary dependencies, compile your application, and run it to see the HTML output. The application will be simple in some respects—it will only have two different pages—but it'll be a fully configured ASP.NET Core application.

Having run your application, the next step is to understand what's going on! We'll take a journey through all the major parts of an ASP.NET Core application, looking at how to configure the web server, the middleware pipeline, and HTML generation, among other things. We won't go into detail at this stage, but you'll get a feel for how they all work together to create a complete application.

We'll begin by looking at the plethora of files created when you start a new project and learn how a typical ASP.NET Core application is laid out. In particular, I'll focus on the Program.cs and Startup.cs files. Virtually the entire configuration of your application takes place in these two files, so it's good to get to grips with what they are for and how they're used. You'll see how to define the middleware pipeline for your application, and how you can customize it.

Finally, you'll see how the app generates HTML in response to a request, looking at each of the components that make up the Razor Pages endpoint. You'll see how it controls what code is run in response to a request, and how to define the HTML that should be returned for a particular request.

At this stage, don't worry if you find parts of the project confusing or complicated; you'll be exploring each section in detail as you move through the book. By the end of the chapter, you should have a basic understanding of how ASP.NET Core applications are put together, right from when your application is first run to when a response is generated. Before we begin though, we'll review how ASP.NET Core applications handle requests.

2.1 A brief overview of an ASP.NET Core application

In chapter 1, I described how a browser makes an HTTP request to a server and receives a response, which it uses to render HTML on the page. ASP.NET Core allows you to dynamically generate that HTML depending on the particulars of the request so that you can, for example, display different data depending on the current logged-in user.

Say you want to create a web app to display information about your company. You could create a simple ASP.NET Core app to achieve this, especially if you might later want to add dynamic features to your app. Figure 2.1 shows how the application would handle a request for a page in your application.

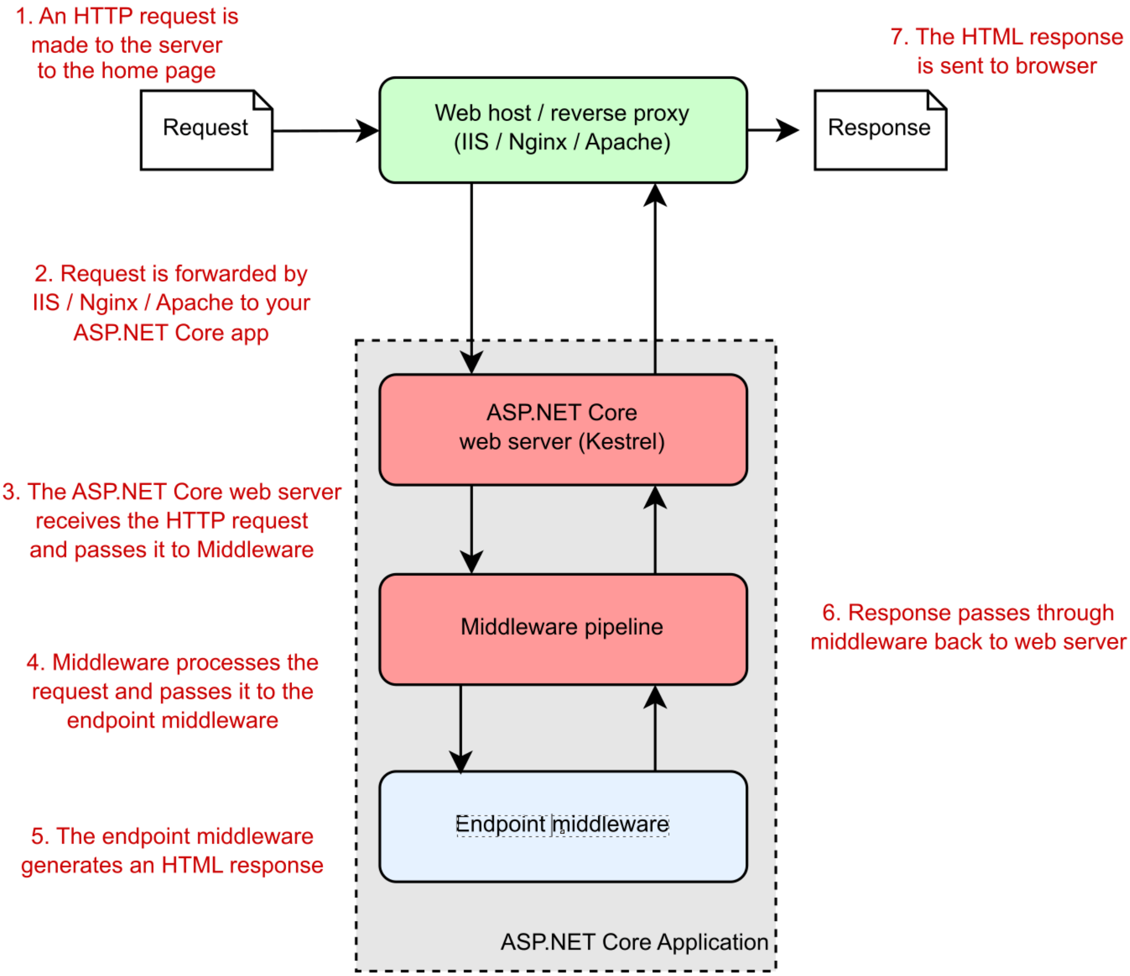

1. An HTTP request is made to the server to the home page
Request
Web host / reverse proxy (IIS / Nginx / Apache)
Response
7. The HTML response is sent to browser
2. Request is forwarded by IIS / Nginx / Apache to your ASP.NET Core app
ASP.NET Core web server (Kestrel)
3. The ASP.NET Core web server receives the HTTP request and passes it to Middleware
Middleware pipeline
6. Response passes through middleware back to web server
4. Middleware processes the request and passes it to the endpoint middleware
Endpoint middleware
5. The endpoint middleware generates an HTML response
ASP.NET Core Application

Figure 2.1 An overview of an ASP.NET Core application. The ASP.NET Core application contains of a number of blocks that process an incoming request from the browser. Every request passes to the middleware pipeline. It potentially modifies it, then passes it to the endpoint middleware at the end of the pipeline to generate a response. The response passes back through the middleware, to the server, and finally, out to the browser.

Much of this diagram should be familiar to you from figure 1.8 in chapter 1; the request and response, the reverse proxy, and the ASP.NET Core web server are all still there, but you'll notice that I've expanded the ASP.NET Core application itself to show the middleware pipeline and the endpoint middleware. This is the main custom part of your app that goes into generating the response from a request.

The first port of call after the reverse proxy forwards a request is the ASP.NET Core web server, which is the default cross-platform Kestrel server. Kestrel takes the raw incoming network request and uses it to generate an `HttpContext` object that the rest of the application can use.

The HttpContext object

The `HttpContext` constructed by the ASP.NET Core web server is used by the application as a sort of storage box for a single request. Anything that's specific to this particular request and the subsequent response can be associated with it and stored in it. This could include properties of the request, request-specific services, data that's been loaded, or errors that have occurred. The web server fills the initial `HttpContext` with details of the original HTTP request and other configuration details and passes it on to the rest of the application.

> **NOTE** Kestrel isn't the only HTTP server available in ASP.NET Core, but it's the most performant and is cross-platform. I'll only refer to Kestrel throughout the book. The main alternative, HTTP.sys, only runs on Windows and can't be used with IIS.[12]

Kestrel is responsible for receiving the request data and constructing a C# representation of the request, but it doesn't attempt to generate a response directly. For that, Kestrel hands the `HttpContext` to the middleware pipeline found in every ASP.NET Core application. This is a series of components that processes the incoming request to perform common operations such as logging, handling exceptions, or serving static files.

> **NOTE** You'll learn about the middleware pipeline in detail in the next chapter.

At the end of the middleware pipeline is the *endpoint* middleware. This middleware is responsible for calling the code that generates the final response. In most applications that will be an MVC or Razor Pages block.

Razor Pages are responsible for generating the HTML that makes up the pages of a typical ASP.NET Core web app. They're also typically where you find most of the business logic of your app, by calling out to various services in response to the data contained in the original request. Not every app needs an MVC or Razor Pages block, but it's typically how you'll build most apps that display HTML to a user.

> **NOTE** I'll cover Razor Pages and MVC controllers in chapter 4, including how to choose between them. I cover generating HTML in chapters 7 and 8.

[12] If you want to learn more about HTTP.sys, the documentation describes the server and how to use it: https://docs.microsoft.com/en-us/aspnet/core/fundamentals/servers/httpsys.

Most ASP.NET Core applications follow this basic architecture, and the example in this chapter is no different. First, you'll see how to create and run your application, then we'll look at how the code corresponds to the outline in figure 2.1. Without further ado, let's create an application!

2.2 Creating your first ASP.NET Core application

You can start building applications with ASP.NET Core in many different ways, depending on the tools and operating system you're using. Each set of tools will have slightly different templates, but they have many similarities. The example used throughout this chapter is based on a Visual Studio 2019 template, but you can easily follow along with templates from the .NET CLI or Visual Studio for Mac.

> **REMINDER** This chapter uses Visual Studio 2019 and ASP.NET Core 3.1.

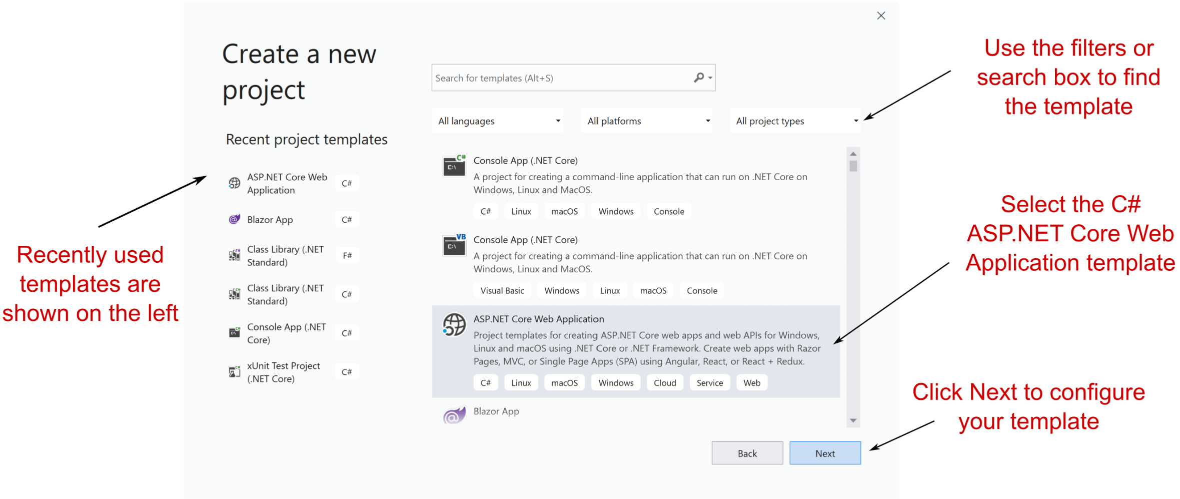
Getting an application up and running typically follows four basic steps, which we'll work through in this chapter:

1. *Generate*—Create the base application from a template to get started.
2. *Restore*—Restore all the packages and dependencies to the local project folder using NuGet.
3. *Build*—Compile the application and generate all the necessary assets.
4. *Run*—Run the compiled application.

2.2.1 Using a template to get started

Using a template can quickly get you up and running with an application, automatically configuring many of the fundamental pieces for you. Both Visual Studio and the .NET CLI come with a number of standard templates for building web applications, console applications, and class libraries. To create your first web application, open Visual Studio and perform the following steps:

1. Choose Create a New Project from the splash screen, or choose File > New > Project from the main Visual Studio screen..
2. From the list of templates, choose ASP.NET Core Web Application, ensuring you select the C# language template, as shown in figure 2.2. Click Next



Create a new project

Recent project templates

ASP.NET Core Web Application C#
Blazor App C#
Class Library (.NET Standard) F#
Class Library (.NET Standard) C#
Console App (.NET Core) C#
xUnit Test Project (.NET Core) C#
Search for templates (Alt+S)
All languages
All platforms
All project types

Console App (.NET Core)
A project for creating a command-line application that can run on .NET Core on Windows, Linux and MacOS.

C#
Linux
macOS
Windows
Console

Console App (.NET Core)
A project for creating a command-line application that can run on .NET Core on Windows, Linux and MacOS.

Visual Basic
Windows
Linux
macOS
Console

ASP.NET Core Web Application
Project templates for creating ASP.NET Core web apps and web APIs for Windows, Linux and macOS using .NET Core or .NET Framework. Create web apps with Razor Pages, MVC, or Single Page Apps (SPA) using Angular, React, or React + Redux.

Use the filters or search box to find the template

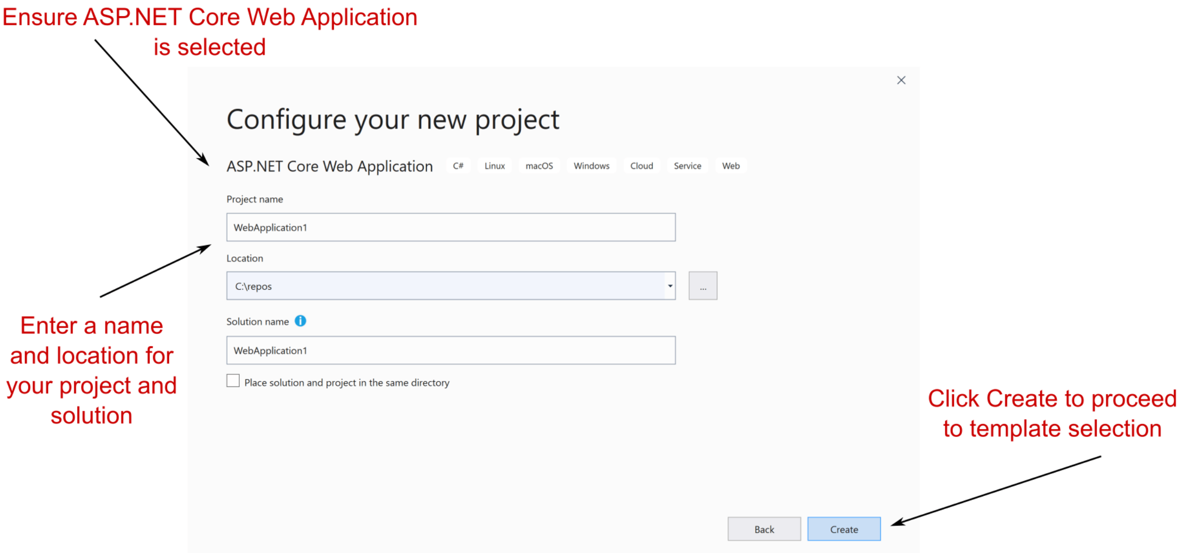
Recently used templates are shown on the left

Select the C# ASP.NET Core Web Application template

Click Next to configure your template

Figure 2.2 The new project dialog. Select the C# ASP.NET Core Web Application template from the list on the right-hand side. When you next create a new project, you can select from the recent templates list on the left.

3. On the next screen, enter a project name, Location, and a solution name, and click Create, as shown in figure 2.3.



Ensure ASP.NET Core Web Application is selected

Configure your new project

ASP.NET Core Web Application

Project name: WebApplication1

Location: C:\repos

Solution name: WebApplication1

□ Place solution and project in the same directory

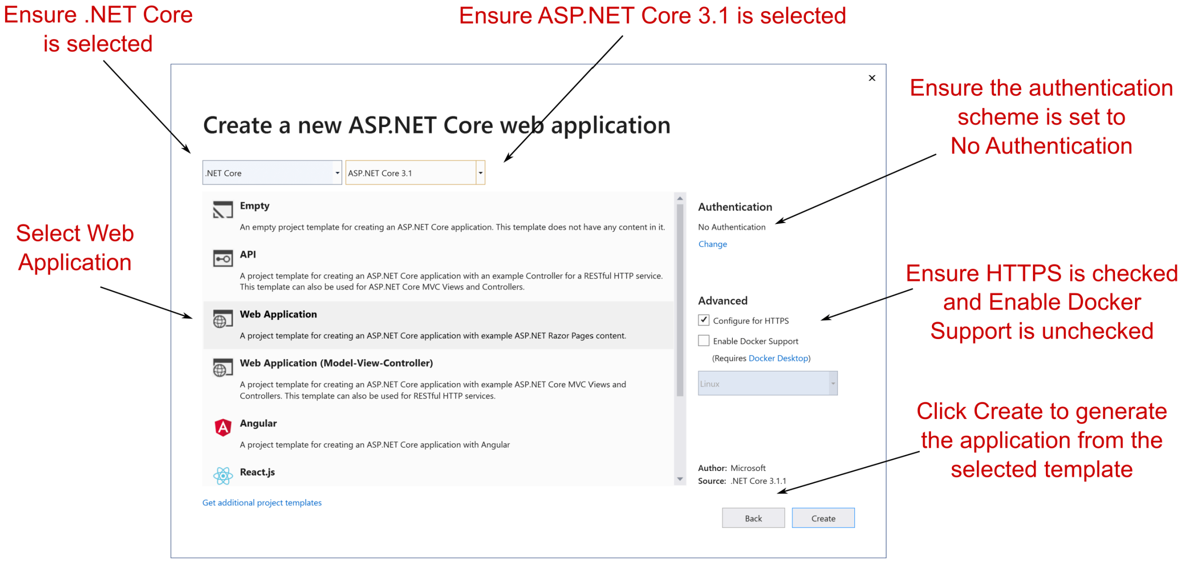
Enter a name and location for your project and solution

Click Create to proceed to template selection

Figure 2.3 The configure your new project dialog. To create a new .NET Core application, select ASP.NET Core Web Application from the template screen. On the following screen, enter a project name, location, and a solution name and click Create.

4. On the following screen (figure 2.4):

- Ensure .NET Core is selected.
- Select ASP.NET Core 3.1. The generated application will target ASP.NET Core 3.1.
- Select Web Application. This ensures you create a Razor Pages web application that generates HTML and is designed to be viewed by users in a web browser directly. The alternative Web Application (Model-View-Controller) template uses traditional MVC controllers instead of Razor Pages. The API template generates an application that returns data in a format that can be consumed by single-page applications (SPAs) and APIs. The Angular, React.js, and React.js and Redux templates create applications for specific SPAs.
- Ensure No Authentication is specified. You'll learn how to add users to your app in chapter 14.
- Ensure Configure for HTTPS is checked
- Ensure Enable Docker Support is unchecked.
- Click Create.



Ensure .NET Core is selected

Ensure ASP.NET Core 3.1 is selected

Ensure the authentication scheme is set to No Authentication

Select Web Application

Ensure HTTPS is checked and Enable Docker Support is unchecked

Click Create to generate the application from the selected template

Create a new ASP.NET Core web application

.NET Core | ASP.NET Core 3.1

Empty
An empty project template for creating an ASP.NET Core application. This template does not have any content in it.

API
A project template for creating an ASP.NET Core application with an example Controller for a RESTful HTTP service. This template can also be used for ASP.NET Core MVC Views and Controllers.

Web Application
A project template for creating an ASP.NET Core application with example ASP.NET Razor Pages content.

Web Application (Model-View-Controller)
A project template for creating an ASP.NET Core application with example ASP.NET Core MVC Views and Controllers. This template can also be used for RESTful HTTP services.

Angular
A project template for creating an ASP.NET Core application with Angular

React.js

Authentication
No Authentication

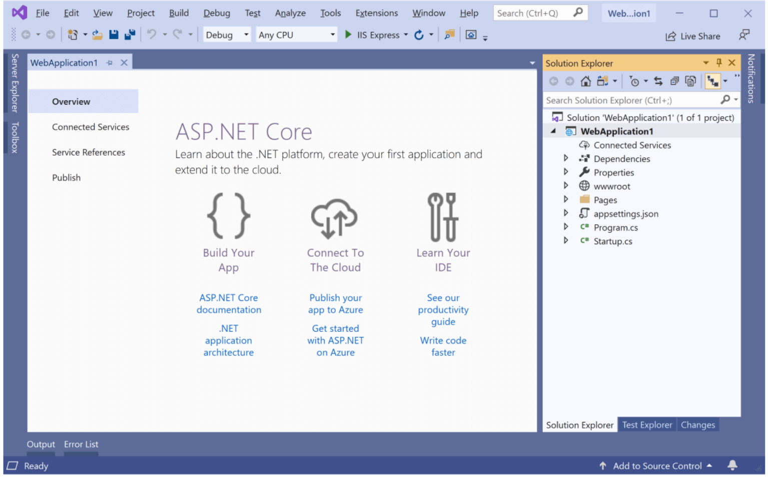
Advanced
☑ Configure for HTTPS
□ Enable Docker Support
(Requires Docker Desktop)

Author: Microsoft
Source: .NET Core 3.1.1

Figure 2.4 The web application template screen. This screen follows on from the configure your project dialog and lets you customize the template that will generate your application. For this starter project, you'll create a Razor Pages web application without authentication.

5. Wait for Visual Studio to generate the application from the template. Once Visual Studio has finished, you'll be presented with an introductory page about ASP.NET Core, and

you should be able to see that Visual Studio has created and added a number of files to your project, as shown in figure 2.5.



Learn about the .NET platform, create your first application and extend it to the cloud.

An introductary page is shown when your project is first created

Solution Explorer shows the files in your project

Figure 2.5 Visual Studio after creating a new ASP.NET Core application from a template. The Solution Explorer shows your newly created project. The introductory page has helpful links for learning about ASP.NET Core.

NOTE **If you're developing using the .NET CLI, you can create a similar application by running** `dotnet new webapp -o WebApplication1` **from the command line. The** `-o` **argument ensures the CLI creates the template in a subfolder called WebApplication1.**

2.2.2 Building the application

At this point, you have most of the files necessary to run your application, but you've got two steps left. First, you need to ensure all the dependencies used by your project are copied to your local directory, and second, you need to compile your application so that it can be run.

The first of these steps isn't strictly necessary, as both Visual Studio and the .NET CLI automatically restore packages when they first create your project, but it's good to know what's going on. In earlier versions of the .NET CLI, before 2.0, you needed to manually restore packages using `dotnet restore`.

You can compile your application by choosing Build > Build Solution, by using the shortcut Ctrl+Shift+B, or by running `dotnet build` from the command line. If you build from Visual Studio, the output window shows the progress of the build, and assuming everything is hunky dory, will compile your application, ready for running. You can also run the `dotnet build` console commands from the Package Manager Console in Visual Studio.

TIP **Visual Studio and the .NET CLI tools will automatically build your application when you run it if they detect that a file has changed, so you generally won't need to explicitly perform this step yourself.**

NuGet packages and the .NET Core command line interface

One of the foundational components of .NET Core cross-platform development is the .NET Core command line interface (CLI). This provides several basic commands for creating, building, and running .NET Core applications. Visual Studio effectively calls these automatically, but you can also invoke them directly from the command line if you're using a different editor. The most common commands during development are

- `dotnet restore`
- `dotnet build`
- `dotnet run`

Each of these commands should be run inside your project folder and will act on that project alone.

All ASP.NET Core applications have dependencies on a number of different external libraries, which are managed through the NuGet package manager. These dependencies are listed in the project, but the files of the libraries themselves aren't included. Before you can build and run your application, you need to ensure there are local copies of each dependency in your project folder. The first command, `dotnet restore`, ensures your application's NuGet dependencies are copied to your project folder.

ASP.NET Core projects list their dependencies in the project's csproj file. This is an XML file that lists each dependency as a `PackageReference` node. When you run `dotnet restore`, it uses this file to establish which NuGet packages to download and copy to your project folder. Any dependencies listed are available for use in your application.

You can compile your application using `dotnet build`. This will check for any errors in your application and, if there are no issues, will produce an output that can be run using `dotnet run`.

Each command contains a number of switches that can modify its behavior. To see the full list of available commands, run

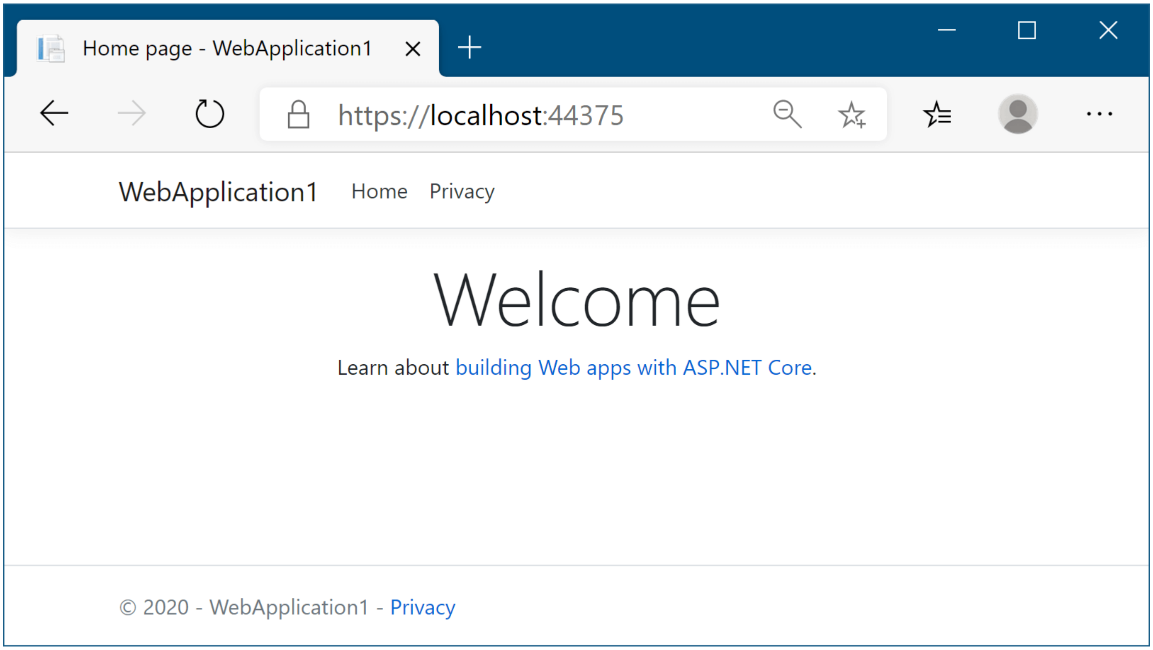
```
dotnet –help
```

or to see the options available for a particular command, `new` for example, run

```
dotnet new --help
```

2.3 Running the web application

You're ready to run your first application and there are a number of different ways to go about it. In Visual Studio, you can either click the green arrow on the toolbar next to IIS Express, or press the F5 shortcut. Visual Studio will automatically open a web browser window for you with the appropriate URL and, after a second or two, you should be presented with your brand-new application, as shown in figure 2.6. Alternatively, you can run the application from the command line with the .NET CLI tools using `dotnet run` and open the URL in a web browser manually, using the address provided on the command line.



Welcome

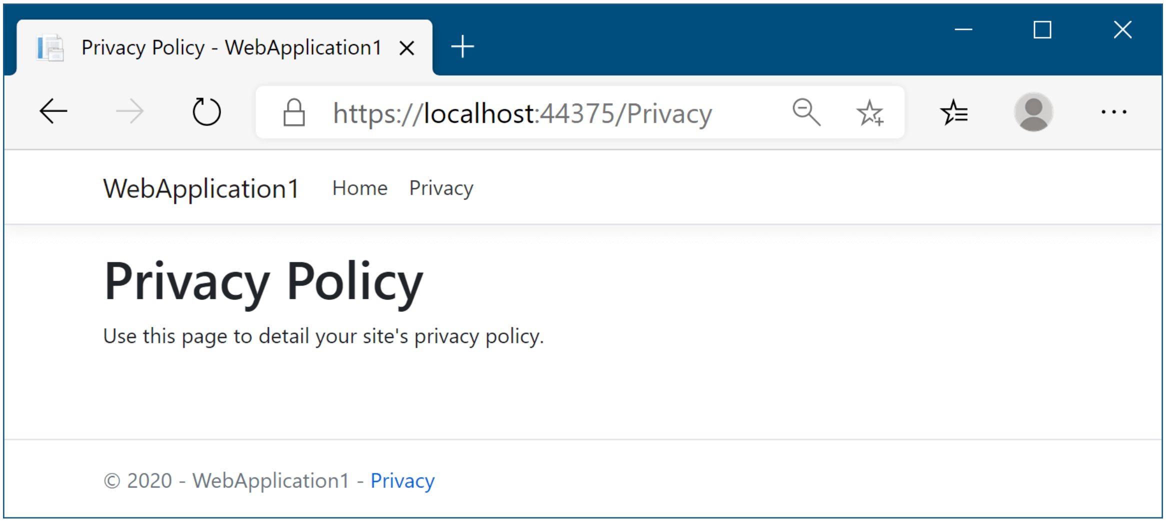
Learn about building Web apps with ASP.NET Core.

© 2020 - WebApplication1 - Privacy

Figure 2.6 The homepage of your new ASP.NET Core application. When you run from Visual Studio, by default IIS Express chooses a random port. If you're running from the command line with `dotnet run`, your application will be available at http://localhost:5000 and https://localhost:5001.

> **TIP** The first time you run the application from Visual Studio you will be prompted to install the development certificate. Doing so ensures your browser doesn't display warnings about an invalid certificate. See chapter 18 for more about HTTPS certificates.

By default, this page shows a simple Welcome banner, and a link to the official Microsoft documentation for ASP.NET Core. At the top of the page are two links: Home and Privacy. The Home link is the page you're currently on. Clicking Privacy will take you to a new page, as shown in figure 2.7. As you'll see shortly, you'll use Razor Pages in your application to define these two pages and to build the HTML they display.


Privacy Policy - WebApplication1
https://localhost:44375/Privacy
WebApplication1
Home
Privacy

Privacy Policy

Use this page to detail your site's privacy policy.

© 2020 - WebApplication1 - Privacy

Figure 2.7 The Privacy page of your application. You can navigate between the two pages of the application using the Home and Privacy links in the application's header. The app generates the content of the pages using Razor Pages.

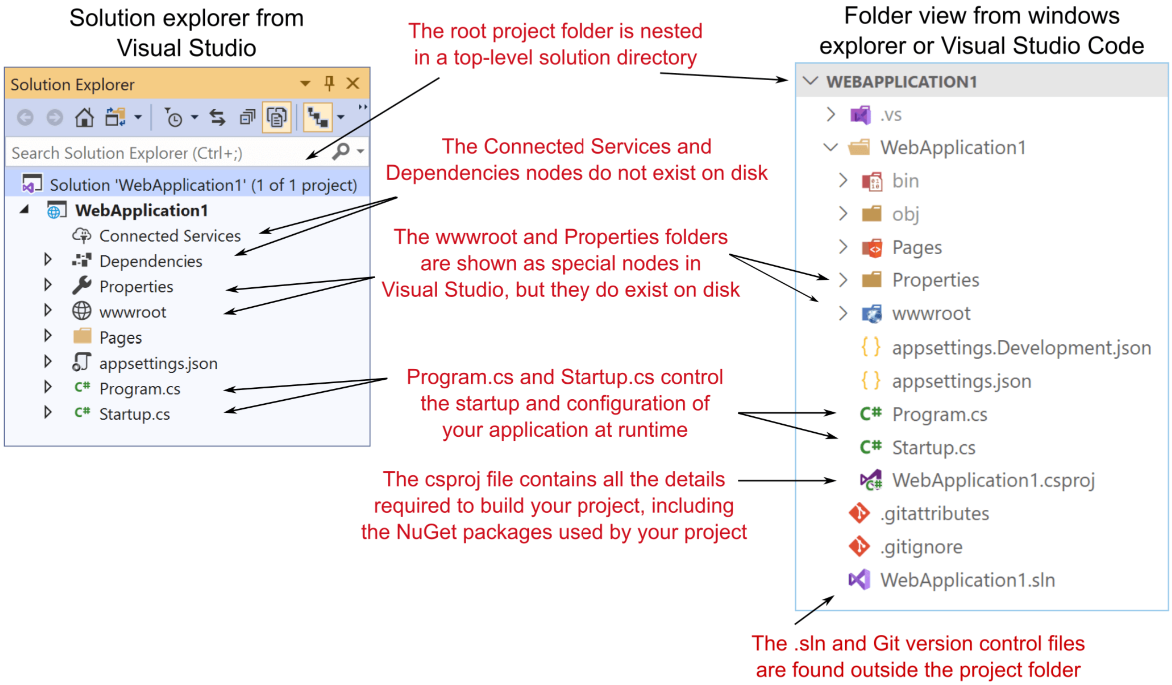
At this point, you need to notice a couple of things. First, the header containing the links and the application title "WebApplication1" is the same on both pages. Second, the title of the page, as shown in the tab of the browser, changes to match the current page. You'll see how to achieve these features in chapter 7, when we discuss the rendering of HTML using Razor templates.

> **NOTE** You can only view the application on the same computer that is running it at the moment, your application isn't exposed to the internet yet. You'll learn how to publish and deploy your application in chapter 16.

There isn't any more to the user experience of the application at this stage. Click around a little and, once you're happy with the behavior of the application, roll up your sleeves—it's time to look at some code!

2.4 Understanding the project layout

When you're new to a framework, creating an application from a template like this can be a mixed blessing. On the one hand, you can get an application up and running quickly, with little input required on your part. Conversely, the number of files can sometimes be overwhelming, leaving you scratching your head working out where to start. The basic web application template doesn't contain a huge number of files and folders, as shown in figure 2.8, but I'll run through the major ones to get you oriented.



The root project folder is nested in a top-level solution directory

The Connected Services and Dependencies nodes do not exist on disk

The wwwroot and Properties folders are shown as special nodes in Visual Studio, but they do exist on disk

Program.cs and Startup.cs control the startup and configuration of your application at runtime

The csproj file contains all the details required to build your project, including the NuGet packages used by your project

The .sln and Git version control files are found outside the project folder

Figure 2.8 The Solution Explorer and folder on disk for a new ASP.NET Core application. The Solution Explorer also displays the Connected Services and Dependencies nodes, which list NuGet and other dependencies, though the folders themselves don’t exist on disk.

The first thing to notice is that the main project, WebApplication1, is nested in a top-level directory with the name of the solution, also WebApplication1 in this case. Within this top-level folder, you’ll also find the solution (.sln) file for use by Visual Studio and files related to Git version control,[13] though these are hidden in Visual Studio’s Solution Explorer view.

> **NOTE** Visual Studio uses the concept of a solution to work with multiple projects. The example solution only consists of a single project, which is listed in the .sln file. If you use a CLI template to create your project, you won’t have a .sln or Git files unless you generate them explicitly using other .NET CLI templates.

Inside the solution folder, you’ll find your project folder, which in turn contains three subfolders—Pages, Properties, and wwwroot. Pages (unsurprisingly) contains the Razor Pages

[13] The Git files will only be added if you choose Add to Source Control in Visual Studio. You don’t have to use Git, but I strongly recommend using some sort of version control when you build applications. If you’re somewhat familiar with Git, but still find it a bit daunting, and a rebase terrifying, I highly recommend reading http://think-like-a-git.net/. It helped me achieve Git enlightenment.

files you’ll use to build your application. The Properties folder contains a single file, launchSettings.json, which controls how Visual Studio will run and debug the application. The wwwroot folder is special, in that it’s the only folder in your application that browsers are allowed to directly access when browsing your web app. You can store your CSS, JavaScript, images, or static HTML files in here and browsers will be able to access them. They won’t be able to access any file that lives outside of wwwroot.

Although the wwwroot and Properties folders exist on disk, you can see that Solution Explorer shows them as special nodes, out of alphabetical order, near the top of your project. You’ve got two more special nodes in the project, Dependencies and Connected Services, but they don’t have a corresponding folder on disk. Instead, they show a collection of all the dependencies, such as NuGet packages and remote services that the project relies on.

In the root of your project folder, you’ll find two JSON files: appsettings.json and appsettings.Development.json. These provide configuration settings which are used at runtime to control the behavior of your app.

The most important file in your project is WebApplication1.csproj, as it describes how to build your project. Visual Studio doesn’t explicitly show the csproj file, but you can edit it if you double-click the project name in Solution Explorer. We’ll have a closer look at this file in the next section.

Finally, Visual Studio shows two C# files in the project folder—Program.cs and Startup.cs. In sections 2.6 and 2.7, you’ll see how these fundamental classes are responsible for configuring and running your application.

2.5 The csproj project file: defining your dependencies

The csproj file is the project file for .NET applications and contains the details required for the .NET tooling to build your project. It defines the type of project being built (web app, console app, or library), which platform the project targets (.NET Core 3.1, .NET 5, and so on), and which NuGet packages the project depends on.

The project file has been a mainstay of .NET applications, but in ASP.NET Core it has had a facelift to make it easier to read and edit. These changes include:

- *No GUIDs*—Previously, Global Unique Identifiers (GUIDs) were used for many things, now they’re rarely used in the project file.
- *Implicit file includes*—Previously, every file in the project had to be listed in the csproj file for it to be included in the build. Now, files are automatically compiled.
- *No paths to NuGet package dlls*—Previously, you had to include the path to the dll files contained in NuGet packages in the csproj, as well as listing the dependencies in a packages.xml file. Now, you can reference the NuGet package directly in your csproj, and don’t need to specify the path on disk.

All of these changes combine to make the project file far more compact than you’ll be used to from previous .NET projects. The following listing shows the entire csproj file for your sample app.

Listing 2.1 The csproj project file, showing SDK, target framework, and references

```
<Project Sdk="Microsoft.NET.Sdk.Web">                                       #A
  <PropertyGroup>
    <TargetFramework>netcoreapp3.1</TargetFramework>                        #B
  </PropertyGroup>
</Project>
```

#A The SDK attribute specifies the type of project you're building.
#B The TargetFramework is the framework you'll run on, in this case, .NET Core 3.1.

For simple applications, you probably won't need to change the project file much. The `Sdk` attribute on the `Project` element includes default settings that describe how to build your project, whereas the `TargetFramework` element describes the framework your application will run on. For .NET Core 3.1 projects, this will have the `netcoreapp3.1` value; if you're running on .NET 5, this would be `net5.0`.

TIP With the new csproj style, Visual Studio users can double-click a project in Solution Explorer to edit the .csproj, without having to close the project first.

The most common changes you'll make to the project file are to add additional NuGet packages using the `PackageReference` element. By default, your app doesn't reference any NuGet packages at all.

Using NuGet libraries in your project

Even though all apps are unique in some way, they also all share common requirements. For example, most apps need to access a database, or manipulate JSON or XML formatted data. Rather than having to reinvent that code in every project, you should use reusable libraries that already exist.

NuGet is the library package manager for .NET, where libraries are packaged into *NuGet packages* and published to https://nuget.org. You can use these packages in your project by referencing the unique package name in your csproj file. These make the package's namespace and classes available in your code files.

You can add a NuGet reference to your project by running `dotnet add package <packagename>` from inside the project folder. This updates your project file with a `<PackageReference>` node and restores the NuGet package for your project. For example, to install the popular Newtonsoft.Json library you would run

```
dotnet add package Newtonsoft.Json
```

This adds a reference to the latest version of the library to your project file, as shown below, and makes the Newtonsoft.Json namespace available in your source code files

```
<Project Sdk="Microsoft.NET.Sdk.Web">
  <PropertyGroup>
    <TargetFramework>netcoreapp3.1</TargetFramework>
  </PropertyGroup>
  <ItemGroup>
    <PackageReference Include="NewtonSoft.Json" Version="12.0.3" />
  </ItemGroup>
</Project>
```

As a point of interest, there's no officially agreed upon pronunciation for NuGet. Feel free to use the popular "noo-get" or "nugget" styles, or if you're feeling especially posh, "noo-jay"!

The simplified project file format is much easier to edit by hand than previous versions, which is great if you're developing cross-platform. But if you're using Visual Studio, don't feel like you have to take this route. You can still use the GUI to add project references, exclude files, manage NuGet packages, and so on. Visual Studio will update the project file itself, as it always has.

> **TIP** For further details on the changes to the csproj format, see the documentation at https://docs.microsoft.com/en-us/dotnet/core/tools/csproj.

The project file defines everything Visual Studio and the .NET CLI need to build your app. Everything, that is, except the code! In the next section, we'll take a look at the entry point for your ASP.NET Core application—the Program.cs class.

2.6 The Program class: building a web host

All ASP.NET Core applications start in the same way as .NET Console applications—with a Program.cs file. This file contains a `static void Main` function, which is a standard characteristic of console apps. This method must exist and is called whenever you start your web application. In ASP.NET Core applications, it's used to build and run an `IHost` instance, as shown in the following listing, which shows the default Program.cs file. The `IHost` is the core of your ASP.NET Core application, containing the application configuration and the Kestrel server that listens for requests and sends responses.

Listing 2.2 The default Program.cs configures and runs an `IWebHost`

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args)                         #A
            .Build()                                    #B
            .Run();                                     #C
}
    public static IHostBuilder CreateHostBuilder(string[] args) =>
        Host.CreateDefaultBuilder(args)                 #D
            .ConfigureWebHostDefaults(webBuilder =>     #E
            {
                webBuilder.UseStartup<Startup>();       #F
            };
    }
}
```

#A Create an IHostBuilder using the CreateHostBuilder method .
#B Build and return an instance of IHost from the IHostBuilder.
#C Run the IHost, start listening for requests and generating responses.
#D Create an IHostBuilder using the default configuration.
#E Configure the application to use Kestrel and listen to HTTP requests
#F The Startup class defines most of your application's configuration.

The `Main` function contains all the basic initialization code required to create a web server and to start listening for requests. It uses a `IHostBuilder`, created by the call to `CreateDefaultBuilder`, to define how the `IHost` is configured, before instantiating the `IWebHost` with a call to `Build()`.

> **NOTE** You'll find this pattern of using a builder object to configure a complex object repeated throughout the ASP.NET Core framework. It's a useful technique for allowing users to configure an object, delaying its creation until all configuration has finished. It's one of the patterns described in the "Gang of Four" book, ***Design Patterns: Elements of Reusable Object-Oriented Software*** (Addison Wesley, 1994).

Much of your app's configuration takes place in the `IHostBuilder` created by the call to `CreateDefaultBuilder`, but it delegates some responsibility to a separate class, `Startup`. The `Startup` class referenced in the generic `UseStartup<>` method is where you configure your app's services and define your middleware pipeline. In section 2.7, we'll spend a while delving into this crucial class.

At this point, you may be wondering why you need two classes for configuration: `Program` and `Startup`. Why not include all of your app's configuration in one class or the other?

Figure 2.9 shows the typical split of configuration components between `Program` and `Startup`. Generally speaking, `Program` is where you configure the infrastructure of your application, such as the HTTP server, integration with IIS, and configuration sources. In contrast, `Startup` is where you define which components and features your application uses, and the middleware pipeline for your app.

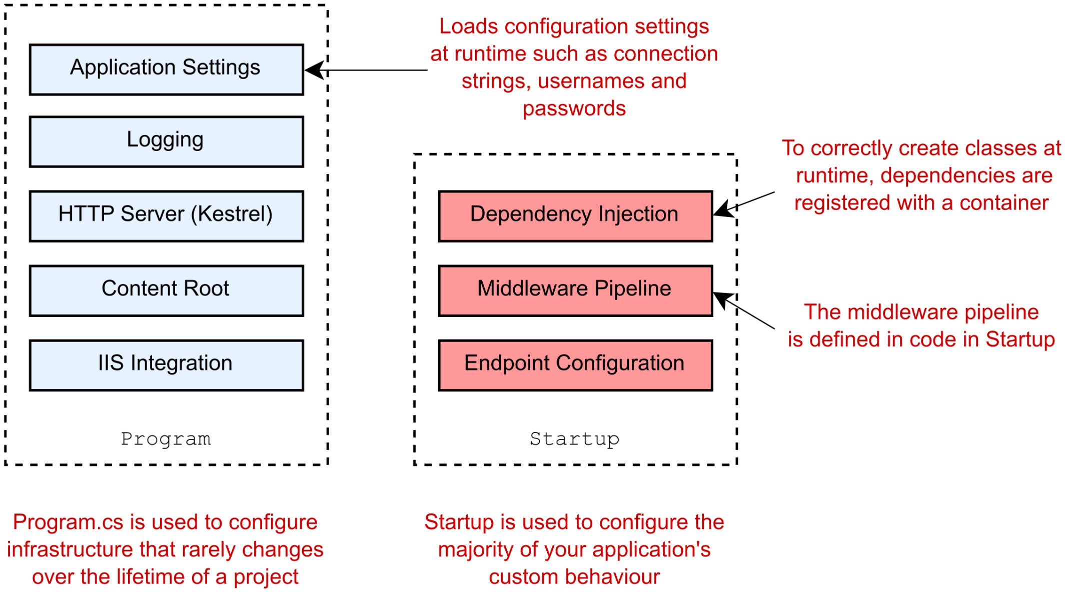

Application Settings
Logging
HTTP Server (Kestrel)
Content Root
IIS Integration
Program
Loads configuration settings at runtime such as connection strings, usernames and passwords
Dependency Injection
Middleware Pipeline
Endpoint Configuration
Startup
To correctly create classes at runtime, dependencies are registered with a container
The middleware pipeline is defined in code in Startup
Program.cs is used to configure infrastructure that rarely changes over the lifetime of a project
Startup is used to configure the majority of your application's custom behaviour

Figure 2.9 The difference in configuration scope for `Program` and `Startup`. `Program` is concerned with infrastructure configuration that will typically remain stable throughout the lifetime of the project. In contrast, you'll often modify `Startup` to add new features and to update application behavior.

The `Program` class for two different ASP.NET Core applications will generally be similar, but the `Startup` classes will often differ significantly (though they generally follow a similar pattern, as you'll see shortly). You'll rarely find that you need to modify `Program` as your application grows, whereas you'll normally update `Startup` whenever you add additional features. For example, if you add a new NuGet dependency to your project, you'll normally need to update `Startup` to make use of it.

The `Program` class is where a lot of app configuration takes place, but in the default templates this is hidden inside the `CreateDefaultBuilder` method. The `CreateDefaultBuilder` method is a static helper method that simplifies the bootstrapping of your app by creating an `IHostBuilder` with some common configuration. In chapter 11, we'll peek inside this method and explore the configuration system, but for now, it's enough to keep figure 2.9 in mind, and to be aware that you can completely change the `IHost` configuration if you need to.

The other helper method used by default is `ConfigureWebHostDefaults`. This uses a `WebHostBuilder` object to configure Kestrel to listen for HTTP requests.

Creating services with the generic host

It might seem strange that you must call `ConfigureWebHostDefaults` as well as `CreateDefaultBuilder`—couldn't we just have one method? Isn't handling HTTP requests the whole *point* of ASP.NET Core?

Well, yes and no! ASP.NET Core 3.0 introduced the concept of a *generic host*. This allows you to use much of the same framework as ASP.NET Core applications to write non-HTTP applications. These apps can be run as console apps or can be installed as Windows services (or as systemd daemons on Linux), to run background tasks or read from message queues, for example.

Kestrel and the web framework of ASP.NET Core builds *on top* of the generic host functionality introduced in ASP.NET Core 3.0. To configure a typical ASP.NET Core app, you configure the generic host features that are common across all apps; features such as configuration, logging, and dependency services. For web applications, you then also configure the services such as Kestrel that are necessary to handle web requests.

In chapter 20 you'll see how to build applications using the generic host for running scheduled tasks and building services.

Once the configuration of the `IHostBuilder` is complete, the call to `Build` produces the `IHost` instance, but the application still isn't handling HTTP requests yet. It's the call to `Run` that starts the HTTP server listening. At this point, your application is fully operational and can respond to its first request from a remote browser.

2.7 The Startup class: configuring your application

As you've seen, `Program` is responsible for configuring a lot of the infrastructure for your app, but you configure some of your app's behavior in `Startup`. The `Startup` class is responsible for configuring two main aspects of your application:

- *Service registration*—Any classes that your application depends on for providing functionality—both those used by the framework and those specific to your application—must be registered so that they can be correctly instantiated at runtime.
- *Middleware and endpoints*—How your application handles and responds to requests.

You configure each of these aspects in its own method in `Startup`, service registration in `ConfigureServices`, and middleware configuration in `Configure`. A typical outline of `Startup` is shown in the following listing.

Listing 2.3 An outline of Startup.cs showing how each aspect is configured

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services)    #A
    {
        // method details
    }
    public void Configure(IApplicationBuilder app)               #B
    {
        // method details
    }
}
```

#A Configure services by registering services with the IServiceCollection.
#B Configure the middleware pipeline for handling HTTP requests.

The IHostBuilder created in Program calls ConfigureServices and then Configure, as shown in figure 2.10. Each call configures a different part of your application, making it available for subsequent method calls. Any services registered in the ConfigureServices method are available to the Configure method. Once configuration is complete, an IHost is created by calling Build() on the IHostBuilder.

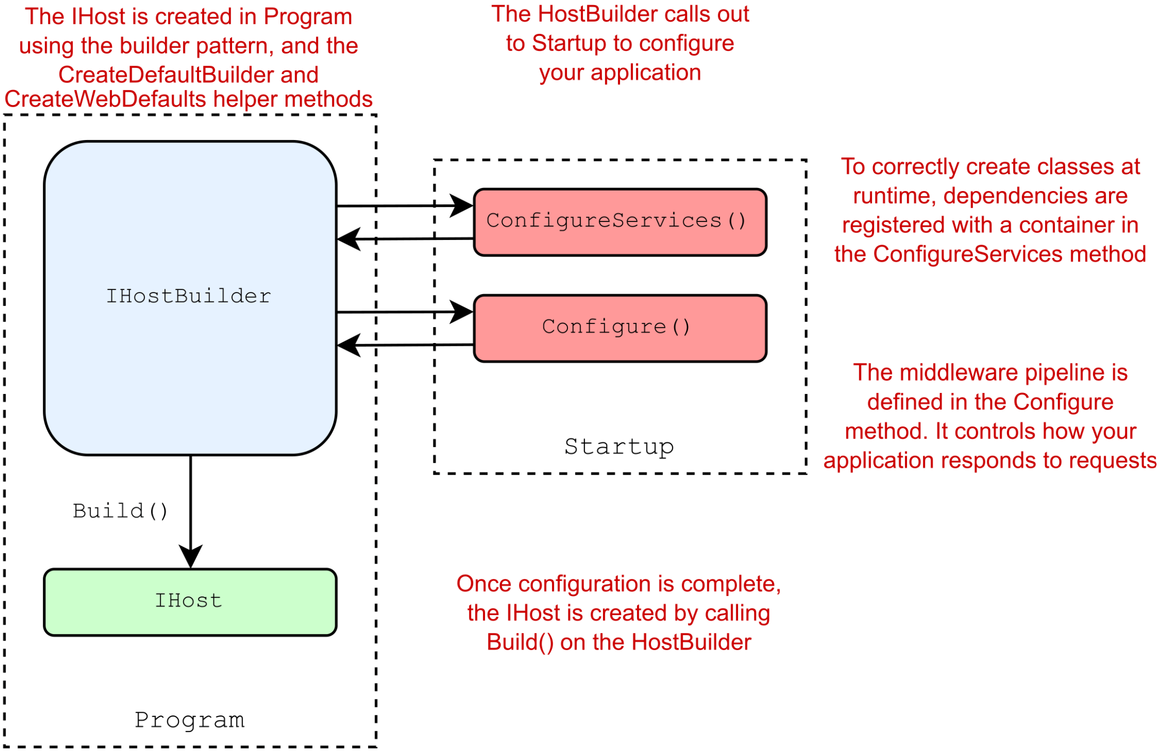

The IHost is created in Program using the builder pattern, and the CreateDefaultBuilder and CreateWebDefaults helper methods
The HostBuilder calls out to Startup to configure your application
To correctly create classes at runtime, dependencies are registered with a container in the ConfigureServices method
The middleware pipeline is defined in the Configure method. It controls how your application responds to requests
Once configuration is complete, the IHost is created by calling Build() on the HostBuilder
IHostBuilder
ConfigureServices()
Configure()
Startup
Build()
IHost
Program

Figure 2.10 The IHostBuilder is created in Program.cs and calls methods on Startup to configure the application's services and middleware pipeline. Once configuration is complete, the IHost is created by calling Build() on the IHostBuilder.

An interesting point about the Startup class is that it doesn't implement an interface as such. Instead, the methods are invoked by using *reflection* to find methods with the predefined names of Configure and ConfigureServices. This makes the class more flexible and enables you to modify the signature of the method to accept additional parameters that are fulfilled automatically. I'll cover how this works in detail in chapter 10, for now it's enough to know that anything that's configured in ConfigureServices can be accessed by the Configure method.

DEFINITION *Reflection* in .NET allows you to obtain information about types in your application at runtime. You can use reflection to create instances of classes at runtime, and to invoke and access them.

Given how fundamental the `Startup` class is to ASP.NET Core applications, the rest of section 2.7 walks you through both `ConfigureServices` and `Configure`, to give you a taste of how they're used. I won't explain them in detail (we have the rest of the book for that!), but you should keep in mind how they follow on from each other and how they contribute to the application configuration as a whole.

2.7.1 Adding and configuring services

ASP.NET Core uses small, modular components for each distinct feature. This allows individual features to evolve separately, with only a loose coupling to others, and is generally considered good design practice. The downside to this approach is that it places the burden on the consumer of a feature to correctly instantiate it. Within your application, these modular components are exposed as one or more *services* that are used by the application.

DEFINITION Within the context of ASP.Net Core, *service* refers to any class that provides functionality to an application and could be classes exposed by a library or code you've written for your application.

For example, in an e-commerce app, you might have a `TaxCalculator` that calculates the tax due on a particular product, taking into account the user's location in the world. Or you might have a `ShippingCostService` that calculates the cost of shipping to a user's location. A third service, `OrderTotalCalculatorService`, might use both of these services to work out the total price the user must pay for an order. Each service provides a small piece of independent functionality, but you can combine them to create a complete application. This is known as the *single responsibility principle*.

DEFINITION The *single responsibility principle* (SRP) states that every class should be responsible for only a single piece of functionality—it should only need to change if that required functionality changes. It's one of the five main design principles promoted by Robert C. Martin in *Agile Software Development, Principles, Patterns, and Practices* (Pearson, 2011).

The `OrderTotalCalculatorService` needs access to an instance of `ShippingCostService` and `TaxCalculator`. A naïve approach to this problem is to use the `new` keyword and create an instance of a service whenever you need it. Unfortunately, this tightly couples your code to the specific implementation you're using and can completely undo all the good work achieved by modularizing the features in the first place. In some cases, it may break the SRP by making you perform initialization code in addition to using the service you created.

One solution to this problem is to make it somebody else's problem. When writing a service, you can declare your dependencies and let another class fill those dependencies for you. Your service can then focus on the functionality for which it was designed, instead of trying to work out how to build its dependencies.

This technique is called dependency injection or the inversion of control (IoC) principle and is a well-recognized *design pattern* that is used extensively.

DEFINITION *Design patterns* are solutions to common software design problems.

Typically, you'll register the dependencies of your application into a "container," which can then be used to create any service. This is true for both your own custom application services and the framework services used by ASP.NET Core. You must register each service with the container before it can be used in your application.

NOTE I'll describe the dependency inversion principle and the IoC container used in ASP.NET Core in detail in chapter 10.

In an ASP.NET Core application, this registration is performed in the `ConfigureServices` method. Whenever you use a new ASP.NET Core feature in your application, you'll need to come back to this method and add in the necessary services. This is not as arduous as it sounds, as shown here, taken from the example application.

Listing 2.4 `Startup.ConfigureServices`: adding services to the IoC container

```
public class Startup
{
    // This method gets called by the runtime.
    // Use this method to add services to the container.
    public void ConfigureServices(IServiceCollection services)
    {
        services.AddRazorPages();
    }
}
```

You may be surprised that a complete Razor Pages application only includes a single call to add the necessary services, but the `AddRazorPages()` method is an extension method that encapsulates all the code required to set up the Razor Pages services. Behind the scenes, it adds various Razor services for rendering HTML, formatter services, routing services, and many more!

As well as registering framework-related services, this method is where you'd register any custom services you have in your application, such as the example `TaxCalculator` discussed previously. The `IServiceCollection` is a list of every known service that your application will need to use. By adding a new service to it, you ensure that whenever a class declares a dependency on your service, the IoC container knows how to provide it.

With your services all configured, it's time to move on to the final configuration step, defining how your application responds to HTTP requests.

2.7.2 Defining how requests are handled with middleware

So far, in the IHostBuilder and Startup class, you've defined the infrastructure of the application and registered your services with the IoC container. In the final configuration method of Startup, Configure, you define the middleware pipeline for the application, which is what defines how your app handles HTTP requests. Here's the Configure method for the template application.

Listing 2.5 Startup.Configure: defining the middleware pipeline

```
public class Startup
{
    public void Configure(
        IApplicationBuilder app,                           #A
        IWebHostEnvironment env)                           #B
    {
        if (env.IsDevelopment())                           #C
        {
            app.UseDeveloperExceptionPage();               #D
        }
        else
        {
            app.UseExceptionHandler("/Error");            #E
            app.UseHsts();                                #E
        }

        app.UseHttpsRedirection();

        app.UseStaticFiles();                             #F

        app.UseRouting();                                 #G
        app.UseAuthorization();                           #H

        app.UseEndpoints(endpoints =>                     #H
        {
            endpoints.MapRazorPages();
        }
    }
}
```

#A The IApplicationBuilder is used to build the middleware pipeline.
#B Other services can be accepted as parameters.
#C Different behavior when in development or production
#D Only runs in a development environment
#E Only runs in a production environment
#F Adds the static file middleware
#G Adds the endpoint routing middleware, which determines which endpoint to execute
#H Adds the endpoint middleware, which executes a Razor Page to generate an HTML response

As I described previously, middleware consists of small components that execute in sequence when the application receives an HTTP request. They can perform a whole host of functions, such as logging, identifying the current user for a request, serving static files, and handling errors.

The IApplicationBuilder that's passed to the Configure method is used to define the order in which middleware executes. The order of the calls in this method is important, as the order in which they're added to the builder is the order they'll execute in the final pipeline. Middleware can only use objects created by previous middleware in the pipeline—it can't access objects created by later middleware.

> **WARNING** It's important that you consider the order of middleware when adding it to the pipeline. Middleware can only use objects created by earlier middleware in the pipeline.

You should also note that an IWebHostEnvironment parameter is used to provide different behavior when you're in a development environment. When you're running in development (when EnvironmentName is set to "Development"), the Configure method adds one piece of exception-handling middleware to the pipeline; in production, it adds a different one.

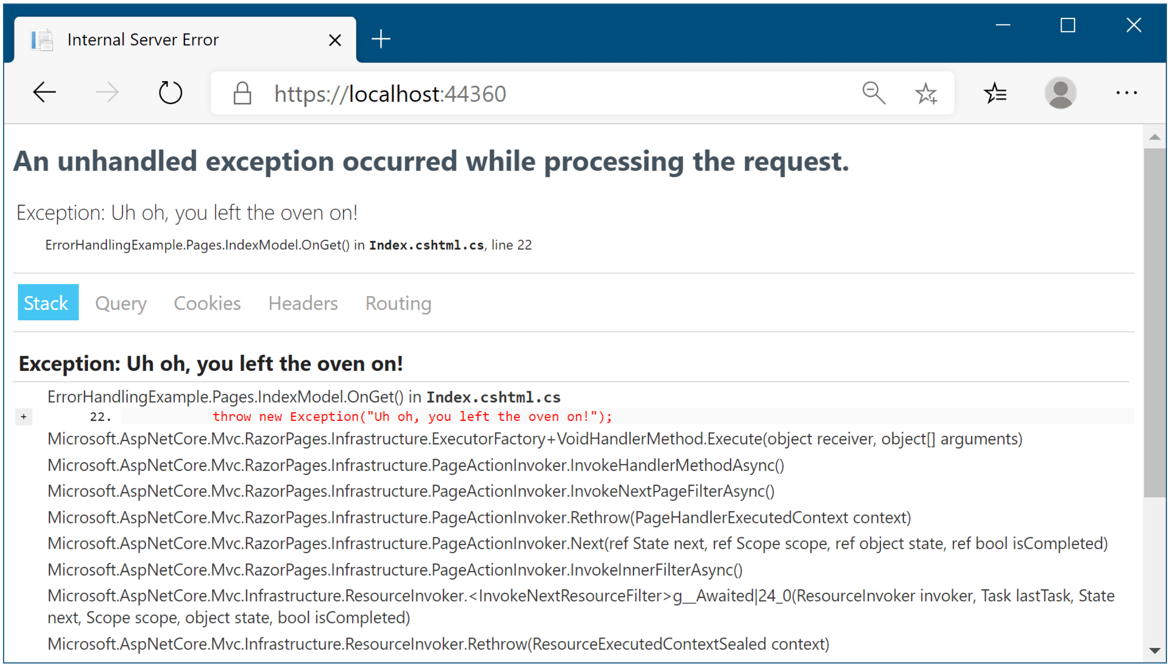
The IWebHostEnvironment object contains details about the current environment, as determined by the IHostBuilder in Program. It exposes a number of properties:

- ContentRootPath—Location of the working directory for the app, typically the folder in which the application is running
- WebRootPath—Location of the wwwroot folder that contains static files
- EnvironmentName—Whether the current environment is a development or production environment

IWebHostEnvironment is already set by the time Startup is invoked; you can't change these values using the application settings in Startup. EnvironmentName is typically set externally by using an environment variable when your application starts.

> **NOTE** You'll learn about hosting environments and how to change the current environment in chapter 11.

In development, DeveloperExceptionPageMiddleware (added by the UseDeveloperExceptionPage() call) ensures that, if your application throws an exception that isn't caught, you'll be presented with as much information as possible in the browser to diagnose the problem, as shown in figure 2.11. It's akin to the "yellow screen of death" in the previous version of ASP.NET, but this time it's white, not yellow!



An unhandled exception occurred while processing the request.

Exception: Uh oh, you left the oven on!

ErrorHandlingExample.Pages.IndexModel.OnGet() in Index.cshtml.cs, line 22

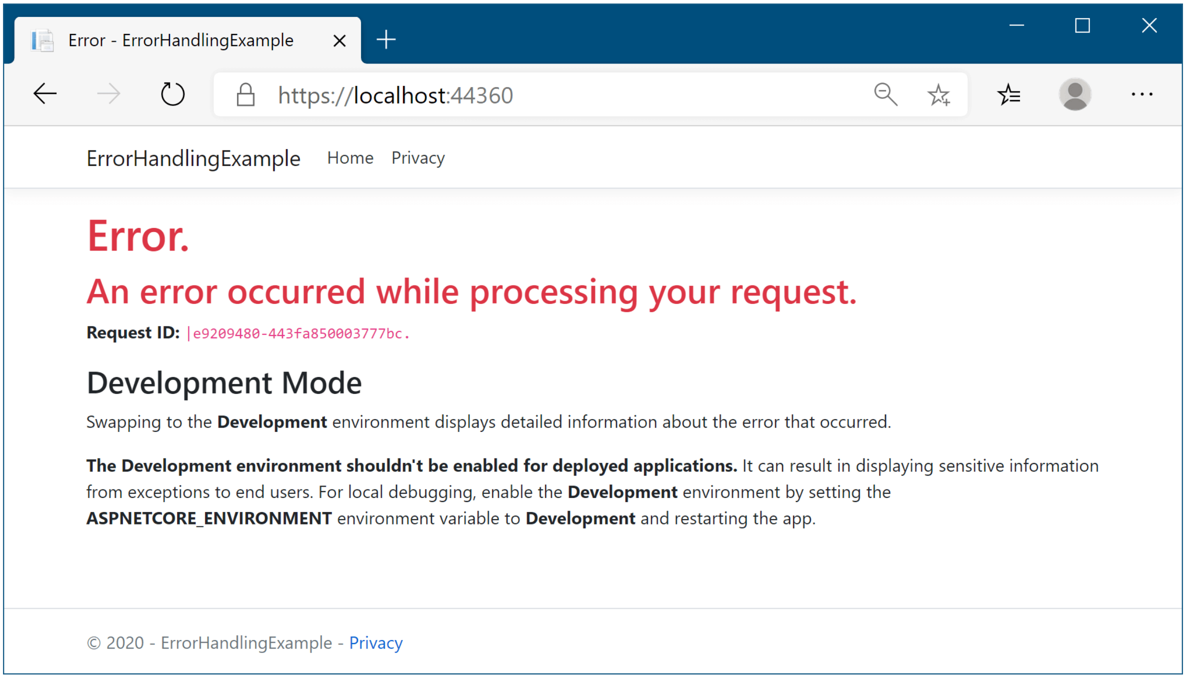
Exception: Uh oh, you left the oven on!

```
ErrorHandlingExample.Pages.IndexModel.OnGet() in Index.cshtml.cs
+     22.              throw new Exception("Uh oh, you left the oven on!");
Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.ExecutorFactory+VoidHandlerMethod.Execute(object receiver, object[] arguments)
Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.InvokeHandlerMethodAsync()
Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.InvokeNextPageFilterAsync()
Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.Rethrow(PageHandlerExecutedContext context)
Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.Next(ref State next, ref Scope scope, ref object state, ref bool isCompleted)
Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.InvokeInnerFilterAsync()
Microsoft.AspNetCore.Mvc.Infrastructure.ResourceInvoker.<InvokeNextResourceFilter>g__Awaited|24_0(ResourceInvoker invoker, Task lastTask, State next, Scope scope, object state, bool isCompleted)
Microsoft.AspNetCore.Mvc.Infrastructure.ResourceInvoker.Rethrow(ResourceExecutedContextSealed context)
```

Figure 2.11 The developer exception page contains many different sources of information to help you diagnose a problem, including the exception stack trace and details about the request that generated the exception.

NOTE The default templates also add `HstsMiddleware` in production which sets security headers in your response, in line with industry best practices. See chapter 18 for details about this and other security-related middleware.

When you're running in a production environment, exposing this amount of data to users would be a big security risk. Instead, `ExceptionHandlerMiddleware` is registered so that, if users encounter an exception in your method, they will be presented with a friendly error page that doesn't reveal the source of the problems. If you run the default template in production mode and trigger an error, then you'll be presented with the message shown in figure 2.12 instead. Obviously, you'd need to update this page to be more visually appealing and more user-friendly, but at least it doesn't reveal the inner workings of your application!



Error.

An error occurred while processing your request.

Request ID: |e9209480-443fa850003777bc.

Development Mode

Swapping to the **Development** environment displays detailed information about the error that occurred.

The Development environment shouldn't be enabled for deployed applications. It can result in displaying sensitive information from exceptions to end users. For local debugging, enable the **Development** environment by setting the **ASPNETCORE_ENVIRONMENT** environment variable to **Development** and restarting the app.

© 2020 - ErrorHandlingExample - Privacy

Figure 2.12 The default exception-handling page. In contrast to the developer exception page, this doesn't reveal any details about your application to users. In reality, you'd update the message to something more user-friendly.

The next piece of middleware added to the pipeline is the `HttpsRedirectionMiddleware`, using the statement:

```
app.UseHttpsRedirection();
```

This ensures your application only responds to secure (HTTPS) requests and is an industry best practice. We'll look more at HTTPS in chapter 18. The `StaticFileMiddleware` is added to the pipeline next using this statement:

```
app.UseStaticFiles();
```

This middleware is responsible for handling requests for static files such as CSS files, JavaScript files, and images. When a request arrives at the middleware, it checks to see if the request is for an existing file. If it is, then the middleware returns the file. If not, the request is ignored and the next piece of middleware can attempt to handle the request. Figure 2.13 shows how the request is processed when a static file is requested. When the static-file middleware handles a request, other middleware that comes later in the pipeline, such as the routing middleware or the endpoint middleware, won't be called at all.

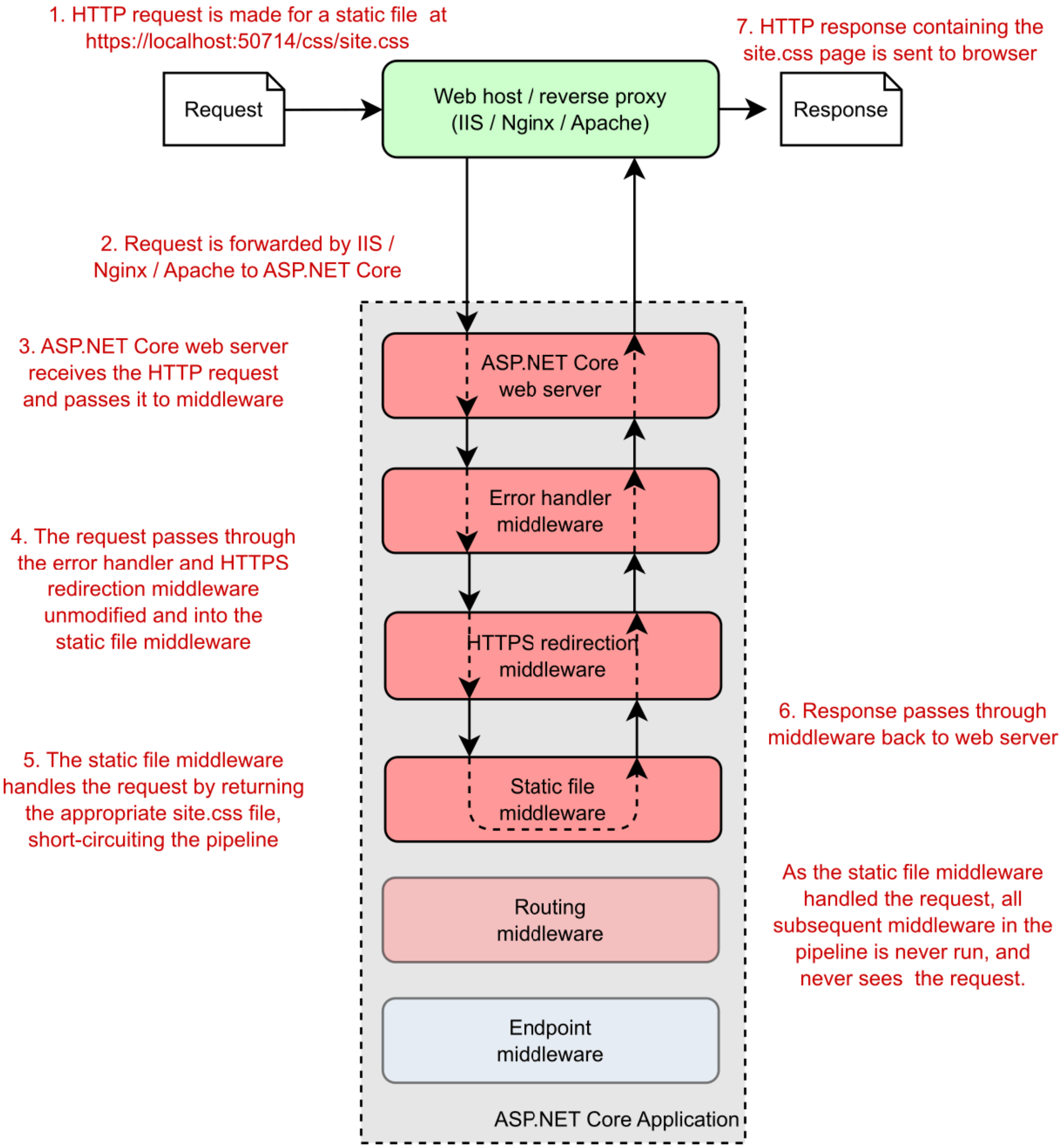

1. HTTP request is made for a static file at https://localhost:50714/css/site.css
Request
Web host / reverse proxy (IIS / Nginx / Apache)
Response
7. HTTP response containing the site.css page is sent to browser
2. Request is forwarded by IIS / Nginx / Apache to ASP.NET Core
3. ASP.NET Core web server receives the HTTP request and passes it to middleware
ASP.NET Core web server
Error handler middleware
4. The request passes through the error handler and HTTPS redirection middleware unmodified and into the static file middleware
HTTPS redirection middleware
6. Response passes through middleware back to web server
5. The static file middleware handles the request by returning the appropriate site.css file, short-circuiting the pipeline
Static file middleware
Routing middleware
As the static file middleware handled the request, all subsequent middleware in the pipeline is never run, and never sees the request.
Endpoint middleware
ASP.NET Core Application

Figure 2.13 An overview of a request for a static file at /css/site.css for an ASP.NET Core application. The request passes through the middleware pipeline until it's handled by the static file middleware. This returns the requested CSS file as the response, which passes back to the web server. The endpoint middleware is never invoked and never sees the request.

Which brings us to the most substantial pieces of middleware in the pipeline: the routing middleware and the endpoint middleware. Together, this pair of middleware are responsible for interpreting the request to determine which Razor Page to invoke, for reading parameters from the request, and for generating the final HTML. Despite that, very little configuration is required—you need only to add the middleware to the pipeline and specify that you wish to use Razor Page endpoints by calling `MapRazorPages`. For each request, the routing middleware uses the request's URL to determine which Razor Page to invoke. The endpoint middleware actually executes the Razor Page to generate the HTML response.

> **NOTE** **The default templates also add the `AuthorizationMiddleware` *between* the routing middleware and the endpoint middleware. This allows the authorization middleware to decide whether to allow access *before* the Razor Page is executed. You'll learn more about this approach in chapter 5 on routing and chapter 15 on authorization.**

Phew! You've finally finished configuring your application with all the settings, services, and middleware it needs. Configuring your application touches on a wide range of different topics that we'll delve into further throughout the book, so don't worry if you don't fully understand all the steps yet.

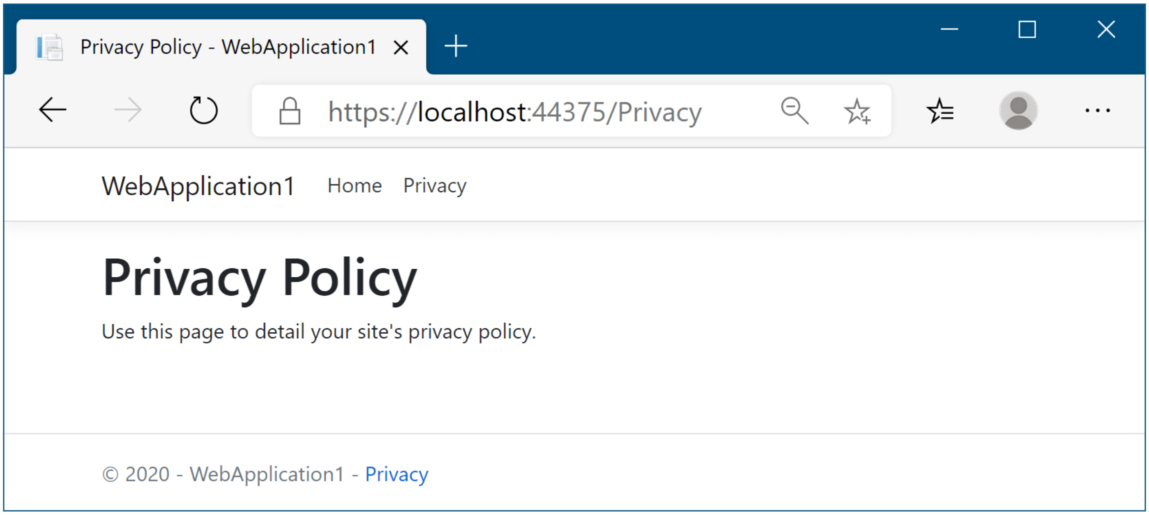
Once the application is configured, it can start handling requests. But *how* does it handle them? I've already touched on `StaticFileMiddleware`, which will serve the image and CSS files to the user, but what about the requests that require an HTML response? In the rest of this chapter, I'll give you a glimpse into Razor Pages and how they generate HTML.

2.8 Generating responses with Razor Pages

When an ASP.NET Core application receives a request, it progresses through the middleware pipeline until a middleware component can handle it, as you saw in figure 2.13. Normally, the final piece of middleware in a pipeline is the endpoint middleware. This middleware works with the routing middleware to match a request URL's path to a configured route, which defines which Razor Page to invoke.

> **DEFINITION** **A path is the remainder of the request URL, once the domain has been removed. For example, for a request to www.microsoft.com/account/manage, the path is /account/manage.**

Once a Razor Page has been selected, the routing middleware stores a note of the selected Razor Page in the request's `HttpContext` and continues executing the middleware pipeline. Eventually the request will reach the endpoint middleware. The endpoint middleware executes the Razor Page to generate the HTML response, and sends it back to the browser, as shown in figure 2.14.



Privacy Policy - WebApplication1
https://localhost:44375/Privacy
WebApplication1
Home
Privacy

Privacy Policy

Use this page to detail your site's privacy policy.

© 2020 - WebApplication1 - Privacy

Figure 2.14 Rendering a Razor template to HTML. The Razor Page is selected based on the URL page /Privacy and is executed to generate the HTML

In the next section we'll look at how Razor Pages generate HTML using the Razor syntax. After that we'll look at how you can use Page Handlers to add business logic and behavior to your Razor Pages.

2.8.1 Generating HTML with Razor Pages

Razor Pages are stored in cshtml files (a portmanteau of cs and html) within the Pages folder of your project. In general, the routing middleware maps request URL paths to a single Razor Page by looking in the Pages folder of your project for a Razor Page with the same path. For example, you can see in figure 2.14 that the Privacy page of your app corresponds to the path `/Privacy` in the browser's address bar. If you look inside the Pages folder of your project, you'll find the Privacy.cshtml file, shown in the listing below.

Listing 2.6 The Privacy.cshtml Razor Page

```
@page                                                         #A
@model PrivacyModel                                           #B
@{
    ViewData["Title"] = "Privacy Policy";                     #C
}
<h1>@ViewData["Title"]</h1>                                   #D

<p>Use this page to detail your site's privacy policy.</p>    #E
```

#A Indicates that this is a Razor Page
#B Links the Razor Page to a specific PageModel
#C C# code that doesn't write to the response
#D HTML with dynamic C# values written to the response

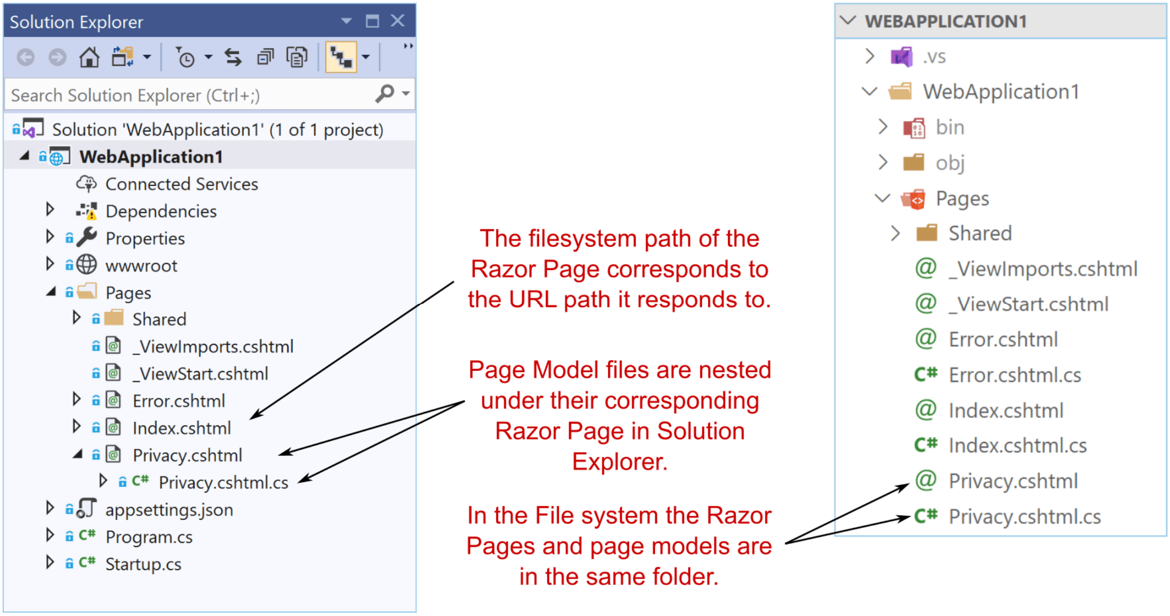
#E Standalone, static HTML

Razor Pages use a templating syntax, called *Razor*, that combines static HTML with dynamic C# code and HTML generation. The `@page` directive on the first line of the Razor Page is the most important. This directive must always be placed on the first line of the file, as it tells ASP.NET Core that the cshtml file is a Razor Page. Without it, you won't be able to view your page correctly.

The next line of the Razor Page defines which `PageModel` in your project the Razor Page is associated with:

```
@model PrivacyModel
```

In this case the `PageModel` is called `PrivacyModel`, and it follows the standard convention for naming Razor Page models. You can find this class in the Privacy.cshtml.cs file in the Pages folder of your project, as shown in figure 2.15. Visual Studio nests these file underneath the Razor Page .cshtml files in Solution explorer. We'll look at the page model in the next section.



The filesystem path of the Razor Page corresponds to the URL path it responds to.

Page Model files are nested under their corresponding Razor Page in Solution Explorer.

In the File system the Razor Pages and page models are in the same folder.

Figure 2.15 By convention page models for Razor Pages are placed in a file with the same name as the Razor Page with a .cs suffix appended. Visual Studio nests these files under the Razor Page in solution explorer.

In addition to the `@page` and `@model` directives, you can see that static HTML is always valid in a Razor Page and will be rendered "as is" in the response.

```
<p>Use this page to detail your site's privacy policy.</p>
```

You can also write ordinary C# code in Razor templates by using this construct

```
@{ /* C# code here */ }
```

Any code between the curly braces will be executed but won't be written to the response. In the listing you're setting the title of the page by writing a key to the `ViewData` dictionary, but you aren't writing anything to the response at this point:

```
@{
    ViewData["Title"] = "Privacy Policy";
}
```

Another feature shown in this template is dynamically writing C# variables to the HTML stream using the `@` symbol. This ability to combine dynamic and static markup is what gives Razor Pages their power. In the example, you're fetching the `"Title"` value from the `ViewData` dictionary and writing the values to the response inside an `<h1>` tag:

```
<h1>@ViewData["Title"]</h1>
```

At this point, you might be a little confused by the template from the listing when compared to the output shown in figure 2.14. The title and the static HTML content appear in both the listing and figure, but some parts of the final web page don't appear in the template. How can that be?

Razor Pages have the concept of *layouts*, which are "base" templates that define the common elements of your application, such as headers and footers. The HTML of the layout combines with the Razor Page template to produce the final HTML that's sent to the browser. This prevents you having to duplicate code for the header and footer in every page and means that, if you need to tweak something, you'll only need to do it in one place.

> **NOTE** **I'll cover Razor templates, including layouts, in detail in chapter 7. You can find layouts in the Pages/Shared folder of your project.**

As you've already seen, you can include C# code in your Razor Pages by using curly braces `@{ }`, but generally speaking you want to limit the code in your cshtml to presentational concerns only. Complex logic, code to access services such as a database, and data manipulation should be handled in the `PageModel` instead.

2.8.2 Handling request logic with PageModels and handlers

As you've already seen, the `@page` directive in a cshtml file marks the page as a Razor Page, but most Razor Pages also have an associated *page model*. By convention, this is placed in a file commonly known as a "code behind" file which has a cs extension, as you saw in figure 2.15. Page models should derive from the `PageModel` base class, and typically contain one or more methods called *page handlers*, that define how to handle requests to the Razor Page.

> **DEFINITION** A *page handler* is a method that runs in response to a request. Razor Page models must be derived from the `PageModel` class. They can contain multiple page handlers, though typically they only contain one or two.

The listing below shows the page model for the Privacy.cshtml Razor Page, found in the file Privacy.cshtml.cs.

Listing 2.7 The `PrivacyModel` in Privacy.cshtmlcs—a Razor Page page model

```
public class PrivacyModel: PageModel                         #A
{
    private readonly ILogger<PrivacyModel> _logger;          #B
    public PrivacyModel(ILogger<PrivacyModel> logger)        #B
    {                                                        #B
        _logger = logger;                                    #B
    }                                                        #B

    public void OnGet()                                      #C
    {
    }
}
```

#A Razor Pages must inherit from PageModel.
#B You can use dependency injection to provide services in the constructor.
#C The default page handler is OnGet. Returning void indicates HTML should be generated

This page model is extremely simple, but it demonstrates a couple of important points:

- Page handlers are driven by convention.
- Page models can use dependency injection to interact with other services.

Page handlers are typically named by convention, based on the *HTTP verb* that they respond to. They return either `void`, indicating that the Razor Page's template should be rendered, or an `IActionResult` which contains other instructions for generating the response, redirecting the user to a different page, for example.

> **DEFINITION** Every HTTP request includes a *verb* that indicates the "type" of the request. When browsing a website, the default verb is `GET`, which *fetches* a page from the server so you can view it. The second most common verb is `POST` which is used to *send* data to the server, for example when completing a form.

The `PrivacyModel` contains a single handler, `OnGet`, which indicates it should run in response to `GET` requests for the page. As the method returns `void`, executing the handler will execute the associated Razor template for the page, to generate the HTML.

Dependency injection is used to inject an `ILogger<PrivacyModel>` instance into the constructor of the page model. The service is unused in this example, but it can be used to record useful information to a variety of destinations, such as the console, to a file, or to a remote logging service. You can access additional services in your page model by accepting them as parameters in the constructor—the ASP.NET Core framework will take care of configuring and injecting an instance of any services you request.

> **NOTE** I describe the dependency inversion principle and the IoC container used in ASP.NET Core in detail in chapter 10. Logging is covered in chapter 17.

Clearly, the `PrivacyModel` page model does not do much in this case, and you may be wondering why it's worth having! If all they do is tell the Razor Page to generate HTML, then why do we need page models at all?

The key thing to remember here is that you now have a framework for performing arbitrarily complex functions in response to a request. You could easily update the handler method to load data from the database, send an email, add a product to a basket, or create an invoice—all in response to a simple HTTP request. This extensibility is where a lot of the power in Razor Pages (and the MVC pattern in general) lies.

The other important point is that you've separated the execution of these methods from the generation of the HTML itself. If the logic changes and you need to add behavior to a page handler, you don't need to touch the HTML generation code, so you're less likely to introduce bugs. Conversely, if you need to change the UI slightly, change the color of the title for example, then your handler method logic is safe.

And there you have it, a complete ASP.NET Core Razor Pages application! Before we move on, we'll take one last look at how our application handles a request. Figure 2.16 shows a request to the `/Privacy` path being handled by the sample application. You've seen everything here already, so the process of handling a request should be familiar. It shows how the request passes through the middleware pipeline before being handled by the endpoint middleware. The Privacy.cshtml Razor Page executes the `OnGet` handler and generates the HTML response, which passes back through the middleware to the ASP.NET Core web server, before being sent to the user's browser.

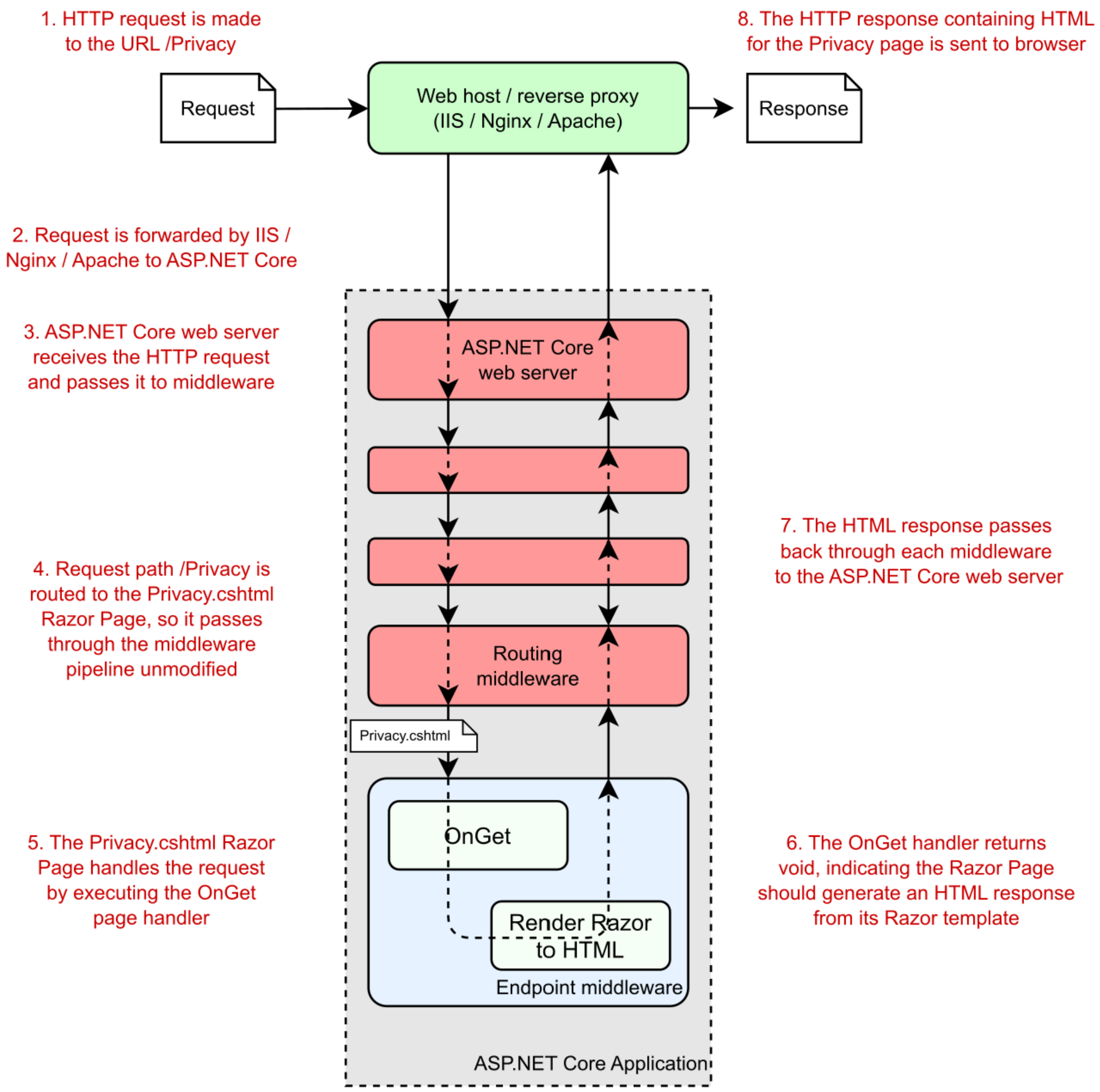

1. HTTP request is made to the URL /Privacy
Request
Web host / reverse proxy (IIS / Nginx / Apache)
8. The HTTP response containing HTML for the Privacy page is sent to browser
Response
2. Request is forwarded by IIS / Nginx / Apache to ASP.NET Core
3. ASP.NET Core web server receives the HTTP request and passes it to middleware
ASP.NET Core web server
7. The HTML response passes back through each middleware to the ASP.NET Core web server
4. Request path /Privacy is routed to the Privacy.cshtml Razor Page, so it passes through the middleware pipeline unmodified
Routing middleware
Privacy.cshtml
5. The Privacy.cshtml Razor Page handles the request by executing the OnGet page handler
OnGet
Render Razor to HTML
Endpoint middleware
6. The OnGet handler returns void, indicating the Razor Page should generate an HTML response from its Razor template
ASP.NET Core Application

Figure 2.16 An overview of a request to the `/Privacy` URL for the sample ASP.NET Razor Pages application. The routing middleware routes the request to `OnGet` handler of the Privacy.cshtml Razor Page. The Razor Page generates an HTML response by executing the Razor template and passes the response back through the middleware pipeline to the browser.

It's been a pretty intense trip, but you now have a good overview of how an entire application is configured and how it handles a request using Razor Pages. In the next chapter, you'll take a closer look at the middleware pipeline that exists in all ASP.NET Core applications. You'll learn how it's composed, how you can use it to add functionality to your application, and how you can use it to create simple HTTP services.

2.9 Summary

- The csproj file contains details of how to build your project, including which NuGet packages it depends on. It's used by Visual Studio and the .NET CLI to build your application.
- Restoring the NuGet packages for an ASP.NET Core application downloads all your project's dependencies so it can be built and run.
- Program.cs defines the `static void Main` entry point for your application. This function is run when your app starts, the same as for console applications.
- Program.cs is where you build an `IHost` instance, using an `IHostBuilder`. The helper method, `Host.CreateDefaultBuilder()`creates an `IHostBuilder` that loads configuration settings and sets up logging. Calling `Build()` creates the `IHost` instance.
- The `ConfigureWebHostDefaults` extension method configures the generic host using a `WebHostBuilder`. It configures the Kestrel HTTP server, adds IIS integration if necessary, and specifies the application's `Startup` class.
- You can start the web server and begin accepting HTTP requests by calling `Run` on the `IHost`.
- `Startup` is responsible for service configuration and defining the middleware pipeline.
- All services, both framework and custom application services, must be registered in the call to `ConfigureServices` in order to be accessed later in your application.
- Middleware is added to the application pipeline with `IApplicationBuilder`. Middleware defines how your application responds to requests.
- The order in which middleware is registered defines the final order of the middleware pipeline for the application. Typically, `EndpointMiddleware` is the last middleware in the pipeline. Earlier middleware, such as `StaticFileMiddleware`, will attempt to handle the request first. If the request is handled, `EndpointMiddleware` will never receive the request.
- Razor Pages are located in the Pages folder and are typically named according to the URL path they handle. For example, Privacy.cshtml handles the path `/Privacy`.
- Razor Pages must contain the `@page` directive as the first line of the file.
- Page models derive from the `PageModel` base class and contain page handlers. Page handlers are methods named using conventions that indicate the HTTP verb they handle. For example, `OnGet` handles the `GET` verb.
- Razor templates can contain standalone C#, standalone HTML, and dynamic HTML generated from C# values. By combining all three, you can build highly dynamic applications.

- Razor layouts define common elements of a web page, such as headers and footers. They let you extract this code into a single file, so you don’t have to duplicate it across every Razor template.

3

Handling requests with the middleware pipeline

This chapter covers

- **What middleware is**
- **Serving static files using middleware**
- **Adding functionality using middleware**
- **Combining middleware to form a pipeline**
- **Handling exceptions and errors with middleware**

In the previous chapter, you had a whistle-stop tour of a complete ASP.NET Core application to see how the components come together to create a web application. In this chapter, we focus in on one small subsection: the middleware pipeline.

The middleware pipeline is one of the most important parts of configuration for defining how your application behaves and how it responds to requests. Understanding how to build and compose middleware is key to adding functionality to your applications.

In this chapter, you'll learn what middleware is and how to use it to create a pipeline. You'll see how you can chain multiple middleware components together, with each component adding a discrete piece of functionality. The examples in this chapter are limited to using existing middleware components, showing how to arrange them in the correct way for your application. In chapter 19, you'll learn how to build your own middleware components and incorporate them into the pipeline.

We'll begin by looking at the concept of middleware, all the things you can achieve with it, and how a middleware component often maps to a "cross-cutting concern." These are the functions of an application that cut across multiple different layers. Logging, error handling, and security are classic cross-cutting concerns that are all required by many different parts of your application. As all requests pass through the middleware pipeline, it's the preferred location to configure and handle these aspects.

In section 3.2, I'll explain how you can compose individual middleware components into a pipeline. You'll start out small, with a web app that only displays a holding page. From there, you'll learn how to build a simple static-file server that returns requested files from a folder on disk.

Next, you'll move on to a more complex pipeline containing multiple middleware. You'll use this example to explore the importance of ordering in the middleware pipeline and to see how requests are handled when your pipeline contains more than one middleware.

In section 3.3, you'll learn how you can use middleware to deal with an important aspect of any application: error handling. Errors are a fact of life for all applications, so it's important that you account for them when building your app. As well as ensuring that your application doesn't break when an exception is thrown or an error occurs, it's important that users of your application are informed about what went wrong in a user-friendly way.

You can handle errors in a few different ways, but as one of the classic cross-cutting concerns, middleware is well placed to provide the required functionality. In section 3.3, I'll show how you can use middleware to handle exceptions and errors using existing middleware provided by Microsoft. In particular, you'll learn about three different components:

- `DeveloperExceptionPageMiddleware`—Provides quick error feedback when building an application
- `ExceptionHandlerMiddleware`—Provides a user-friendly generic error page in production
- `StatusCodePagesMiddleware`—Converts raw error status codes into user-friendly error pages

By combining these pieces of middleware, you can ensure that any errors that do occur in your application won't leak security details and won't break your app. On top of that, they will leave users in a better position to move on from the error, giving them as friendly an experience as possible.

You won't see how to build your own middleware in this chapter—instead, you'll see that you can go a long way using the components provided as part of ASP.NET Core. Once you understand the middleware pipeline and its behavior, it will be much easier to understand when and why custom middleware is required. With that in mind, let's dive in!

3.1 What is middleware?

The word *middleware* is used in a variety of contexts in software development and IT, but it's not a particularly descriptive word—what is middleware?

In ASP.NET Core, middleware are C# classes that can handle an HTTP request or response. Middleware can

- Handle an incoming HTTP *request* by generating an HTTP *response*.

- Process an incoming HTTP *request*, modify it, and pass it on to another piece of middleware.
- Process an outgoing HTTP *response*, modify it, and pass it on to either another piece of middleware, or the ASP.NET Core web server.

You can use middleware in a multitude of ways in your own applications. For example, a piece of logging middleware might note when a request arrived and then pass it on to another piece of middleware. Meanwhile, an image-resizing middleware component might spot an incoming request for an image with a specified size, generate the requested image, and send it back to the user without passing it on.

The most important piece of middleware in most ASP.NET Core applications is the `EndpointMiddleware` class. This class normally generates all your HTML pages and API responses and is the focus of most of this book. Like the image-resizing middleware, it typically receives a request, generates a response, and then sends it back to the user, as shown in figure 3.1.

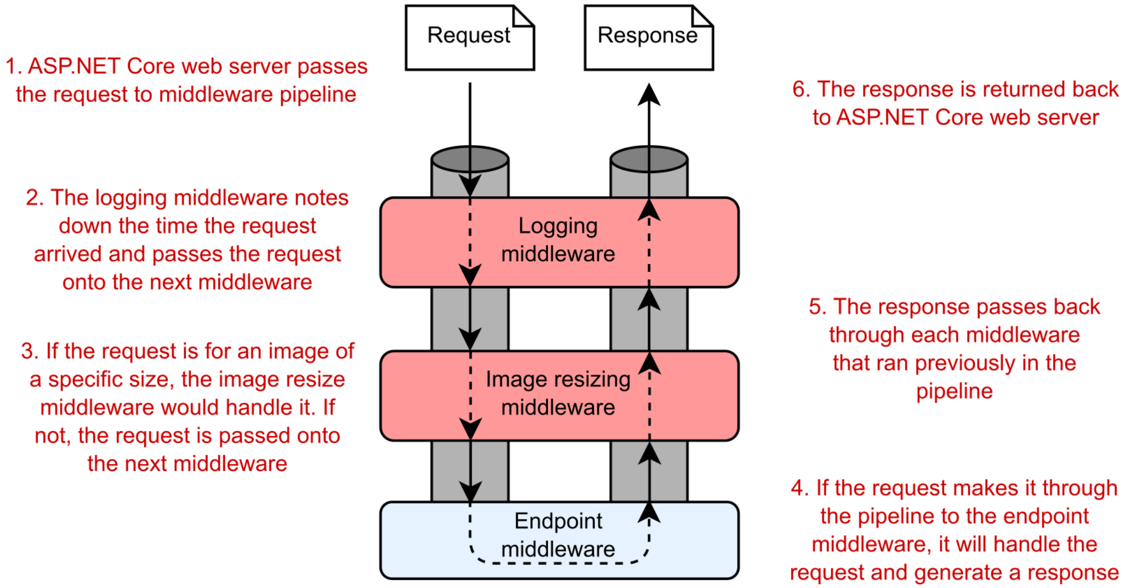

Request
Response
1. ASP.NET Core web server passes the request to middleware pipeline
6. The response is returned back to ASP.NET Core web server
2. The logging middleware notes down the time the request arrived and passes the request onto the next middleware
Logging middleware
5. The response passes back through each middleware that ran previously in the pipeline
3. If the request is for an image of a specific size, the image resize middleware would handle it. If not, the request is passed onto the next middleware
Image resizing middleware
Endpoint middleware
4. If the request makes it through the pipeline to the endpoint middleware, it will handle the request and generate a response

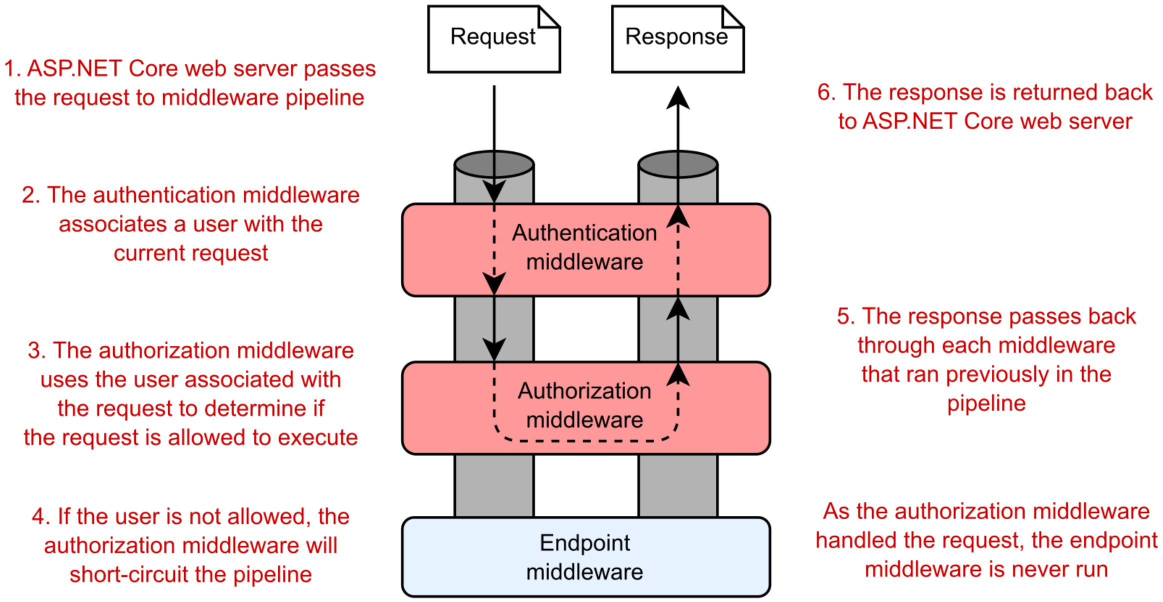
Figure 3.1 Example of a middleware pipeline. Each middleware handles the request and passes it on to the next middleware in the pipeline. After a middleware generates a response, it passes it back through the pipeline. When it reaches the ASP.NET Core web server, the response is sent to the user's browser.

DEFINITION This arrangement, where a piece of middleware can call another piece of middleware, which in turn can call another, and so on, is referred to as a *pipeline*. You can think of each piece of middleware as a section of pipe—when you connect all the sections, a request flows through one piece and into the next.

One of the most common use cases for middleware is for the cross-cutting concerns of your application. These aspects of your application need to occur with every request, regardless of the specific path in the request or the resource requested. These include things like

- Logging each request
- Adding standard security headers to the response
- Associating a request with the relevant user
- Setting the language for the current request

In each of these examples, the middleware would receive a request, modify it, and then pass the request on to the next piece of middleware in the pipeline. Subsequent middleware could use the details added by the earlier middleware to handle the request in some way. For example, in figure 3.2, the authentication middleware associates the request with a user. The authorization middleware uses this detail to verify whether the user has permission to make that specific request to the application or not.



1. ASP.NET Core web server passes the request to middleware pipeline

2. The authentication middleware associates a user with the current request

3. The authorization middleware uses the user associated with the request to determine if the request is allowed to execute

4. If the user is not allowed, the authorization middleware will short-circuit the pipeline

6. The response is returned back to ASP.NET Core web server

5. The response passes back through each middleware that ran previously in the pipeline

As the authorization middleware handled the request, the endpoint middleware is never run

Figure 3.2 Example of a middleware component modifying the request for use later in the pipeline. Middleware can also short-circuit the pipeline, returning a response before the request reaches later middleware.

If the user has permission, the authorization middleware will pass the request on to the endpoint middleware to allow it to generate a response. If the user doesn’t have permission, the authorization middleware can short-circuit the pipeline, generating a response directly. It returns the response to the previous middleware before the endpoint middleware has even seen the request.

A key point to glean from this is that the pipeline is *bidirectional*. The request passes through the pipeline in one direction until a piece of middleware generates a response, at which point the response passes *back* through the pipeline, passing through each piece of middleware for a *second* time, until it gets back to the first piece of middleware. Finally, this first/last piece of middleware will pass the response back to the ASP.NET Core web server.

The HttpContext object

We mentioned the `HttpContext` in chapter 2, and it's sitting behind the scenes here too. The ASP.NET Core web server constructs an `HttpContext`, which the ASP.NET Core application uses as a sort of storage box for a single request. Anything that's specific to this particular request and the subsequent response can be associated with and stored in it. This could include properties of the request, request-specific services, data that's been loaded, or errors that have occurred. The web server fills the initial `HttpContext` with details of the original HTTP request and other configuration details and passes it on to the rest of the application.

All middleware has access to the `HttpContext` for a request. It can use this, for example, to determine whether the request contains any user credentials, which page the request is attempting to access, and to fetch any posted data. It can then use these details to determine how to handle the request.

Once the application has finished processing the request, it will update the `HttpContext` with an appropriate response and return it through the middleware pipeline to the web server. The ASP.NET Core web server then converts the representation into a raw HTTP response and sends it back to the reverse proxy, which forwards it to the user's browser.

As you saw in chapter 2, you define the middleware pipeline in code as part of your initial application configuration in `Startup`. You can tailor the middleware pipeline specifically to your needs—simple apps may need only a short pipeline, whereas large apps with a variety of features may use much more middleware. Middleware is the fundamental source of behavior in your application—ultimately, the middleware pipeline is responsible for responding to any HTTP requests it receives.

Requests are passed to the middleware pipeline as `HttpContext` objects. As you saw in chapter 2, the ASP.NET Core web server builds an `HttpContext` object from an incoming request, which passes up and down the middleware pipeline. When you're using existing middleware to build a pipeline, this is a detail you'll rarely have to deal with. But, as you'll see in the final section of this chapter, its presence behind the scenes provides a route to exerting extra control over your middleware pipeline.

Middleware vs. HTTP modules and HTTP handlers

In the previous version of ASP.NET, the concept of a middleware pipeline isn't used. Instead, you have HTTP modules and HTTP handlers.

An *HTTP handler* is a process that runs in response to a request and generates the response. For example, the ASP.NET page handler runs in response to requests for .aspx pages. Alternatively, you could write a custom handler that returns resized images when an image is requested.

HTTP modules handle the cross-cutting concerns of applications, such as security, logging, or session management. They run in response to the lifecycle events that a request progresses through when it's received by the server. Examples of events include `BeginRequest`, `AcquireRequestState`, and `PostAcquireRequestState`.

This approach works, but it's sometimes tricky to reason about which modules will run at which points. Implementing a module requires a relatively detailed understanding of the state of the request at each individual lifecycle event.

The middleware pipeline makes understanding your application far simpler. The pipeline is completely defined in code, specifying which components should run, and in which order. Behind the scenes, the middleware pipeline in ASP.NET Core is simply a chain of method calls, where each middleware function calls the next in the pipeline.

That's pretty much all there is to the concept of middleware. In the next section, I'll discuss ways you can combine middleware components to create an application, and how to use middleware to separate the concerns of your application.

3.2 Combining middleware in a pipeline

Generally speaking, each middleware component has a single primary concern. It will handle one aspect of a request only. Logging middleware will only deal with logging the request, authentication middleware is only concerned with identifying the current user, and static-file middleware is only concerned with returning static files.

Each of these concerns is highly focused, which makes the components themselves small and easy to reason about. It also gives your app added flexibility; adding a static-file middleware doesn't mean you're forced into having image-resizing behavior or authentication. Each of these features is an additional piece of middleware.

To build a complete application, you compose multiple middleware components together into a pipeline, as shown in the previous section. Each middleware has access to the original request, plus any changes made by previous middleware in the pipeline. Once a response has been generated, each middleware can inspect and/or modify the response as it passes back through the pipeline, before it's sent to the user. This allows you to build complex application behaviors from small, focused components.

In the rest of this section, you'll see how to create a middleware pipeline by composing small components together. Using standard middleware components, you'll learn to create a holding page and to serve static files from a folder on disk. Finally, you'll take another look at the default middleware pipeline you built previously, in chapter 2, and decompose it to understand why it's built like it is.

3.2.1 Simple pipeline scenario 1: a holding page

For your first app, and your first middleware pipeline, you'll learn how to create an app consisting of a holding page. This can be useful when you're first setting up your application, to ensure it's processing requests without errors.

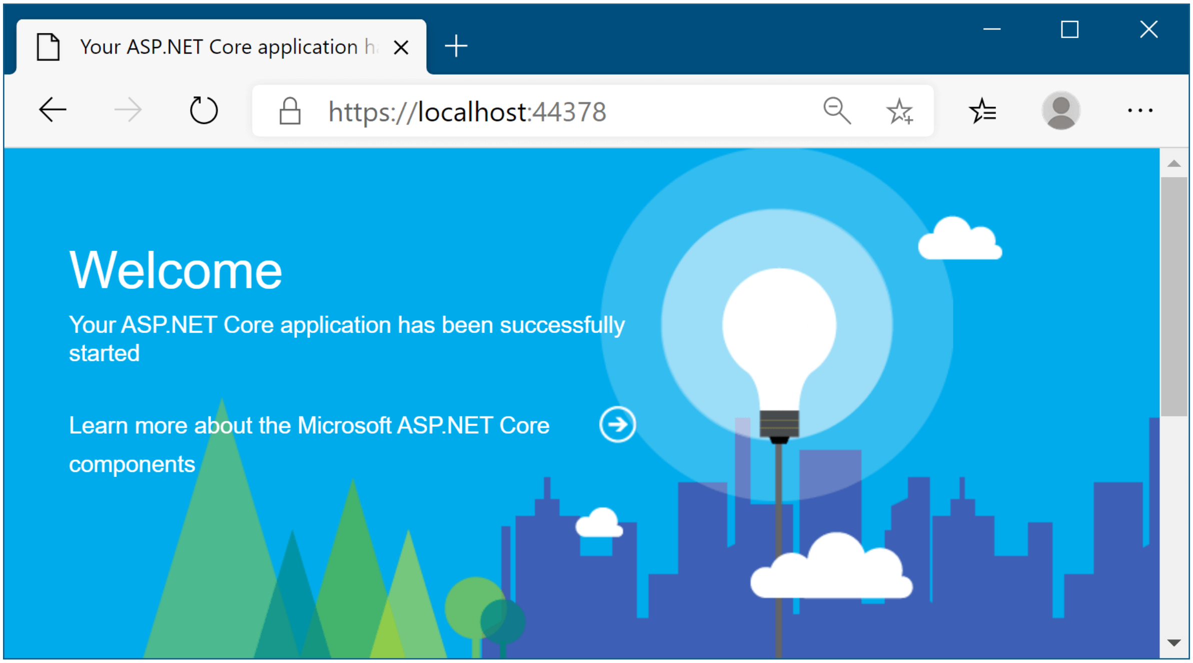
TIP Remember, you can view the application code for this book in the GitHub repository at https://github.com/andrewlock/asp-dot-net-core-in-action-2e.

In previous chapters, I've mentioned that the ASP.NET Core framework is composed of many small, individual libraries. You typically add a piece of middleware by referencing a package in your application's csproj project file and configuring the middleware in the `Configure` method of your `Startup` class. Microsoft ships many standard middleware components with ASP.NET Core for you to choose from, and you can also use third-party components from NuGet and GitHub, or you can build your own custom middleware.

NOTE I'll discuss building custom middleware in chapter 19.

Unfortunately, there isn't a definitive list of middleware available, but you can view the source code for all the middleware that comes as part of ASP.NET Core in the main ASP.NET Core GitHub repository (https://github.com/aspnet/aspnetcore). You can find most of the middleware in the src/Middleware folder, though some middleware is in other folders where it forms part of a larger feature. For example, the authentication and authorization middleware can be found in the src/Security folder instead. Alternatively, with a bit of searching on https://nuget.org you can often find middleware with the functionality you need.

In this section, you'll see how to create one of the simplest middleware pipelines, consisting of `WelcomePageMiddleware` only. `WelcomePageMiddleware` is designed to quickly provide a sample page when you're first developing an application, as you can see in figure 3.3. You wouldn't use it in a production app, as you can't customize the output, but it's a single, self-contained middleware component you can use to ensure your application is running correctly.



Your ASP.NET Core application h
https://localhost:44378
Welcome
Your ASP.NET Core application has been successfully started
Learn more about the Microsoft ASP.NET Core components

Figure 3.3 The Welcome page middleware response. Every request to the application, at any path, will return the same Welcome page response.

> **TIP** `WelcomePageMiddleware` **is included as part of the base ASP.NET Core framework, so you don't need to add a reference to any additional NuGet packages.**

Even though this application is simple, the exact same process occurs when it receives an HTTP request, as shown in figure 3.4.

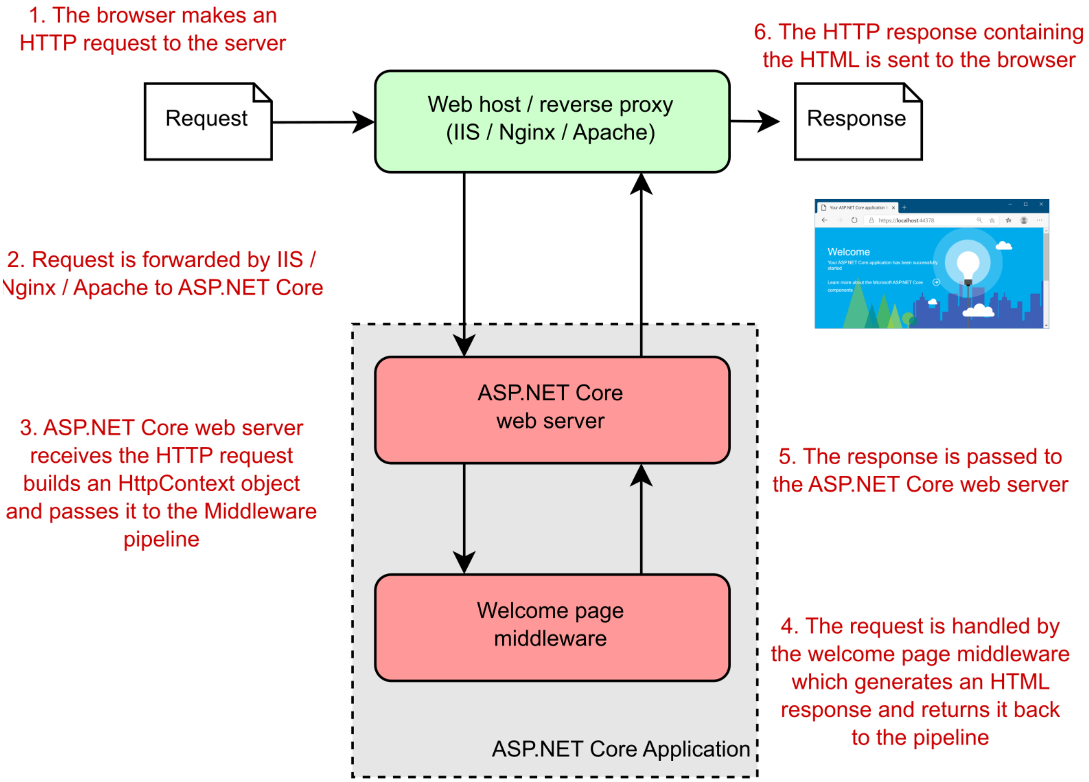

1. The browser makes an HTTP request to the server
Request
Web host / reverse proxy (IIS / Nginx / Apache)
6. The HTTP response containing the HTML is sent to the browser
Response
2. Request is forwarded by IIS / Nginx / Apache to ASP.NET Core
Welcome
3. ASP.NET Core web server receives the HTTP request builds an HttpContext object and passes it to the Middleware pipeline
ASP.NET Core web server
5. The response is passed to the ASP.NET Core web server
Welcome page middleware
4. The request is handled by the welcome page middleware which generates an HTML response and returns it back to the pipeline
ASP.NET Core Application

Figure 3.4 `WelcomePageMiddleware` **handles a request. The request passes from the reverse proxy to the ASP.NET Core web server and, finally, to the middleware pipeline, which generates an HTML response.**

The request passes to the ASP.NET Core web server, which builds a representation of the request and passes it to the middleware pipeline. As it’s the first (only!) middleware in the pipeline, `WelcomePageMiddleware` receives the request and must decide how to handle it. The middleware responds by generating an HTML response, no matter what request it receives. This response passes back to the ASP.NET Core web server, which forwards it on to the user to display in their browser.

As with all ASP.NET Core applications, you define the middleware pipeline in the `Configure` method of `Startup` by adding middleware to an `IApplicationBuilder` object. To create your first middleware pipeline, consisting of a single middleware component, you need just a single method call.

Listing 3.1 Startup for a Welcome page middleware pipeline

```
using Microsoft.AspNetCore.Builder;
namespace CreatingAHoldingPage
```

```
{
    public class Startup                                  #A
    {
        public void Configure(IApplicationBuilder app)    #B
        {
            app.UseWelcomePage();                         #C
        }
    }
}
```

#A The Startup class is very simple for this basic application.
#B The Configure method is used to define the middleware pipeline.
#C The only middleware in the pipeline

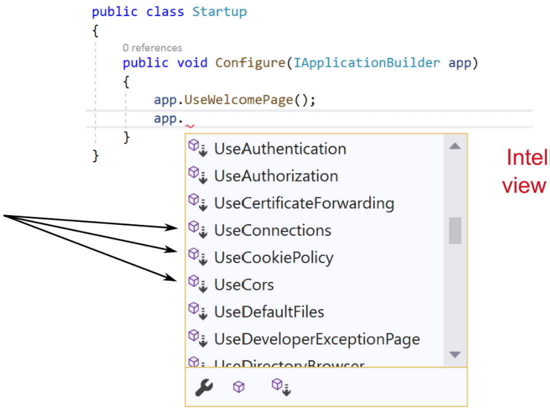
As you can see, the `Startup` for this application is very simple. The application has no configuration and no services, so `Startup` doesn't have a constructor or a `ConfigureServices` method. The only required method is `Configure`, in which you call `UseWelcomePage`.

You build the middleware pipeline in ASP.NET Core by calling methods on `IApplicationBuilder`, but this interface doesn't define methods like `UseWelcomePage` itself. Instead, these are *extension* methods.

Using extension methods allows you to effectively add functionality to the `IApplicationBuilder` class, while keeping their implementations isolated from it. Under the hood, the methods are typically calling *another* extension method to add the middleware to the pipeline. For example, behind the scenes, the `UseWelcomePage` method adds the `WelcomePageMiddleware` to the pipeline using

```
UseMiddleware<WelcomePageMiddleware>();
```

This convention of creating an extension method for each piece of middleware and starting the method name with `Use` is designed to improve discoverability when adding middleware to your application. ASP.NET Core includes a lot of middleware as part of the core framework, so you can use IntelliSense in Visual Studio and other IDEs to view all the middleware available, as shown in figure 3.5.



```
public class Startup
{
    0 references
    public void Configure(IApplicationBuilder app)
    {
        app.UseWelcomePage();
        app.
    }
}
```

By convention, extension methods to add middleware to the pipeline start with Use.

IntelliSense allows you to easily view all the middleware currently available to add.

Figure 3.5 IntelliSense makes it easy to view all the middleware available to add to your middleware pipeline.

Calling the `UseWelcomePage` method adds the `WelcomePageMiddleware` as the next middleware in the pipeline. Although you're only using a single middleware component here, it's important to remember that the order in which you make calls to `IApplicationBuilder` in `Configure` defines the order that the middleware will run in the pipeline.

> **WARNING** **Always take care when adding middleware to the pipeline and consider the order in which it will run. A component can only access data created by middleware that comes before it in the pipeline.**

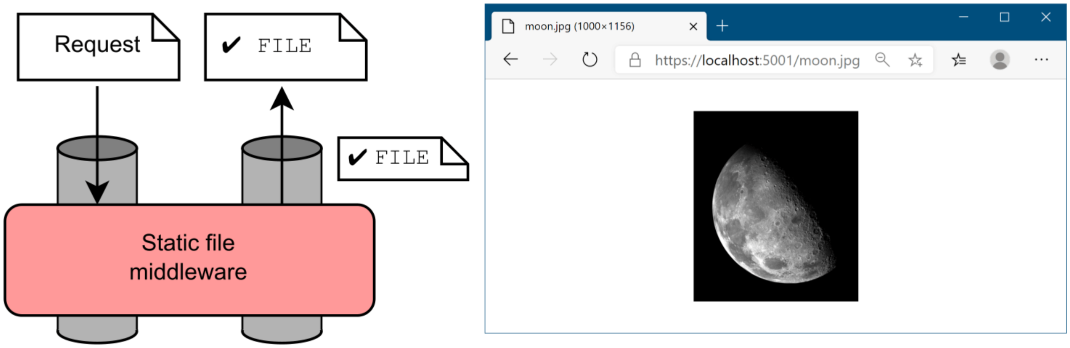
This is the most basic of applications, returning the same response no matter which URL you navigate to, but it shows how easy it is to define your application behavior using middleware. Now we'll make things a little more interesting and return a different response when you make requests to different paths.

3.2.2 Simple pipeline scenario 2: Handling static files

In this section, I'll show how to create one of the simplest middleware pipelines you can use for a full application: a static file application.

Most web applications, including those with dynamic content, serve a number of pages using static files. Images, JavaScript, and CSS stylesheets are normally saved to disk during development and are served up when requested, normally as part of a full HTML page request.

For now, you'll use `StaticFileMiddleware` to create an application that only serves static files from the wwwroot folder when requested, as shown in figure 3.6. In this example, an image called moon.jpg exists in the wwwroot folder. When you request the file using the `/moon.jpg` path, it's loaded and returned as the response to the request.



1. The static file middleware handles the request by returning the file requested

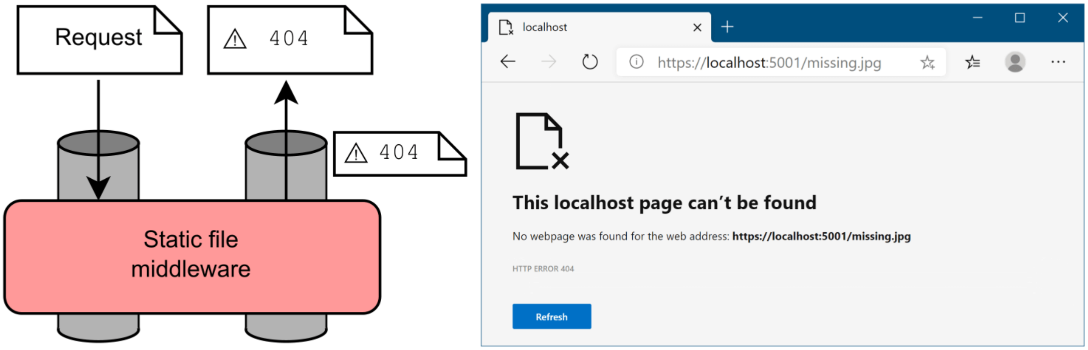
2. The file stream is sent back through the middleware pipeline, and out to the browser

3. The browser displays the file returned in the response

Figure 3.6 Serving a static image file using the static file middleware

If the user requests a file that doesn't exist in the wwwroot folder, for example missing.jpg, then the static file middleware won't serve a file. Instead, a 404 HTTP error code response will be sent to the user's browser, which will show its default "File Not Found" page, as shown in figure 3.7.

> **NOTE** How this page looks will depend on your browser. In some browsers, for example Internet Explorer (IE), you might see a completely blank page.



This localhost page can't be found

No webpage was found for the web address: **https://localhost:5001/missing.jpg**

HTTP ERROR 404

Refresh

1. The static file middleware handles the request by trying to return the requested file, but as it doesn't exist, it returns a raw 404 response

2. The 404 HTTP error code is sent back through the middleware pipeline and to the user

3. The browser displays its default "File Not Found" error page

Figure 3.7 Returning a 404 to the browser when a file doesn’t exist. The requested file did not exist in the wwwroot folder, so the ASP.NET Core application returned a 404 response. The browser, Microsoft Edge in this case, will then show the user a default “File Not Found” error.

Building the middleware pipeline for this application is easy, consisting of a single piece of middleware, `StaticFileMiddleware`, as you can see in the following listing. You don’t need any services, so configuring the middleware pipeline in `Configure` with `UseStaticFiles` is all that’s required.

Listing 3.2 Startup for a static file middleware pipeline

```
using Microsoft.AspNetCore.Builder;

namespace CreatingAStaticFileWebsite
{
    public class Startup                                   #A
    {
        public void Configure(IApplicationBuilder app)     #B
        {
            app.UseStaticFiles();                          #C
        }
    }
```

#A The Startup class is very simple for this basic static file application.
#B The Configure method is used to define the middleware pipeline.
#C The only middleware in the pipeline

> **TIP** Remember, you can view the application code for this book in the GitHub repository at https://github.com/andrewlock/asp-dot-net-core-in-action-2e.

When the application receives a request, the ASP.NET Core web server handles it and passes it to the middleware pipeline. `StaticFileMiddleware` receives the request and determines whether or not it can handle it. If the requested file exists, the middleware handles the request and returns the file as the response, as shown in figure 3.8.

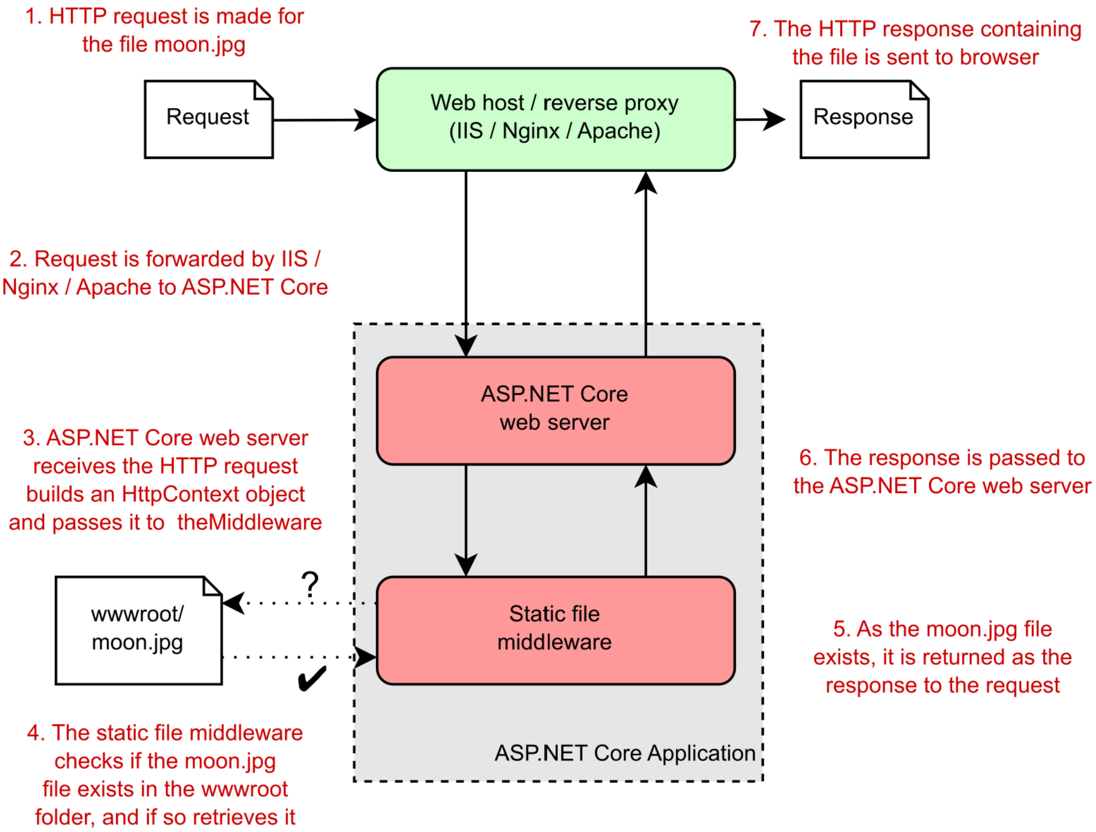

1. HTTP request is made for the file moon.jpg
Request
Web host / reverse proxy (IIS / Nginx / Apache)
Response
7. The HTTP response containing the file is sent to browser
2. Request is forwarded by IIS / Nginx / Apache to ASP.NET Core
ASP.NET Core web server
3. ASP.NET Core web server receives the HTTP request builds an HttpContext object and passes it to theMiddleware
6. The response is passed to the ASP.NET Core web server
wwwroot/ moon.jpg
?
✔
Static file middleware
5. As the moon.jpg file exists, it is returned as the response to the request
4. The static file middleware checks if the moon.jpg file exists in the wwwroot folder, and if so retrieves it
ASP.NET Core Application

Figure 3.8 `StaticFileMiddleware` **handles a request for a file. The middleware checks the wwwroot folder to see if the requested moon.jpg file exists. The file exists, so the middleware retrieves it and returns it as the response to the web server and, ultimately, out to the browser.**

If the file doesn't exist, then the request effectively passes *through* the static file middleware unchanged. But wait, you only added one piece of middleware, right? Surely you can't pass the request through to the next middleware if there *isn't* another one?

ASP.NET Core automatically adds an "dummy" piece of middleware to the end of the pipeline. This middleware always returns a 404 response if it's called.

TIP Remember, if no middleware generates a response for a request, the pipeline will automatically return a simple 404 error response to the browser.

HTTP response status codes

Every HTTP response contains a *status code* and, optionally, a *reason phrase* describing the status code. Status codes are fundamental to the HTTP protocol and are a standardized way of indicating common results. A 200 response, for example, means the request was successfully answered, whereas a 404 response indicates that the resource requested couldn't be found.

Status codes are always three digits long and are grouped into five different classes, based on the first digit:

- *1xx*—Information. Not often used, provides a general acknowledgment.
- *2xx*—Success. The request was successfully handled and processed.
- *3xx*—Redirection. The browser must follow the provided link, to allow the user to log in, for example.
- *4xx*—Client error. There was a problem with the request. For example, the request sent invalid data, or the user isn't authorized to perform the request.
- *5xx*—Server error. There was a problem on the server that caused the request to fail.

These status codes typically drive the behavior of a user's browser. For example, the browser will handle a 301 response automatically, by redirecting to the provided new link and making a second request, all without the user's interaction.

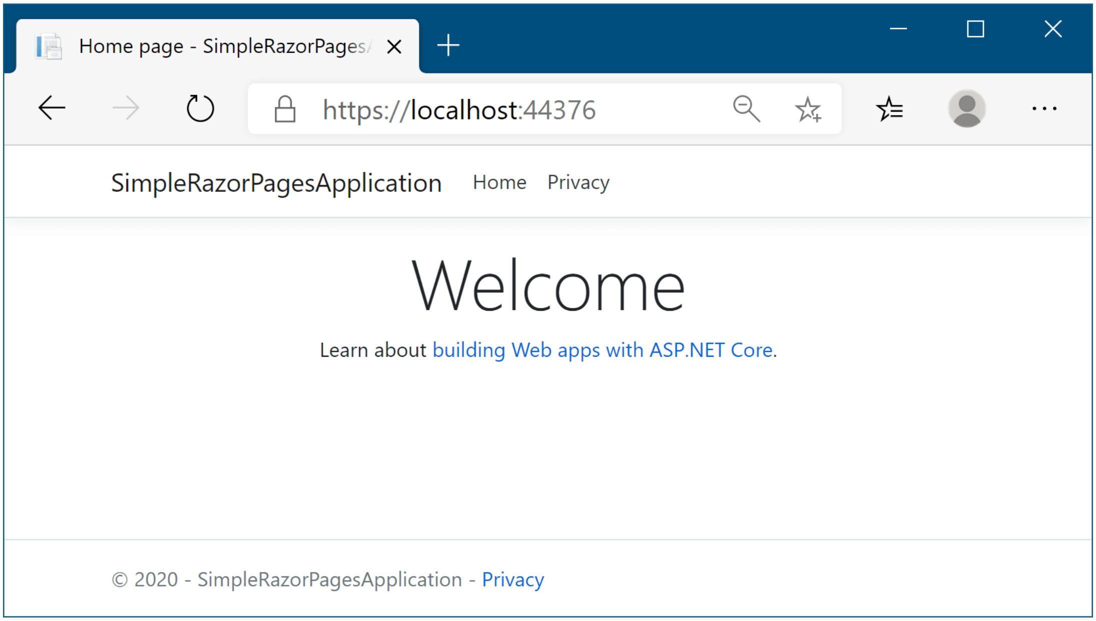
Error codes are found in the 4xx and 5xx classes. Common codes include a 404 response when a file couldn't be found, a 400 error when a client sends invalid data (an invalid email address for example), and a 500 error when an error occurs on the server. HTTP responses for error codes may or may not include a response body, which is content to display when the client receives the response.

This basic ASP.NET Core application allows you to easily see the behavior of the ASP.NET Core middleware pipeline and the static file middleware in particular, but it's unlikely your applications will be as simple as this. It's more likely that static files will form one part of your middleware pipeline. In the next section, we'll look at how to combine multiple middleware, looking at a simple Razor Pages application.

3.2.3 Simple pipeline scenario 3: A Razor Pages application

By this point, you, I hope, have a decent grasp of the middleware pipeline, insofar as understanding that it defines your application's behavior. In this section, you'll see how to combine multiple middleware to form a pipeline, using several standard middleware components. As before, this is performed in the `Configure` method of `Startup` by adding middleware to an `IApplicationBuilder` object.

You'll begin by creating a basic middleware pipeline that you'd find in a typical ASP.NET Core Razor Pages template and then extend it by adding middleware. The output when you navigate to the homepage of the application is shown in figure 3.9—identical to the sample application shown in chapter 2.



Welcome

Learn about building Web apps with ASP.NET Core.

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Figure 3.9 A simple Razor Pages application. The application uses only four pieces of middleware: routing middleware to choose a Razor Page to run, endpoint middleware to generate the HTML from a Razor Page, static file middleware to serve the CSS files, and an exception handler middleware to capture any errors.

Creating this application requires only four pieces of middleware: routing middleware to choose a Razor Page to execute, endpoint middleware to generate the HTML from a Razor Page, static file middleware to serve the CSS and image files from the wwwroot folder, and an exception handler middleware to handle any errors that might occur.

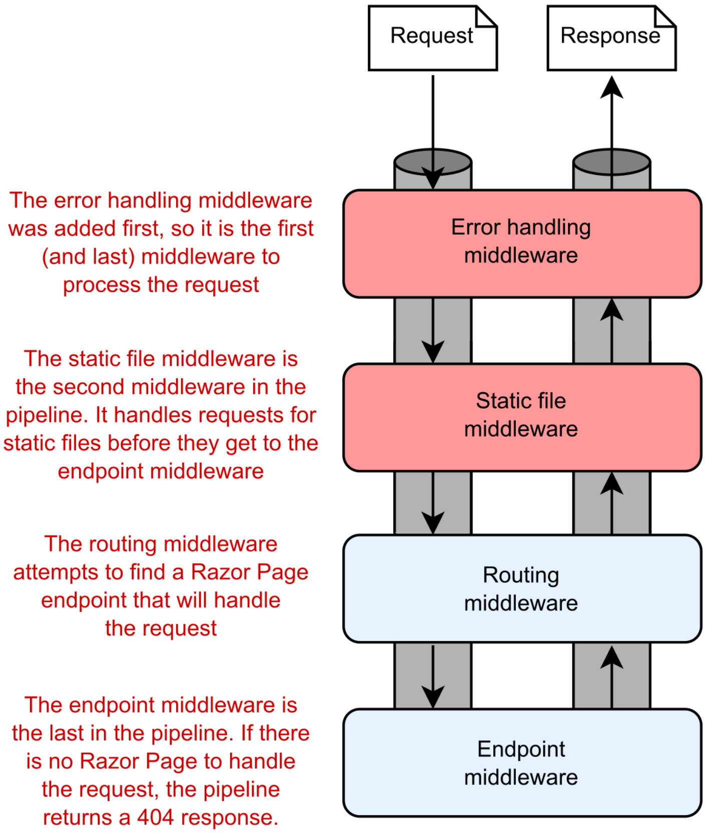
The configuration of the middleware pipeline for the application occurs in the `Configure` method of `Startup`, as always, and is shown in the following listing. As well as the middleware configuration, this also shows the call to `AddRazorPages()` in `ConfigureServices`, which is required when using Razor Pages. You'll learn more about service configuration in chapter 10.

Listing 3.3 A basic middleware pipeline for a Razor Pages application

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services
    {
        services.AddRazorPages();
    }
    public void Configure(IApplicationBuilder app)
    {
        app.UseExceptionHandler("/Error");
        app.UseStaticFiles();
        app.UseRouting();
        app.UseEndpoints(endpoints =>
        {
            endpoints.MapRazorPages();
        });
    }
}
```

The addition of middleware to `IApplicationBuilder` to form the pipeline should be familiar to you now, but there are a couple of points worth noting in this example. First, all of the methods for adding middleware all start with `Use`. As I mentioned earlier, this is thanks to the convention of using extension methods to extend the functionality of `IApplicationBuilder`; by prefixing the methods with `Use` they should be easier to discover.

Another important point about this listing is the order of the `Use` methods in the `Configure` method. The order in which you add the middleware to the `IApplicationBuilder` object is the same order in which they're added to the pipeline. This creates a pipeline similar to that shown in figure 3.10.



The error handling middleware was added first, so it is the first (and last) middleware to process the request

The static file middleware is the second middleware in the pipeline. It handles requests for static files before they get to the endpoint middleware

The routing middleware attempts to find a Razor Page endpoint that will handle the request

The endpoint middleware is the last in the pipeline. If there is no Razor Page to handle the request, the pipeline returns a 404 response.

Figure 3.10 The middleware pipeline for the example application in listing 3.3. The order in which you add the middleware to `IApplicationBuilder` defines the order of the middleware in the pipeline.

The exception handler middleware is called first, which passes the request on to the static file middleware. The static file handler will generate a response if the request corresponds to a file, otherwise it will pass the request on to the routing middleware. The routing middleware selects a Razor page based on the request URL, and the endpoint middleware executes the selected Razor Page. If no Razor Page can handle the requested URL, the automatic dummy middleware returns a 404 response.

> **NOTE** In versions 1.x and 2.x of ASP.NET Core, the routing and endpoint middleware were combined into a single “MVC” middleware. Splitting the responsibilities for routing from execution makes it possible to insert middleware *between* the routing and endpoint middleware. I discuss routing further in chapter 5.

The impact of ordering can most obviously be seen when you have two pieces of middleware that are both listening for the same path. For example, the endpoint middleware in the example pipeline currently responds to a request to the homepage of the application (with the `"/"` path) by generating the HTML response shown previously in figure 3.9. Figure 3.11 shows what happens if you reintroduce a piece of middleware you saw previously, `WelcomePageMiddleware`, and configure it to respond to the `"/"` path as well.

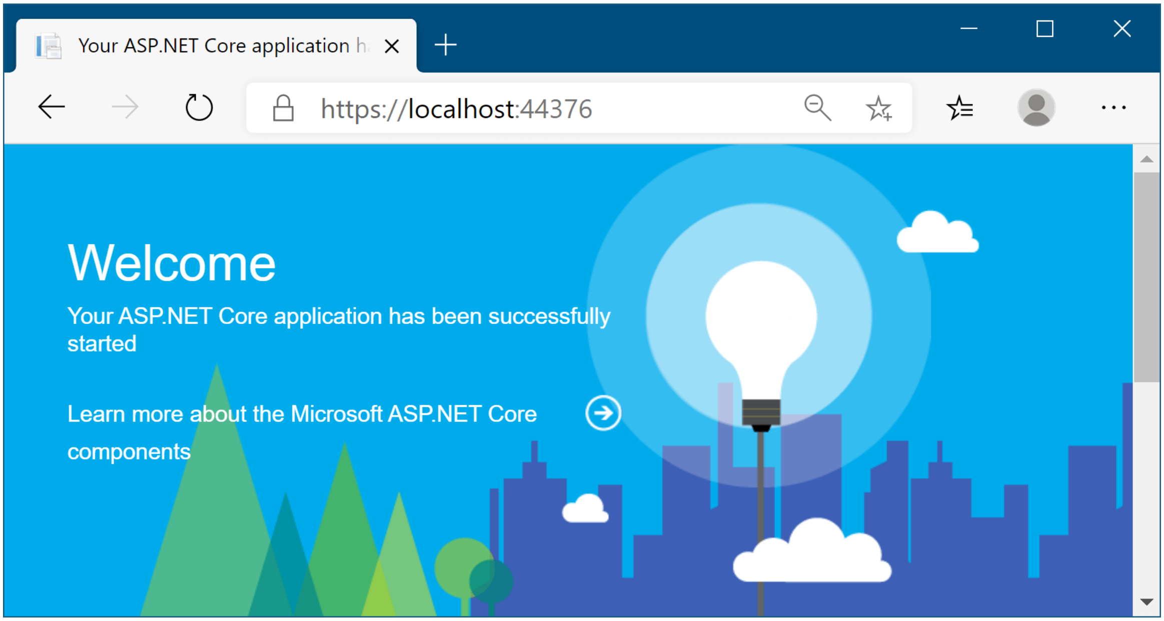

Your ASP.NET Core application h
https://localhost:44376
Welcome
Your ASP.NET Core application has been successfully started
Learn more about the Microsoft ASP.NET Core components

Figure 3.11 The Welcome page middleware response. The Welcome page middleware comes before the endpoint middleware, so a request to the homepage returns the Welcome page middleware instead of the Razor Pages response.

As you saw in section 3.2.1, `WelcomePageMiddleware` is designed to return a fixed HTML response, so you wouldn't use it in a production app, but it illustrates the point nicely. In the following listing, it's added to the start of the middleware pipeline and configured to respond only to the `"/"` path.

Listing 3.4 Adding `WelcomePageMiddleware` to the pipeline

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services
    {
        services.AddRazorPages();
    }
    public void Configure(IApplicationBuilder app)
    {
        app.UseWelcomePage("/");                        #A
        app.UseExceptionHandler("/Error");
        app.UseStaticFiles();
        app.UseRouting();
        app.UseEndpoints(endpoints =>                   #B
        {
            endpoints.MapRazorPages();
        });
    }
}
```

#A WelcomePageMiddleware handles all requests to the "/" path and returns a sample HTML response.
#B Requests to "/" will never reach the endpoint middleware.

Even though you know the endpoint middleware can also handle the "/" path, WelcomePageMiddleware is earlier in the pipeline, so it returns a response when it receives the request to "/", short-circuiting the pipeline, as shown in figure 3.12. None of the other middleware in the pipeline runs for the request, so none has an opportunity to generate a response.

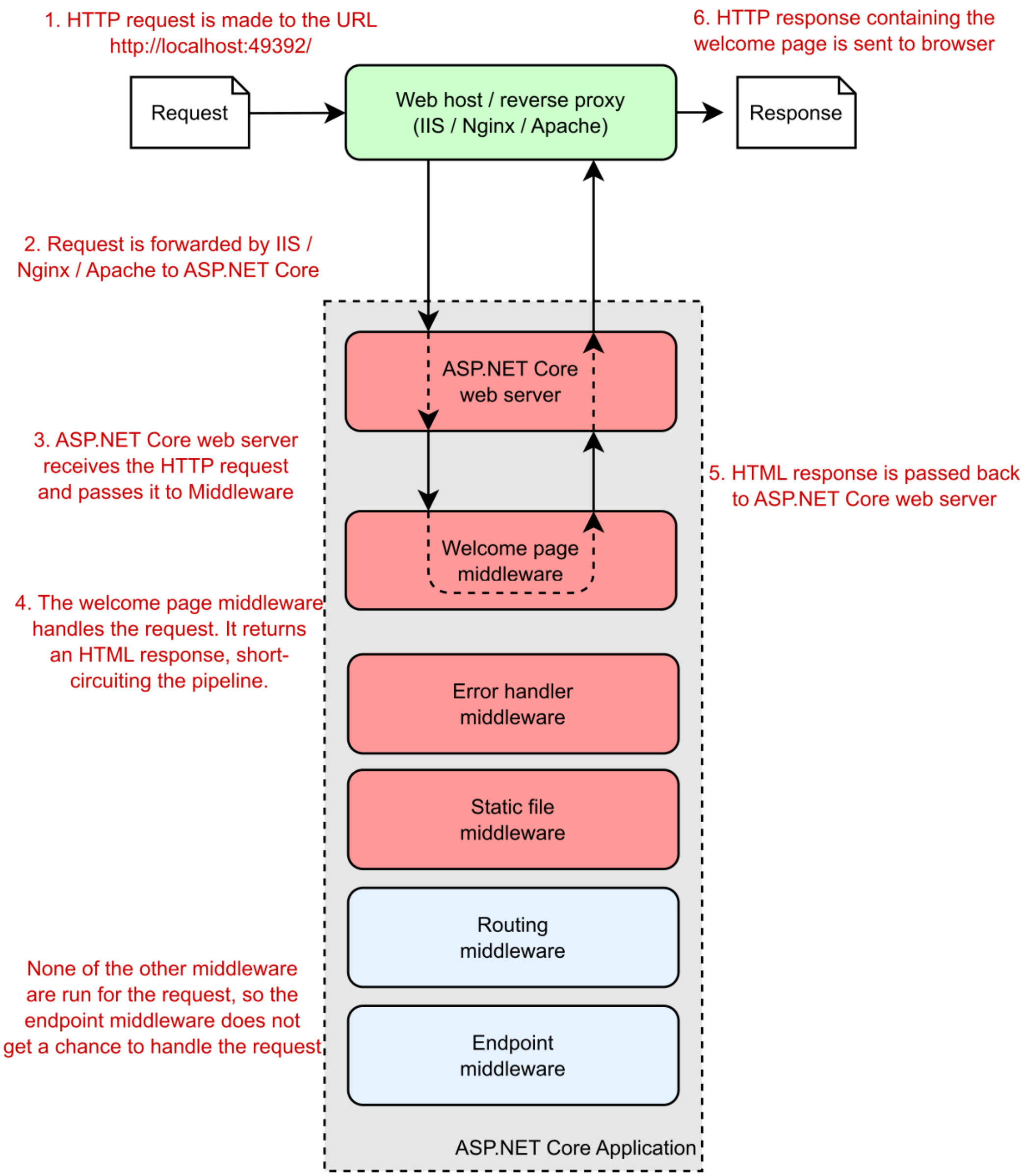

1. HTTP request is made to the URL http://localhost:49392/
6. HTTP response containing the welcome page is sent to browser
Request
Web host / reverse proxy (IIS / Nginx / Apache)
Response
2. Request is forwarded by IIS / Nginx / Apache to ASP.NET Core
ASP.NET Core web server
3. ASP.NET Core web server receives the HTTP request and passes it to Middleware
5. HTML response is passed back to ASP.NET Core web server
Welcome page middleware
4. The welcome page middleware handles the request. It returns an HTML response, short-circuiting the pipeline.
Error handler middleware
Static file middleware
Routing middleware
None of the other middleware are run for the request, so the endpoint middleware does not get a chance to handle the request
Endpoint middleware
ASP.NET Core Application

Figure 3.12 Overview of the application handling a request to the "/" path. The welcome page middleware is first in the middleware pipeline, so it receives the request before any other middleware. It generates an HTML response, short-circuiting the pipeline. No other middleware runs for the request.

If you moved `WelcomePageMiddleware` to the end of the pipeline, after the call to `UseEndpoints`, then you'd have the opposite situation. Any requests to `"/"` would be handled by the endpoint middleware and you'd never see the Welcome page.

> **TIP** You should always consider the order of middleware when adding to the `Configure` method. Middleware added earlier in the pipeline will run (and potentially return a response) before middleware added later.

All the examples shown so far attempt to handle an incoming request and generate a response, but it's important to remember that the middleware pipeline is bi-directional. Each middleware component gets an opportunity to handle both the incoming request and the outgoing response. The order of middleware is most important for those components that create or modify the outgoing response.

In the previous example, I included `ExceptionHandlerMiddleware` at the start of the application's middleware pipeline, but it didn't seem to do anything. Error handling middleware characteristically ignores the incoming request as it arrives in the pipeline, and instead inspects the outgoing response, only modifying it when an error has occurred. In the next section, I'll detail the types of error handling middleware that are available to use with your application and when to use them.

3.3 Handling errors using middleware

Errors are a fact of life when developing applications. Even if you write perfect code, as soon as you release and deploy your application, users will find a way to break it, whether by accident or intentionally! The important thing is that your application handles these errors gracefully, providing a suitable response to the user, and doesn't cause your whole application to fail.

The design philosophy for ASP.NET Core is that every feature is opt-in. So, as error handling is a feature, you need to explicitly enable it in your application. Many different types of errors could occur in your application and there are many different ways to handle them, but in this section I'll focus on two: exceptions and error status codes.

Exceptions typically occur whenever you find an unexpected circumstance. A typical (and highly frustrated) exception you'll no doubt have experienced before is `NullReferenceException`, which is thrown when you attempt to access an object that hasn't been initialized[14]. If an exception occurs in a middleware component, it propagates up the pipeline, as shown in figure 3.13. If the pipeline doesn't handle the exception, the web server will return a 500 status code back to the user.

[14] C# 8.0 introduced non-nullable reference types. These provide a way to more clearly handle null values, with the promise of finally ridding .NET of `NullReferenceExceptions`! It will take a while for that to come true, as the feature is opt-in, and requires library support, but the future's bright. See the documentation to get started: https://docs.microsoft.com/en-us/dotnet/csharp/tutorials/nullable-reference-types

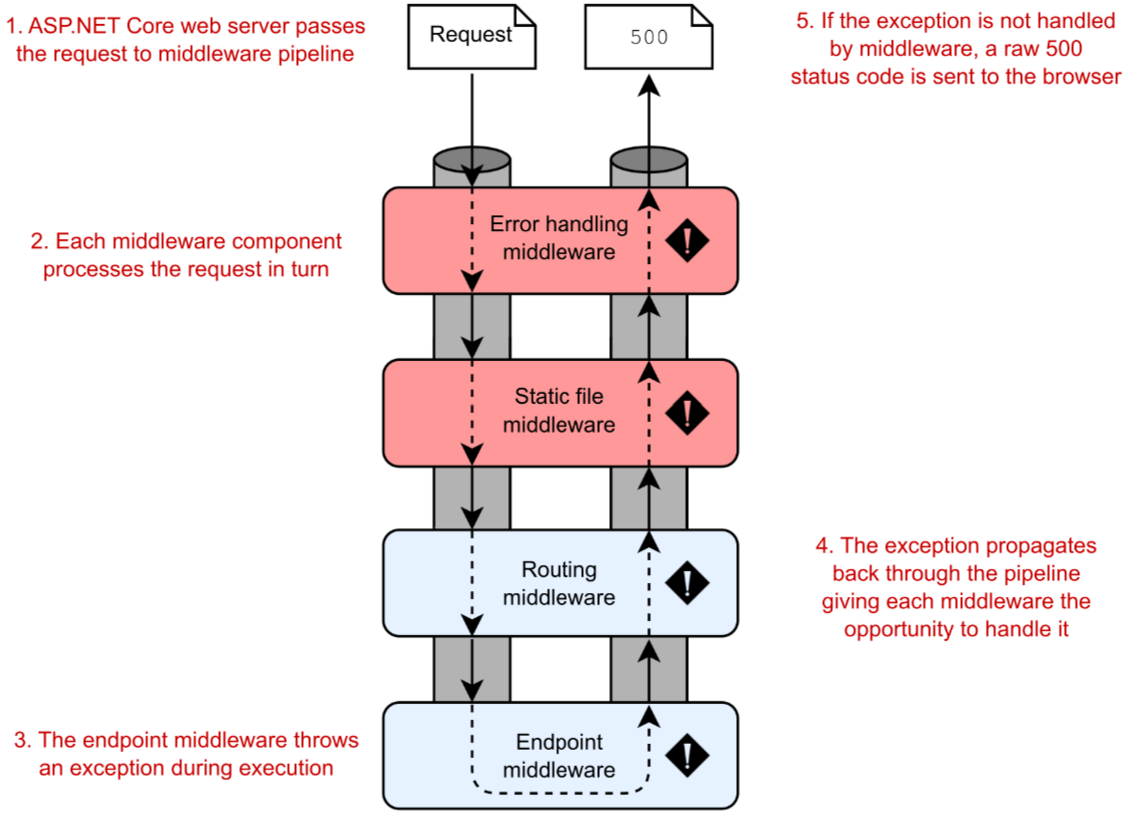
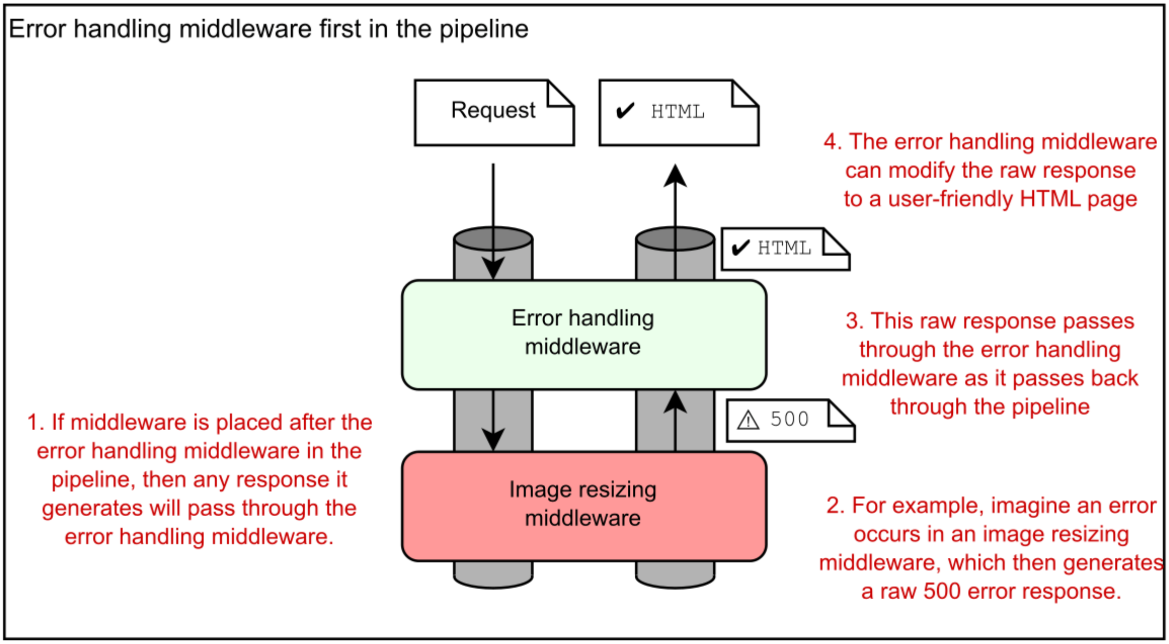

1. ASP.NET Core web server passes the request to middleware pipeline
Request
500
5. If the exception is not handled by middleware, a raw 500 status code is sent to the browser
2. Each middleware component processes the request in turn
Error handling middleware
Static file middleware
Routing middleware
4. The exception propagates back through the pipeline giving each middleware the opportunity to handle it
3. The endpoint middleware throws an exception during execution
Endpoint middleware

Figure 3.13 An exception in the endpoint middleware propagates through the pipeline. If the exception isn't caught by middleware earlier in the pipeline, then a 500 "Server error" status code is sent to the user's browser.

In some situations, an error won't cause an exception. Instead, middleware might generate an error status code. One such case you've already seen is when a requested path isn't handled. In that situation, the pipeline will return a 404 error, which results in a generic, unfriendly page being shown to the user, as you saw in figure 3.7. Although this behavior is "correct," it doesn't provide a great experience for users of your application.

Error handling middleware attempts to address these problems by modifying the response before the app returns it to the user. Typically, error handling middleware either returns details of the error that occurred, or it returns a generic, but friendly, HTML page to the user. You should always place error handling middleware early in the middleware pipeline to ensure it will catch any errors generated in subsequent middleware, as shown in figure 3.14. Any responses generated by middleware earlier in the pipeline than the error handling middleware can't be intercepted.

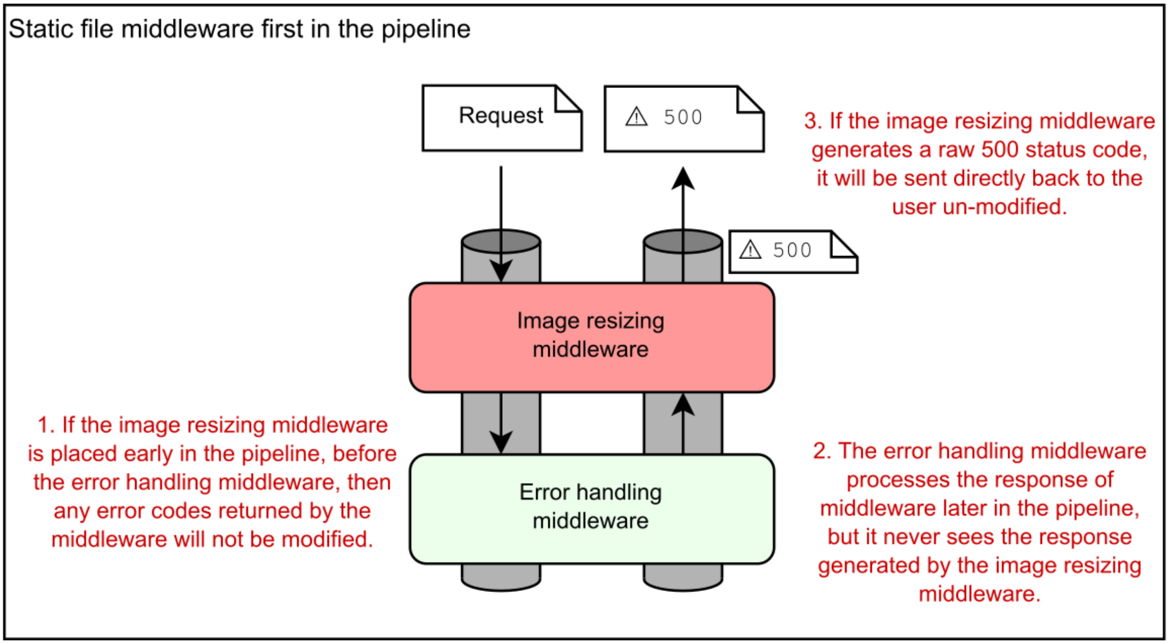

Error handling middleware first in the pipeline
Request
✔ HTML
✔ HTML
Error handling middleware
⚠ 500
Image resizing middleware

4. The error handling middleware can modify the raw response to a user-friendly HTML page

3. This raw response passes through the error handling middleware as it passes back through the pipeline

1. If middleware is placed after the error handling middleware in the pipeline, then any response it generates will pass through the error handling middleware.

2. For example, imagine an error occurs in an image resizing middleware, which then generates a raw 500 error response.


Static file middleware first in the pipeline
Request
⚠ 500
⚠ 500
Image resizing middleware
Error handling middleware

3. If the image resizing middleware generates a raw 500 status code, it will be sent directly back to the user un-modified.

1. If the image resizing middleware is placed early in the pipeline, before the error handling middleware, then any error codes returned by the middleware will not be modified.

2. The error handling middleware processes the response of middleware later in the pipeline, but it never sees the response generated by the image resizing middleware.

Figure 3.14 Error handling middleware should be placed early in the pipeline to catch raw status code errors. In the first case, the error handling middleware is placed before the image resizing middleware, so it can replace raw status code errors with a user-friendly error page. In the second case, the error handling middleware is placed after the image resizing middleware, so raw error status codes can’t be modified.

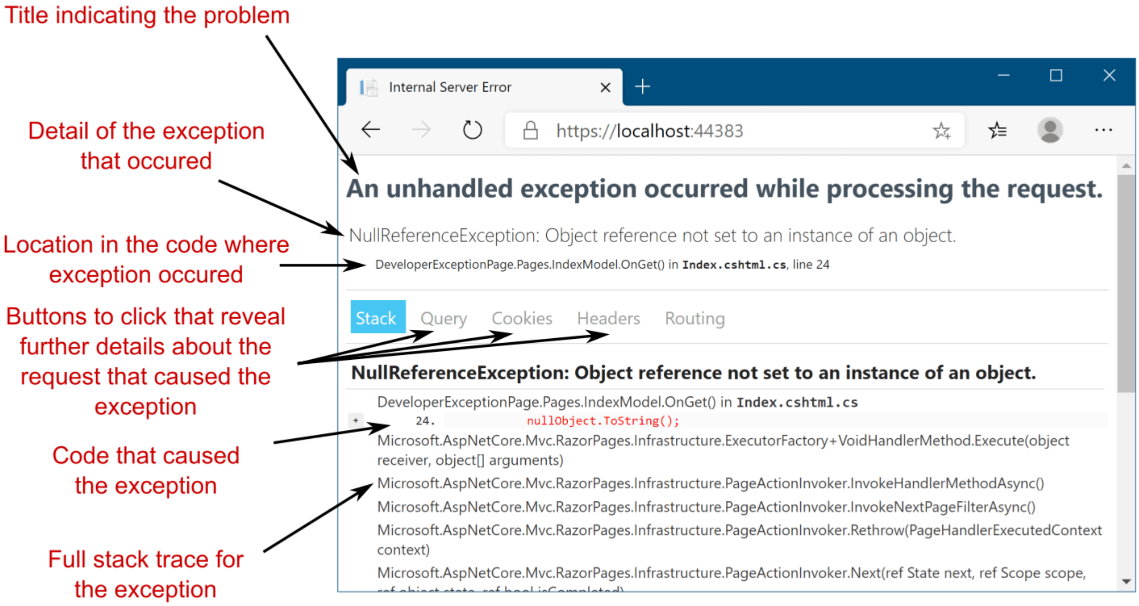
The remainder of this section shows several types of error handling middleware that are available for use in your application. They are available as part of the base ASP.NET Core framework, so you don’t need to reference any additional NuGet packages to use them.

3.3.1 Viewing exceptions in development: DeveloperExceptionPage

When you’re developing an application, you typically want access to as much information as possible when an error occurs somewhere in your app. For that reason, Microsoft provides `DeveloperExceptionPageMiddleware`, which can be added to your middleware pipeline using

```
app.UseDeveloperExceptionPage();
```

When an exception is thrown and propagates up the pipeline to this middleware, it will be captured. The middleware then generates a friendly HTML page, which it returns with a 500 status code to the user, as shown in figure 3.15. This page contains a variety of details about the request and the exception, including the exception stack trace, the source code at the line the exception occurred, and details of the request, such as any cookies or headers that had been sent.


Title indicating the problem
Detail of the exception that occured
Location in the code where exception occured
Buttons to click that reveal further details about the request that caused the exception
Code that caused the exception
Full stack trace for the exception
Internal Server Error
https://localhost:44383
Stack
Query
Cookies
Headers
Routing

An unhandled exception occurred while processing the request.

NullReferenceException: Object reference not set to an instance of an object.

DeveloperExceptionPage.Pages.IndexModel.OnGet() in `Index.cshtml.cs`, line 24

NullReferenceException: Object reference not set to an instance of an object.

DeveloperExceptionPage.Pages.IndexModel.OnGet() in `Index.cshtml.cs`

```
24.             nullObject.ToString();
```

Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.ExecutorFactory+VoidHandlerMethod.Execute(object receiver, object[] arguments)

Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.InvokeHandlerMethodAsync()

Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.InvokeNextPageFilterAsync()

Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.Rethrow(PageHandlerExecutedContext context)

Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker.Next(ref State next, ref Scope scope,

Figure 3.15 The developer exception page shows details about the exception when it occurs during the process of a request. The location in the code that caused the exception, the source code line itself, and the stack trace are all shown by default. You can also click the Query, Cookies, Headers, or Routing buttons to reveal further details about the request that caused the exception.

Having these details available when an error occurs is invaluable for debugging a problem, but they also represent a security risk if used incorrectly. You should never return more details about your application to users than absolutely necessary, so you should only ever use `DeveloperExceptionPage` when developing your application. The clue is in the name!

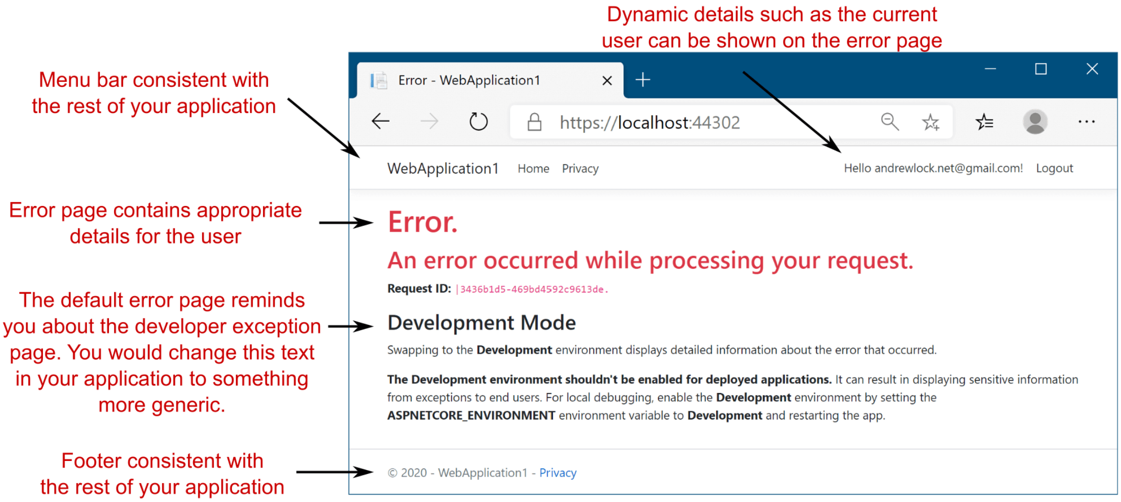
> **WARNING** Never use the developer exception page when running in production. Doing so is a security risk as it could publicly reveal details about your application's code, making you an easy target for attackers.

If the developer exception page isn't appropriate for production use, what should you use instead? Luckily, there's another general-purpose error handling middleware you *can* use in production, one that you've already seen and used: `ExceptionHandlerMiddleware`.

3.3.2 Handling exceptions in production: ExceptionHandlerMiddleware

The developer exception page is handy when developing your applications, but you shouldn't use it in production as it can leak information about your app to potential attackers. You still want to catch errors though, otherwise users will see unfriendly error pages or blank pages, depending on the browser they're using.

You can solve this problem by using `ExceptionHandlerMiddleware`. If an error occurs in your application, the user will be presented with a custom error page that's consistent with the rest of the application, but that only provides the necessary details about the error. For example, a custom error page, such as the one shown in figure 3.16, can keep the look and feel of the application by using the same header, displaying the currently logged-in user, and only displaying an appropriate message to the user instead of the full details of the exception.



Dynamic details such as the current user can be shown on the error page

Menu bar consistent with the rest of your application

Error page contains appropriate details for the user

The default error page reminds you about the developer exception page. You would change this text in your application to something more generic.

Footer consistent with the rest of your application

Error.

An error occurred while processing your request.

Request ID: |3436b1d5-469bd4592c9613de.

Development Mode

Swapping to the **Development** environment displays detailed information about the error that occurred.

The Development environment shouldn't be enabled for deployed applications. It can result in displaying sensitive information from exceptions to end users. For local debugging, enable the **Development** environment by setting the **ASPNETCORE_ENVIRONMENT** environment variable to **Development** and restarting the app.

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Figure 3.16 A custom error page created by `ExceptionHandlerMiddleware`. The custom error page can keep the same look and feel as the rest of the application by reusing elements such as the header and footer. More importantly, you can easily control the error details displayed to users.

If you were to peek at the `Configure` method of almost any ASP.NET Core application, you'd almost certainly find the developer exception page used in combination with `ExceptionHandlerMiddleware`, in a similar manner to that shown here.

Listing 3.5 Configuring exception handling for development and production

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    if (env.IsDevelopment())                            #A
    {
        app.UseDeveloperExceptionPage();                #B
    }
    else
    {
        app.UseExceptionHandler("/Error");             #C
    }

    // additional middleware configuration
}
```

#A Configure a different pipeline when running in development.
#B The developer exception page should only be used when running in development mode.
#C When in production, ExceptionHandlerMiddleware is added to the pipeline.

As well as demonstrating how to add `ExceptionHandlerMiddleware` to your middleware pipeline, this listing shows that it's perfectly acceptable to configure different middleware pipelines depending on the environment when the application starts up. You could also vary your pipeline based on other values, such as settings loaded from configuration.

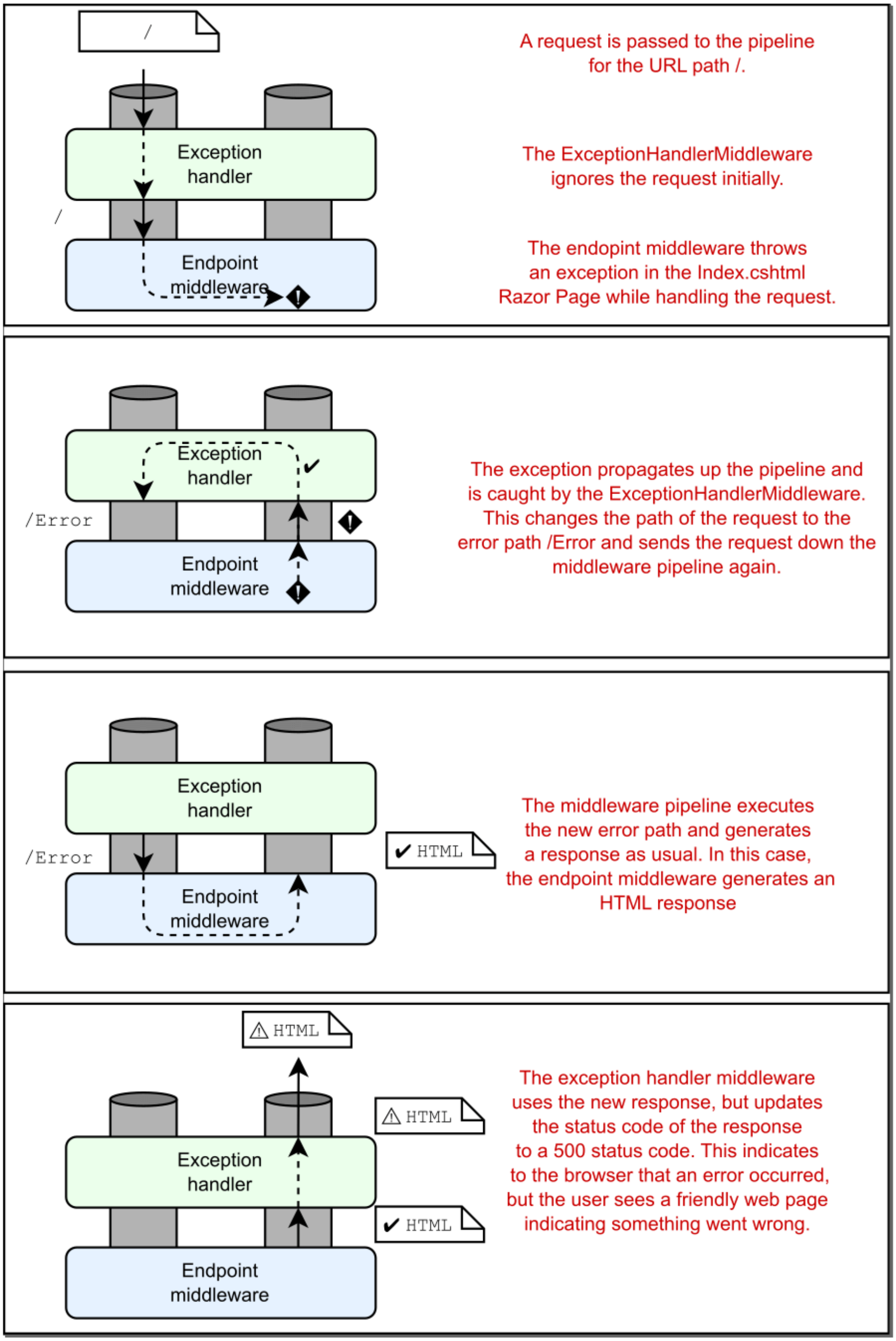
NOTE **You'll see how to use configuration values to customize the middleware pipeline in chapter 11.**

When adding `ExceptionHandlerMiddleware` to your application, you'll typically provide a path to the custom error page that will be displayed to the user. In the example listing, you used an error handling path of `"/Error"`:

```
app.UseExceptionHandler("/Error");
```

`ExceptionHandlerMiddleware` will invoke this path after it captures an exception, in order to generate the final response. The ability to dynamically generate a response is a key feature of `ExceptionHandlerMiddleware`—it allows you to re-execute a middleware pipeline in order to generate the response sent to the user.

Figure 3.17 shows what happens when `ExceptionHandlerMiddleware` handles an exception. It shows the flow of events when the Index.chstml Razor Page generates an exception when a request is made to the `"/"` path. The final response returns an error status code but also provides an HTML response to display to the user, using the `"/Error"` path.



A request is passed to the pipeline for the URL path /.

The ExceptionHandlerMiddleware ignores the request initially.

The endopint middleware throws an exception in the Index.cshtml Razor Page while handling the request.

The exception propagates up the pipeline and is caught by the ExceptionHandlerMiddleware. This changes the path of the request to the error path /Error and sends the request down the middleware pipeline again.

The middleware pipeline executes the new error path and generates a response as usual. In this case, the endpoint middleware generates an HTML response

The exception handler middleware uses the new response, but updates the status code of the response to a 500 status code. This indicates to the browser that an error occurred, but the user sees a friendly web page indicating something went wrong.

Figure 3.17 `ExceptionHandlerMiddleware` **handling an exception to generate an HTML response. A request to the / path generates an exception, which is handled by the middleware. The pipeline is re-executed using the /Error path to generate the HTML response.**

The sequence of events when an exception occurs somewhere in the middleware pipeline after `ExceptionHandlerMiddleware` is as follows:

1. A piece of middleware throws an exception.
2. `ExceptionHandlerMiddleware` catches the exception.
3. Any partial response that has been defined is cleared.
4. The middleware overwrites the request path with the provided error handling path.
5. The middleware sends the request back down the pipeline, as though the original request had been for the error handling path.
6. The middleware pipeline generates a new response as normal.
7. When the response gets back to `ExceptionHandlerMiddleware`, it modifies the status code to a 500 error and continues to pass the response up the pipeline to the web server.

The main advantage that re-executing the pipeline brings is the ability to have your error messages integrated into your normal site layout, as shown previously in figure 3.16. It's certainly possible to return a fixed response when an error occurs, but you wouldn't be able to have a menu bar with dynamically generated links or display the current user's name in the menu. By re-executing the pipeline, you can ensure that all the dynamic areas of your application are correctly integrated, as if the page was a standard page of your site.

> **NOTE** You don't need to do anything other than add `ExceptionHandlerMiddleware` to your application and configure a valid error handling path to enable re-executing the pipeline. The middleware will catch the exception and re-execute the pipeline for you. Subsequent middleware will treat the re-execution as a new request, but previous middleware in the pipeline won't be aware anything unusual happened.

Re-executing the middleware pipeline is a great way to keep consistency in your web application for error pages, but there are some gotchas to be aware of. First, middleware can only modify a response generated further down the pipeline if the response *hasn't yet been sent to the client*. This can be a problem if, for example, an error occurs while ASP.NET Core is sending a static file to a client. In that case, where bytes have already begun to be sent, the error handling middleware won't be able to run, as it can't reset the response. Generally speaking, there's not a lot you can do about this issue, but it's something to be aware of.

A more common problem occurs when the error handling path throws an error during the re-execution of the pipeline. Imagine there's a bug in the code that generates the menu at the top of the page:

1. When the user reaches your homepage, the code for generating the menu bar throws an exception.
2. The exception propagates up the middleware pipeline.

3. When reached, `ExceptionHandlerMiddleware` captures it and the pipe is re-executed using the error handling path.
4. When the error page executes, it attempts to generate the menu bar for your app, which again throws an exception.
5. The exception propagates up the middleware pipeline.
6. `ExceptionHandlerMiddleware` has already tried to intercept a request, so it will let the error propagate all the way to the top of the middleware pipeline.
7. The web server returns a raw 500 error, as though there was no error handling middleware at all.

Thanks to this problem, it's often good practice to make your error handling pages as simple as possible, to reduce the possibility of errors occurring.

> **WARNING** If your error handling path generates an error, the user will see a generic browser error. It's often better to use a static error page that will always work, rather than a dynamic page that risks throwing more errors.

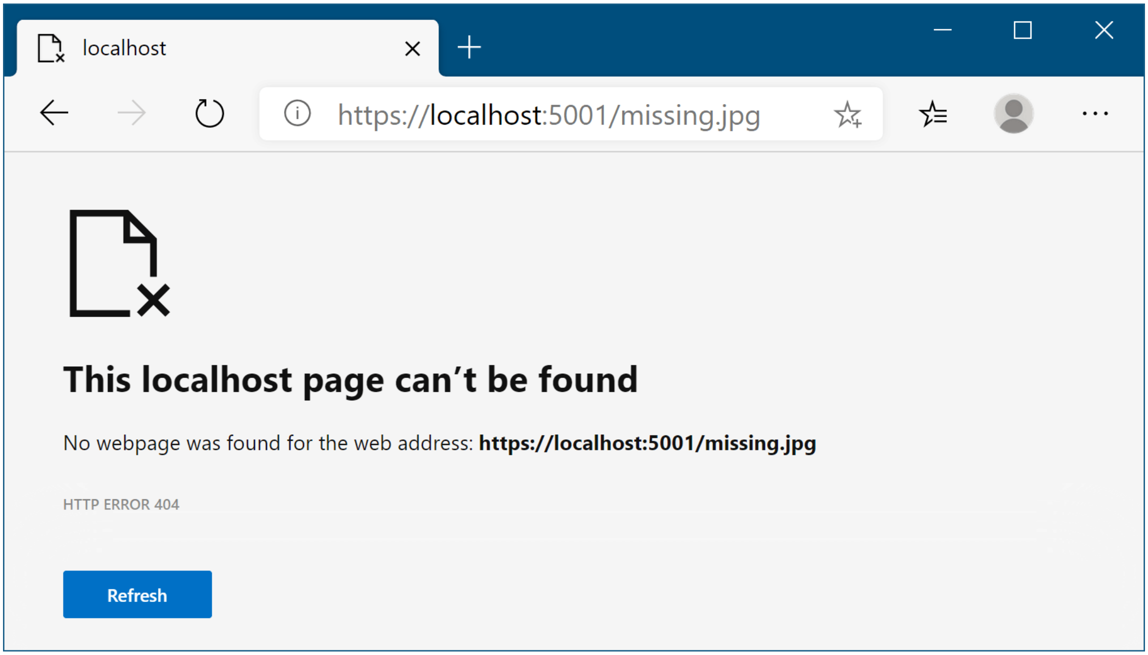
`ExceptionHandlerMiddleware` and `DeveloperExceptionPageMiddleware` are great for catching exceptions in your application, but exceptions aren't the only sort of errors you'll encounter. In some cases, your middleware pipeline will return an HTTP error status code in the response. It's important to handle both exceptions and error status codes to provide a coherent user experience.

3.3.3 Handling other errors: StatusCodePagesMiddleware

Your application can return a wide range of HTTP status codes that indicate some sort of error state. You've already seen that a 500 "server error" is sent when an exception occurs and isn't handled and that a 404 "file not found" error is sent when a URL isn't handled by any middleware. 404 errors, in particular, are common, often occurring when a user enters an invalid URL.

> **TIP** As well as indicating a completely unhandled URL, 404 errors are often used to indicate that a specific requested object was not found. For example, a request for the details of a product with an ID of 23 might return a 404 if no such product exists.

Without handling these status codes, users will see a generic error page, such as in figure 3.18, which may leave many confused and thinking your application is broken. A better approach would be to handle these error codes and return an error page that's in keeping with the rest of your application or, at the very least, doesn't make your application look broken.



This localhost page can't be found

No webpage was found for the web address: **https://localhost:5001/missing.jpg**

HTTP ERROR 404

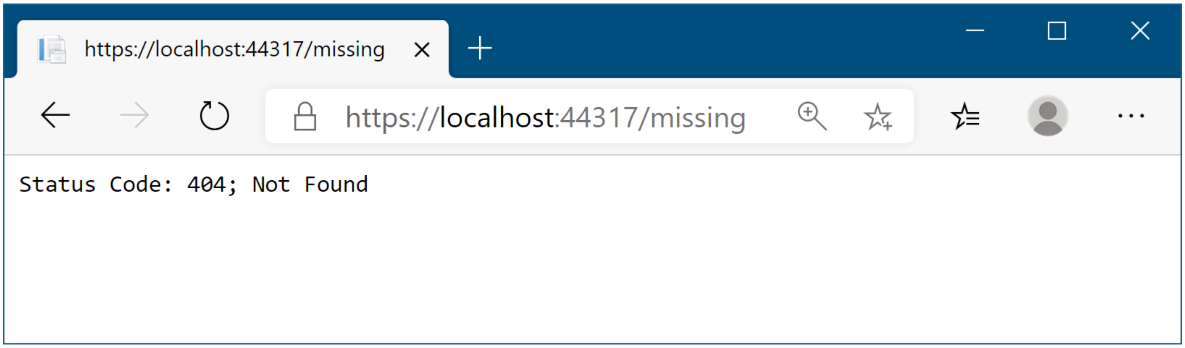
Figure 3.18 A generic browser error page. If the middleware pipeline can't handle a request, it will return a 404 error to the user. The message is of limited usefulness to users and may leave many confused or thinking your web application is broken.

Microsoft provides `StatusCodePagesMiddleware` for handling this use case. As with all error handling middleware, you should add it early in your middleware pipeline, as it will only handle errors generated by later middleware components.

You can use the middleware a number of different ways in your application. The simplest approach is to add the middleware to your pipeline without any additional configuration, using

```
app.UseStatusCodePages();
```

With this method, the middleware will intercept any response that has an HTTP Status code that starts with 4xx or 5xx and has no response body. For the simplest case, where you don't provide any additional configuration, the middleware will add a plain text response body, indicating the type and name of the response, as shown in figure 3.19. This is arguably worse than the default message at this point, but it is a starting point for providing a more consistent experience to users!



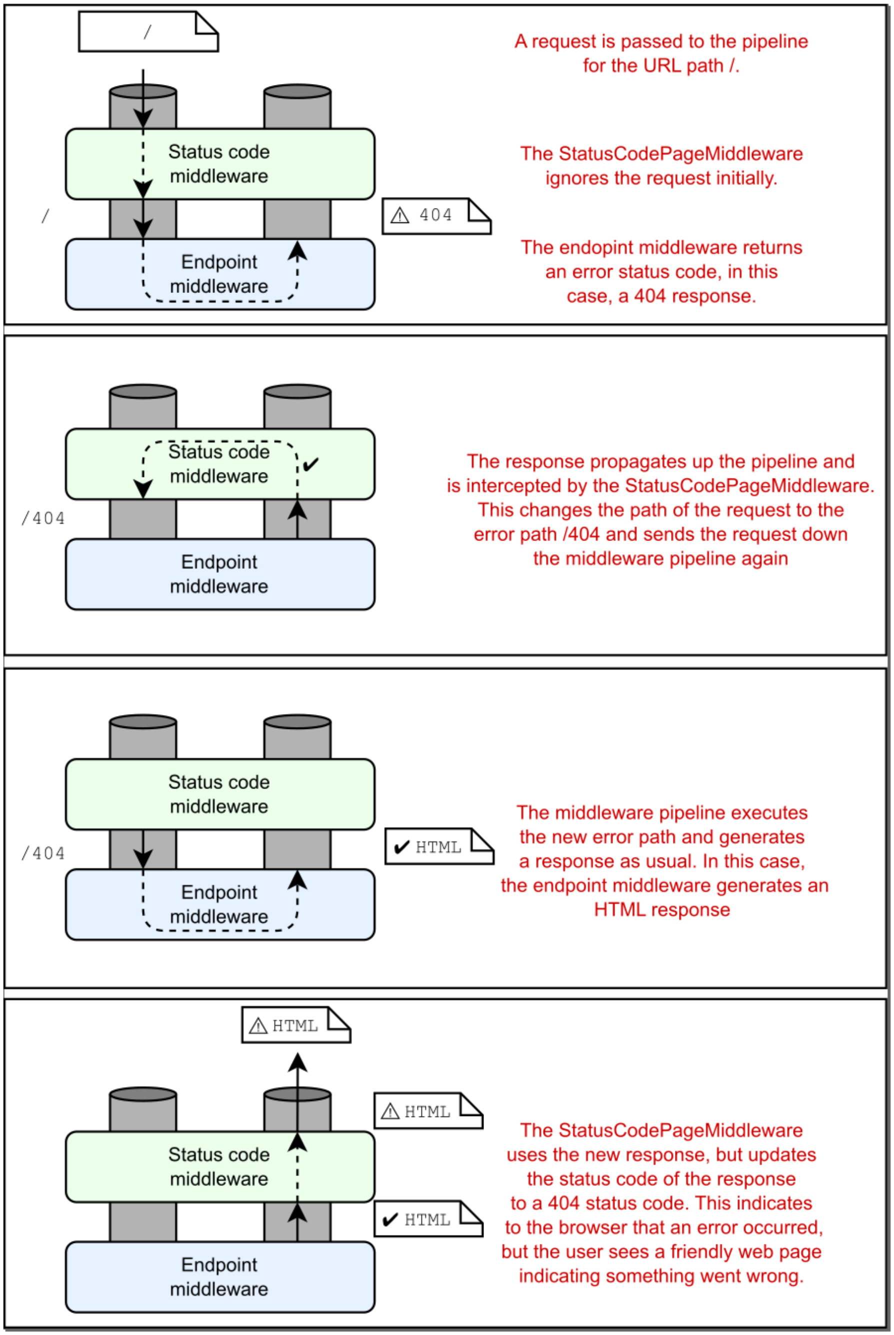
```
Status Code: 404; Not Found
```

Figure 3.19 Status code error pages for a 404 error. You generally won't use this version of the middleware in production as it doesn't provide a great user experience, but it demonstrates that the error codes are being correctly intercepted.

A more typical approach to using `StatusCodePageMiddleware` in production is to re-execute the pipeline when an error is captured, using a similar technique to the `ExceptionHandlerMiddleware`. This allows you to have dynamic error pages that fit with the rest of your application. To use this technique, replace the call to `UseStatusCodePages` with the following extension method

```
app.UseStatusCodePagesWithReExecute("/{0}");
```

This extension method configures `StatusCodePageMiddleware` to re-execute the pipeline whenever a 4xx or 5xx response code is found, using the provided error handling path. This is similar to the way `ExceptionHandlerMiddleware` re-executes the pipeline, as shown in figure 3.20.



A request is passed to the pipeline for the URL path /.

The StatusCodePageMiddleware ignores the request initially.

The endopint middleware returns an error status code, in this case, a 404 response.

The response propagates up the pipeline and is intercepted by the StatusCodePageMiddleware. This changes the path of the request to the error path /404 and sends the request down the middleware pipeline again

The middleware pipeline executes the new error path and generates a response as usual. In this case, the endpoint middleware generates an HTML response

The StatusCodePageMiddleware uses the new response, but updates the status code of the response to a 404 status code. This indicates to the browser that an error occurred, but the user sees a friendly web page indicating something went wrong.

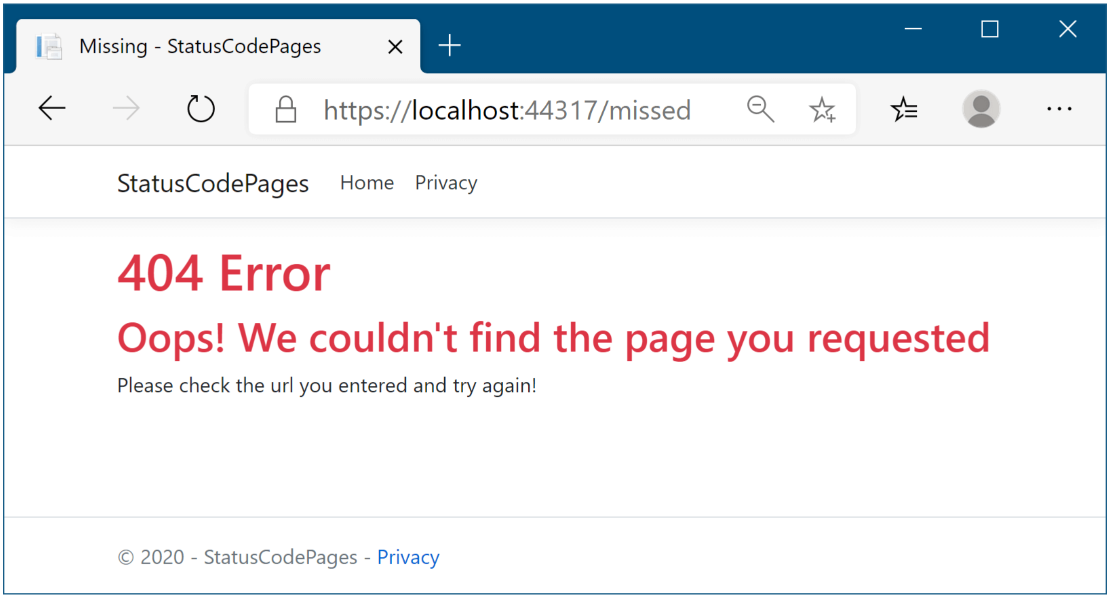
Figure 3.20 `StatusCodePagesMiddleware` re-executing the pipeline to generate an HTML body for a 404 response. A request to the / path returns a 404 response, which is handled by the status code middleware. The pipeline is re-executed using the / 404 path to generate the HTML response.

Note that the error handling path `"/{0}"` contains a format string token, `{0}`. When the path is re-executed, the middleware will replace this token with the status code number. For example, a 404 error would re-execute the `/404` path. The handler for the path (typically a Razor Page) has access to the status code and can optionally tailor the response, depending on the status code. You can choose any error handling path, as long as your application knows how to handle it.

NOTE You'll learn about how routing maps request paths to Razor Pages in chapter 5.

With this approach in place, you can create different error pages for different error codes, such as the 404-specific error page shown in figure 3.21. This technique ensures your error pages are consistent with the rest of your application, including any dynamically generated content, while also allowing you to tailor the message for common errors.

WARNING As before, when re-executing the pipeline, you must be careful your error handling path doesn't generate any errors.



404 Error

Oops! We couldn't find the page you requested

Please check the url you entered and try again!

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Figure 3.21 An error status code page for a missing file. When an error code is detected (in this case, a 404 error), the middleware pipeline is re-executed to generate the response. This allows dynamic portions of your web page to remain consistent on error pages.

You can use the StatusCodePagesMiddleware in combination with other exception handling middleware by adding both to the pipeline. StatusCodePagesMiddleware will only modify the response if no response body has been written. So if another component, for example the ExceptionHandlerMiddleware, returns a message body along with an error code, it won't be modified.

> **NOTE** StatusCodePageMiddleware **has additional overloads that let you execute custom middleware when an error occurs, instead of re-executing a Razor Pages path.**

Error handling is essential when developing any web application; errors happen, and you need to handle them gracefully. But depending on your application, you may not always want your error handling middleware to generate HTML pages.

3.3.4 Error handling middleware and Web APIs

ASP.NET Core isn't only great for creating user-facing web applications, it's also great for creating HTTP services that can be accessed either from another server application, from a mobile app, or from a user's browser when running a client-side single-page application. In all these cases, you probably won't be returning HTML to the client, but rather XML or JSON.

In that situation, if an error occurs, you probably don't want to be sending back a big HTML page saying, "Oops, something went wrong." Returning an HTML page to an application that's expecting JSON could easily break it unexpectedly. Instead, the HTTP 500 status code and a JSON body describing the error is more useful to a consuming application. Luckily, ASP.NET Core allows you to do exactly this when you create Web API controllers.

> **NOTE I'll discuss MVC and Web API controllers in chapter 4. I discuss Web APIs and handling errors in detail in chapter 9.**

That brings us to the end of middleware in ASP.NET Core for now. You've seen how to use and compose middleware to form a pipeline, as well as how to handle errors in your application. This will get you a long way when you start building your first ASP.NET Core applications. Later, you'll learn how to build your own custom middleware, as well as how to perform complex operations on the middleware pipeline, such as forking it in response to specific requests.

In the next chapter, you'll look in more depth at Razor Pages, and how they can be used to build websites. You'll also learn about the MVC design pattern, its relationship with Razor Pages in ASP.NET Core, and when to choose one approach over the other.

3.4 Summary

- Middleware has a similar role to HTTP modules and handlers in ASP.NET but is more easily reasoned about.

- Middleware is composed in a pipeline, with the output of one middleware passing to the input of the next.
- The middleware pipeline is two-way: requests pass through each middleware on the way in and responses pass back through in the reverse order on the way out.
- Middleware can short-circuit the pipeline by handling a request and returning a response, or it can pass the request on to the next middleware in the pipeline.
- Middleware can modify a request by adding data to, or changing, the `HttpContext` object.
- If an earlier middleware short-circuits the pipeline, not all middleware will execute for all requests.
- If a request isn't handled, the middleware pipeline will return a 404 status code.
- The order in which middleware is added to `IApplicationBuilder` defines the order in which middleware will execute in the pipeline.
- The middleware pipeline can be re-executed, as long as a response's headers haven't been sent.
- When added to a middleware pipeline, `StaticFileMiddleware` will serve any requested files found in the wwwroot folder of your application.
- `DeveloperExceptionPageMiddleware` provides a lot of information about errors when developing an application but should never be used in production.
- `ExceptionHandlerMiddleware` lets you provide user-friendly custom error handling messages when an exception occurs in the pipeline.
- `StatusCodePagesMiddleware` lets you provide user-friendly custom error handling messages when the pipeline returns a raw error response status code.
- Microsoft provides some common middleware and there are many third-party options available on NuGet and GitHub.

4 Creating a web site with Razor Pages

This chapter covers

- **Introducing Razor Pages and the Model-View-Controller (MVC) design pattern**
- **Using Razor Pages in ASP.NET Core**
- **Choosing between Razor Pages and MVC controllers**
- **Controlling application flow using action results**

In chapter 3, you learned about the middleware pipeline, which defines how an ASP.NET Core application responds to a request. Each piece of middleware can modify or handle an incoming request, before passing the request to the next middleware in the pipeline.

In ASP.NET Core web applications, your middleware pipeline will normally include the `EndpointMiddleware`. This is typically where you write the bulk of your application logic, by calling various other classes in your app. It also serves as the main entry point for users to interact with your app. It typically takes one of three forms:

- *An HTML web application, designed for direct use by users.* If the application is consumed directly by users, as in a traditional web application, then Razor Pages is responsible for generating the web pages that the user interacts with. It handles requests for URLs, it receives data posted using forms, and it generates the HTML that users use to view and navigate your app.
- *An API designed for consumption by another machine or in code.* The other main possibility for a web application is to serve as an API to backend server processes, to a mobile app, or to a client framework for building single page applications (SPAs). In

this case, your application serves data in machine-readable formats such as JSON or XML, instead of the human-focused HTML output.

- *Both an HTML web application, and an API.* It is also possible to have applications that serve both needs! This can let you cater to a wider range of clients, while sharing logic in your application

In this chapter, you'll learn how ASP.NET Core uses Razor Pages to handle the first of these options, creating server-side rendered HTML pages. You'll start by looking at the Model-View-Controller (MVC) design pattern to see the benefits that can be achieved through its use and learn why it's been adopted by so many web frameworks as a model for building maintainable applications.

Next, you'll learn how the MVC design pattern applies to ASP.NET Core. The MVC pattern is a broad concept that can be applied in a variety of situations, but the use case in ASP.NET Core is specifically as a UI abstraction. You'll see how Razor Pages implements the MVC design pattern, and how it builds on top of the ASP.NET Core MVC framework, comparing the two approaches.

Next, you'll see how to add Razor Pages to an existing application, and how to create your first Razor Pages. You'll learn how to define page handlers to execute when your application receives a request and how to generate a result that can be used to create an HTTP response to return.

I won't cover how to create Web APIs in this chapter. Web APIs still use the ASP.NET Core MVC framework, but they're used in a slightly different way to Razor Pages. Instead of returning web pages that are directly displayed on a user's browser, they return data formatted for consumption in code. Web APIs are often used for providing data to mobile and web applications, or to other server applications. But they still follow the same general MVC pattern. You'll see how to create a Web API in chapter 9.

> **NOTE** This chapter is the first of several on Razor Pages and MVC in ASP.NET Core. As I've already mentioned, these frameworks are often responsible for handling all the business logic and UI code for your application, so, perhaps unsurprisingly, they're large and somewhat complicated. The next five chapters all deal with a different aspect of the MVC pattern that make up the MVC and Razor Pages frameworks.

In this chapter, I'll try to prepare you for each of the upcoming topics, but you may find that some of the behavior feels a bit like magic at this stage. Try not to become too concerned with exactly how all the pieces tie together; focus on the specific concepts being addressed. It should all become clear as we cover the associated details in the remainder of this first part of the book.

4.1 An introduction to Razor Pages

The Razor Pages programming model was introduced in ASP.NET Core 2.0 as a way to build server-side rendered "page-based" web sites. It builds on top of the ASP.NET Core infrastructure to provide a streamlined experience, using conventions where possible to reduce the amount of boilerplate code and configuration required.

> **DEFINITION** A *page-based* web site is one in which the user browses between multiple pages, enters data into forms, and generally consumes content. This contrasts with applications like games or single page applications (SPAs), which are heavily interactive on the client-side.

You've already seen a very basic example of a Razor Page in chapter 2. In this section we'll start by looking at a slightly more complex Razor Page, to better understand the overall design of Razor Pages. I cover:

- An example of a typical Razor Page
- The MVC design pattern and how it applies to Razor Pages
- How to add Razor Pages to your application

At the end of this section you should have a good understanding of the overall design behind Razor Pages, and how they relate to the MVC pattern.

4.1.1 Exploring a typical Razor Page

In chapter 2 we looked at a very simple Razor Page. It didn't contain any logic, and instead just rendered the associated Razor view. This pattern may be common if you're building a content-heavy marketing website, for example, but more commonly your Razor Pages will contain some logic, load data from a database, or use forms to allow users to submit information, for example.

To give more of a flavor of how typical Razor Pages work, in this section we look briefly at a slightly more complex Razor Page. This page is taken from a to-do list application and is used to display all the to-do items for a given category. We're not focusing on the HTML generation at this point, so the listing below shows only the Page Model code-behind for the Razor Page.

Listing 4.1 A Razor Page for viewing all to-do items in a given category

```
public class CategoryModel : PageModel
{
    private readonly ToDoService _service;                #A
    public CategoryModel(ToDoService service)             #A
    {
        _service = service;
    }

    public ActionResult OnGet(string category)            #B
    {
        Items = _service.GetItemsForCategory(category);     #C
        return Page();                                      #D
    }

    public List<ToDoListModel> Items { get; set; }        #E
}
```

#A The ToDoService is provided in the model constructor using dependency injection.
#B OnGet handler takes a parameter, category.
#C The handler calls out to the ToDoService to retrieve data and sets the Items property
#D Returns a PageResult indicating the Razor view should be rendered
#E The Razor View can access the Items property when it is rendered.

This example is still relatively simple, but it demonstrates a variety of features compared to the basic example from chapter 2:

- The page handler, `OnGet`, accepts a method parameter, `category`. This parameter is automatically populated by the Razor Page infrastructure using values from the incoming request, in a process called "model binding". I discuss model in detail in chapter 6.
- The handler doesn't interact with the database directly. Instead, it uses the `category` value provided to interact with the `ToDoService`, which is injected as a constructor argument using dependency injection.
- The handler returns `Page()` at the end of the method to indicate the associated Razor view should be rendered. The return statement is actually optional in this case; by convention, if the page handler is a `void` method, the Razor view will still be rendered, behaving as if you had called `return Page()` at the end of the method.
- The Razor View has access to the `CategoryModel` instance, so it can access the `Items` property that is set by the handler. It uses these items to build the HTML that is ultimately sent to the user.

The pattern of interactions in the Razor Page of listing 4.1 shows a common pattern. The page handler is the central controller for the Razor Page. It receives an input from the user (the `category` method parameter), calls out to the "brains" of the application (the `ToDoService`) and passes data (by exposing the `Items` property) to the Razor view which generates the HTML response. If you squint, this looks like the Model-View-Controller (MVC) design pattern.

Depending on your background in software development, you may have previously come across the MVC pattern in some form. In web development, MVC is a common paradigm and is used in frameworks such as Django, Rails, and Spring MVC. But as it's such a broad concept, you can find MVC in everything from mobile apps to rich-client desktop applications. Hopefully that's indicative of the benefits the pattern can bring if used correctly! In the next section I look at the MVC pattern in general and how it's used by ASP.NET Core.

4.1.2 The MVC design pattern

The MVC design pattern is a common pattern for designing apps that have UIs. The original MVC pattern has many different interpretations, each of which focuses on a slightly different aspect of the pattern. For example, the original MVC design pattern was specified with rich-client graphical user interface (GUI) apps in mind, rather than web applications, and so uses terminology and paradigms associated with a GUI environment. Fundamentally, though, the pattern aims to separate the management and manipulation of data from its visual representation.

Before I dive too far into the design pattern itself, let's consider a typical request. Imagine a user of your application requests the Razor Page from the previous section that displays a to-do list category. Figure 4.1 shows how a Razor Page handles different aspects of a request, all of which combine to generate the final response.

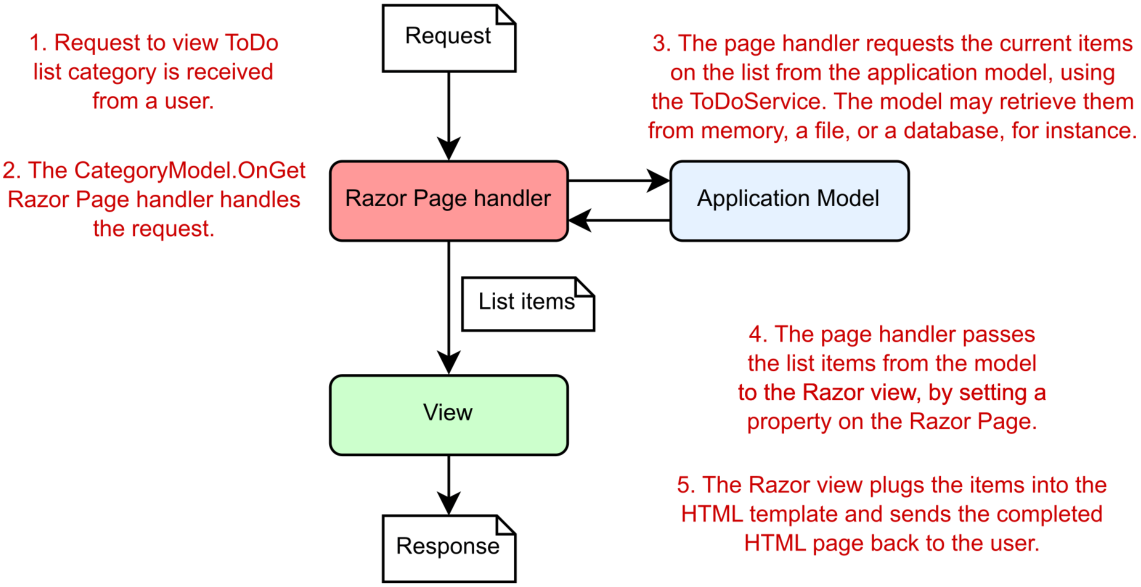

1. Request to view ToDo list category is received from a user.
Request
2. The CategoryModel.OnGet Razor Page handler handles the request.
Razor Page handler
3. The page handler requests the current items on the list from the application model, using the ToDoService. The model may retrieve them from memory, a file, or a database, for instance.
Application Model
List items
4. The page handler passes the list items from the model to the Razor view, by setting a property on the Razor Page.
View
5. The Razor view plugs the items into the HTML template and sends the completed HTML page back to the user.
Response

Figure 4.1 Requesting a to-do list page for a Razor Pages application. A different "component" handles each aspect of the request.

In general, three "components" make up the MVC design pattern:

- *Model*—The data that needs to be displayed, the global state of the application. Accessed via the `ToDoService` in Listing 4.1.
- *View*—The template that displays the data provided by the model.
- *Controller*—Updates the model and provides the data for display to the view. This role is taken by the page handler in Razor Pages. This is the `OnGet` method in listing 4.1.

Each component in the MVC design pattern is responsible for a single aspect of the overall system that, when combined, can be used to generate a UI. The to-do list example considers MVC in terms of a web application using Razor Pages, but a request could also be equivalent to the click of a button in a desktop GUI application.

In general, the order of events when an application responds to a user interaction or request is as follows:

1. The controller (the Razor Page handler) receives the request.
2. Depending on the request, the controller either fetches the requested data from the application model using injected services, or it updates the data that makes up the model.
3. The controller selects a view to display and passes a representation of the model to it.
4. The view uses the data contained in the model to generate the UI.

When we describe MVC in this format, the controller (the Razor Page handler) serves as the entry point for the interaction. The user communicates with the controller to instigate an interaction. In web applications, this interaction takes the form of an HTTP request, so when a request to a URL is received, the controller handles it.

Depending on the nature of the request, the controller may take a variety of actions, but the key point is that the actions are undertaken using the application model. The model here contains all the business logic for the application, so it's able to provide requested data or perform actions.

> **NOTE** In this description of MVC, the model is considered to be a complex beast, containing all the logic for how to perform an action, as well as any internal state. The Razor Page `PageModel` class is **not** the model we're talking about! Unfortunately, as in all software development, naming things is hard!

Consider a request to view a product page for an e-commerce application, for example. The controller would receive the request and would know how to contact some product service that's part of the application model. This might fetch the details of the requested product from a database and return them to the controller.

Alternatively, imagine a controller receives a request to add a product to the user's shopping cart. The controller would receive the request, and most likely invoke a method on the model to request that the product be added. The model would then update its internal representation of the user's cart, by adding, for example, a new row to a database table holding the user's data.

> **TIP** You can think of each Razor Page handler as a mini controller focused on a single page. Every web request is another independent call to a controller, which orchestrates the response. Although there are many different controllers, the handlers all interact with the *same* application model.

After the model has been updated, the controller needs to decide what response to generate. One of the advantages of using the MVC design pattern is that the model representing the application's data is decoupled from the final representation of that data, called the view. The controller is responsible for deciding whether the response should generate an HTML view, whether it should send the user to a new page, or whether it should return an error page.

One of the advantages of the model being independent of the view is that it improves testability. UI code is classically hard to test, as it's dependent on the environment—anyone who has written UI tests simulating a user clicking buttons and typing in forms knows that it's typically fragile. By keeping the model independent of the view, you can ensure the model stays easily testable, without any dependencies on UI constructs. As the model often contains your application's business logic, this is clearly a good thing!

The view can use the data passed to it by the controller to generate the appropriate HTML response. The view is only responsible for generating the final representation of the data, it's not involved in any of the business logic.

This is all there is to the MVC design pattern in relation to web applications. Much of the confusion related to MVC seems to stem from slightly different uses of the term for slightly different frameworks and types of application. In the next section, I'll show how the ASP.NET Core framework uses the MVC pattern with Razor Pages, along with more examples of the pattern in action.

4.1.3 Applying the MVC design pattern to Razor Pages

In the previous section I discussed the MVC *pattern* as typically used in web applications, and as used by Razor Pages. But ASP.NET Core also includes a *framework* called ASP.NET Core MVC. This framework (unsurprisingly) very closely mirrors the MVC design pattern, using *controllers* and *action methods* in place of Razor Pages and page handlers. Razor Pages builds directly on top of the underlying ASP.NET Core MVC framework, using the MVC framework "under the hood" for their behavior.

If you prefer, you can avoid Razor Pages entirely, and work with the MVC framework directly in ASP.NET Core. This was the *only* option in early versions of ASP.NET Core and the previous version of ASP.NET.

TIP I look in greater depth at choosing between Razor Pages and the MVC framework in section 4.2.

In this section we look in greater depth at how the MVC design pattern applies to Razor Pages in ASP.NET Core. This will also help clarify the role of various features of Razor Pages.

Do Razor Pages use MVC or MVVM?

Occasionally I've seen people describe Razor Pages as using the Model-View-View Model (MVVM) design pattern, rather than the MVC design pattern. Personally, I don't agree, but it's worth being aware of the differences.

MVVM is a UI pattern that is often used in mobile apps, desktop apps, and in some client-side frameworks. It differs from MVC in that there is a bi-directional interaction between the view and the view model. The view model tells the view what to display, but the view can also trigger changes directly on the view model. It's often used with two-way databinding where a view model is "bound" to a view.

Some people consider the Razor Pages `PageModel` to be filling this role, but I'm not convinced. Razor Pages definitely seems based on the MVC pattern to me (it's based on the ASP.NET Core MVC framework after all!) and doesn't have the same "two-way binding" that I would expect with MVVM.

As you’ve seen in previous chapters, ASP.NET Core implements Razor Page endpoints using a combination of the `RoutingMiddleware` and `EndpointMiddleware`, as shown in figure 4.2. Once a request has been processed by earlier middleware (and assuming none of them handle the request and short-circuit the pipeline), the routing middleware will select which Razor Page handler should be executed, and the Endpoint middleware executes the page handler.

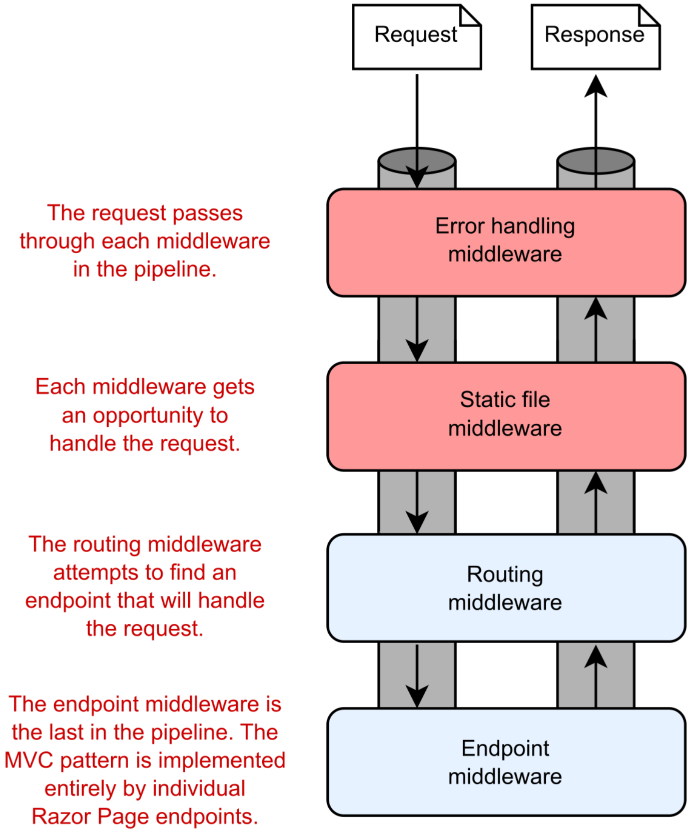

Request
Response
The request passes through each middleware in the pipeline.
Error handling middleware
Each middleware gets an opportunity to handle the request.
Static file middleware
The routing middleware attempts to find an endpoint that will handle the request.
Routing middleware
The endpoint middleware is the last in the pipeline. The MVC pattern is implemented entirely by individual Razor Page endpoints.
Endpoint middleware

Figure 4.2 The middleware pipeline for a typical ASP.NET Core application. The request is processed by each middleware in sequence. If the request reaches the routing middleware, the middleware selects an endpoint, such as a Razor Page, to execute. The endpoint middleware executes the selected endpoint.

Middleware often handles cross-cutting concerns or narrowly defined requests, such as requests for files. For requirements that fall outside of these functions, or that have many external dependencies, a more robust framework is required. Razor Pages (and/or ASP.NET Core MVC) can provide this framework, allowing interaction with your application’s core business logic, and the generation of a UI. It handles everything from mapping the request to an appropriate controller to generating the HTML or API response.

In the traditional description of the MVC design pattern, there's only a single type of model, which holds all the non-UI data and behavior. The controller updates this model as appropriate and then passes it to the view, which uses it to generate a UI.

One of the problems when discussing MVC is the vague and ambiguous terms that it uses, such as "controller" and "model." Model, in particular, is such an overloaded term that it's often difficult to be sure exactly what it refers to—is it an object, a collection of objects, an abstract concept? Even ASP.NET Core uses the word "model" to describe several related, but different, components, as you'll see shortly.

DIRECTING A REQUEST TO A RAZOR PAGE AND BUILDING A BINDING MODEL

The first step when your app receives a request is routing the request to an appropriate Razor Page handler. Let's think about the category to-do list page again, from Listing 4.1. On this page, you're displaying a list of items that have a given category label. If you're looking at the list of items with a category of "Simple," you'd make a request to the `/category/Simple` URL.

Routing takes the headers and path of the request, `/category/Simple`, and maps it against a preregistered list of patterns. These patterns match a path to a single Razor Page and page handler. You'll learn more about routing in the next chapter.

> **TIP** **I'm using the term Razor Page to refer to the combination of the Razor view and the `PageModel` that includes the page handler. Note that that `PageModel` class is *not* the "model" we're referring to when describing the MVC pattern. It fulfills other roles, as you will see later in this section.**

Once a page handler is selected, the *binding model* (if applicable) is generated. This model is built based on the incoming request, the properties of the `PageModel` marked for binding, and the method parameters required by the page handler, as shown in figure 4.3. A binding model is normally one or more standard C# objects, with properties that map to the requested data. We'll look at binding models in detail in chapter 6.

> **DEFINITION** **A *binding model* is one or more objects that act as a "container" for the data provided in a request that's required by a page handler.**

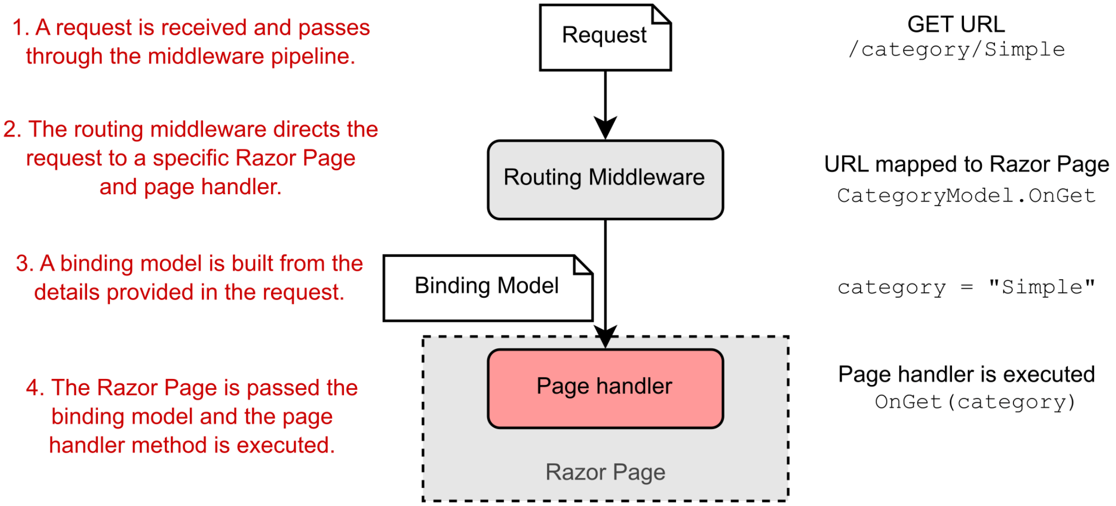

1. A request is received and passes through the middleware pipeline.
2. The routing middleware directs the request to a specific Razor Page and page handler.
3. A binding model is built from the details provided in the request.
4. The Razor Page is passed the binding model and the page handler method is executed.
Request
Routing Middleware
Binding Model
Page handler
Razor Page
GET URL
/category/Simple
URL mapped to Razor Page
CategoryModel.OnGet
category = "Simple"
Page handler is executed
OnGet(category)

Figure 4.3 Routing a request to a controller and building a binding model. A request to the `/category/Simple` URL results in the `CategoryModel.OnGet` page handler being executed, passing in a populated binding model, `category`.

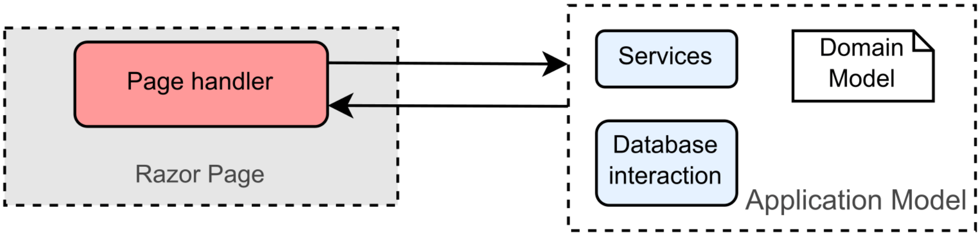
In this case, the binding model is a simple string, `category`, which is “bound” to the `"Simple"` value. This value is provided in the request URL’s path. A more complex binding model could also have been used, where multiple properties were populated.

This binding model in this case corresponds to the method parameter of the `OnGet` page handler. An instance of the Razor Page is created using it’s constructor, and the binding model is passed to the page handler when it executes, so it can be used to decide how to respond. For this example, the page handler uses it to decide which to-do items to display on the page.

EXECUTING A HANDLER USING THE APPLICATION MODEL

The role of the page handler as the controller in the MVC pattern is to *coordinate* the generation of a response to the request it’s handling. That means it should perform only a limited number of actions. In particular, it should

- Validate that the data contained in the binding model provided is valid for the request.
- Invoke the appropriate actions on the application model using services.
- Select an appropriate response to generate based on the response from the application model.



1. The page handler uses the category provided in the binding model to determine which method to invoke in the application model.

2. The page handler method calls into services that make up the application model. This might use the domain model to determine whether to include completed ToDo items, for example.

3. The services load the details of the ToDO items from the database and return them back to the action method.

Figure 4.4 When executed, an action will invoke the appropriate methods in the application model.

Figure 4.4 shows the page handler invoking an appropriate method on the application model. Here, you can see that the application model is a somewhat abstract concept that encapsulates the remaining non-UI part of your application. It contains the *domain model*, a number of services, and the database interaction.

> **DEFINITION** The *domain model* encapsulates complex business logic in a series of classes that don't depend on any infrastructure and can be easily tested.

The page handler typically calls into a single point in the application model. In our example of viewing a to-do list category, the application model might use a variety of services to check whether the current user is allowed to view certain items, to search for items in the given category, to load the details from the database, or to load a picture associated with an item from a file.

Assuming the request is valid, the application model will return the required details to the page handler. It's then up to the page handler to choose a response to generate.

BUILDING HTML USING THE VIEW MODEL

Once the page handler has called out to the application model that contains the application business logic, it's time to generate a response. A *view model* captures the details necessary for the view to generate a response.

> **DEFINITION** A *view model* is all the data required by the view to render a UI. It's typically some transformation of the data contained in the application model, plus extra information required to render the page, for example the page's title.

The term *view model* is used extensively in ASP.NET Core MVC, where it typically refers to a single object that is passed to the Razor view to render. However, with Razor Pages, the Razor view can access the Razor Page's *page model* class directly. Therefore, the Razor Page `PageModel` typically *acts* as the view model in Razor Pages, with the data required by the Razor view exposed via properties, as you saw previously in Listing 4.1.

> **NOTE** **Razor Pages use the `PageModel` class itself as the view model for the Razor view, by exposing the required data as properties.**

The Razor view uses the data exposed in the page model to generate the final HTML response. Finally, this is sent back through the middleware pipeline and out to the user's browser, as shown in figure 4.5.

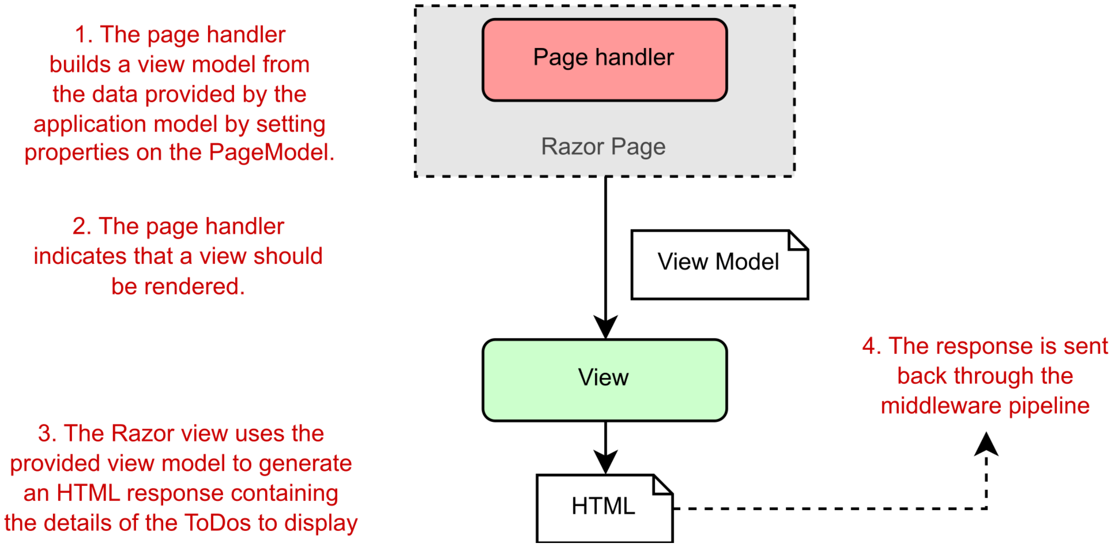

1. The page handler builds a view model from the data provided by the application model by setting properties on the PageModel.
Page handler
Razor Page
2. The page handler indicates that a view should be rendered.
View Model
View
4. The response is sent back through the middleware pipeline
3. The Razor view uses the provided view model to generate an HTML response containing the details of the ToDos to display
HTML

Figure 4.5 The page handler builds a view model by setting properties on the `PageModel`. It's the view that generates the response.

It's important to note that although the page handler selects *whether* to execute the view, and the data to use, it doesn't control *what HTML is generated*. It's the view itself that decides what the content of the response will be.

PUTTING IT ALL TOGETHER: A COMPLETE RAZOR PAGE REQUEST

Now that you've seen each of the steps that goes into handling a request in ASP.NET Core using Razor Pages, let's put it all together from request to response. Figure 4.6 shows how the steps combine to handle the request to display the list of to-do items for the “Simple” category. The traditional MVC pattern is still visible in Razor Pages, made up of the page handler (controller), the view, and the application model.

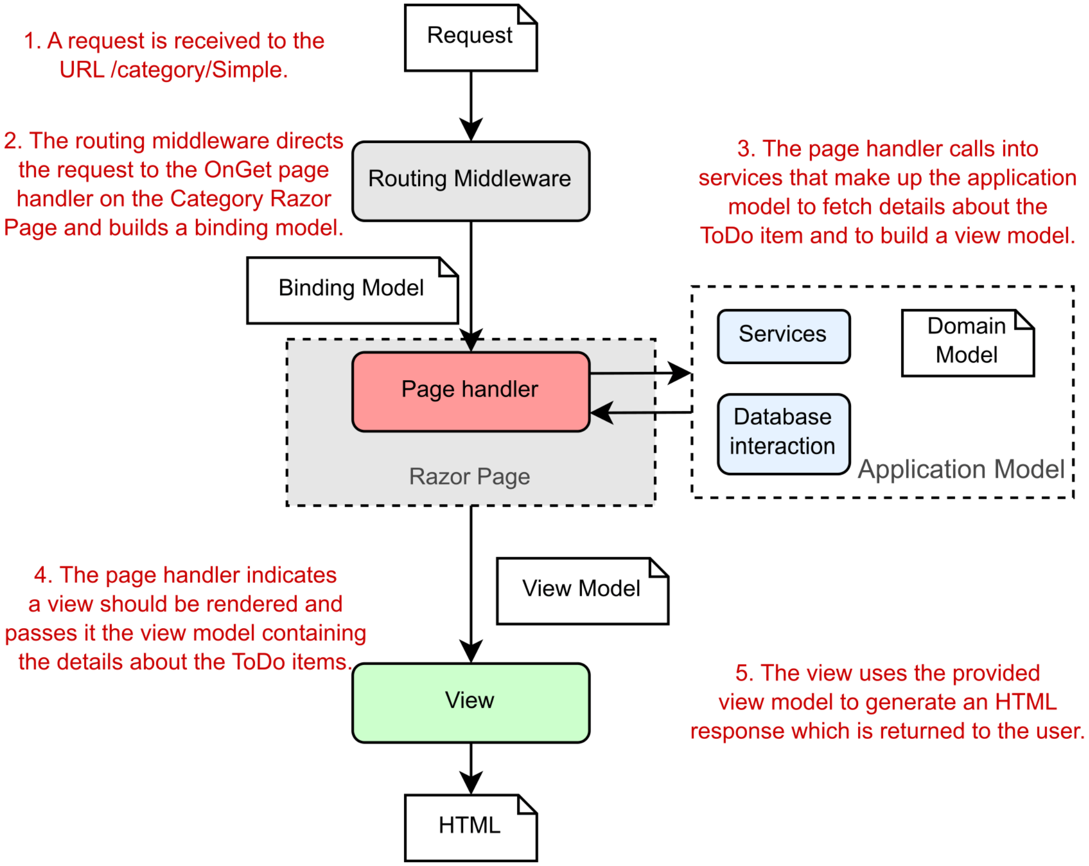

1. A request is received to the URL /category/Simple.
Request
2. The routing middleware directs the request to the OnGet page handler on the Category Razor Page and builds a binding model.
Routing Middleware
3. The page handler calls into services that make up the application model to fetch details about the ToDo item and to build a view model.
Binding Model
Services
Domain Model
Page handler
Database interaction
Razor Page
Application Model
4. The page handler indicates a view should be rendered and passes it the view model containing the details about the ToDo items.
View Model
View
5. The view uses the provided view model to generate an HTML response which is returned to the user.
HTML

Figure 4.6 A complete Razor Pages request for the list of to-dos in the “Simple” category.

By now, you might be thinking this whole process seems rather convoluted—so many steps to display some HTML! Why not allow the application model to create the view directly, rather than having to go on a dance back and forth with the page handler method?

The key benefit throughout this process is the *separation of concerns*:

- The view is responsible only for taking some data and generating HTML.
- The application model is responsible only for executing the required business logic.

- The page handler (controller) is responsible only for validating the incoming request and selecting the appropriate view to display, based on the output of the application model.

By having clearly defined boundaries, it's easier to update and test each of the components without depending on any of the others. If your UI logic changes, you won't necessarily have to modify any of your business logic classes, so you're less likely to introduce errors in unexpected places.

The dangers of tight coupling

Generally speaking, it's a good idea to reduce coupling between logically separate parts of your application as much as possible. This makes it easier to update your application without causing adverse effects or requiring modifications in seemingly unrelated areas. Applying the MVC pattern is one way to help with this goal.

As an example of when coupling rears its head, I remember a case a few years ago when I was working on a small web app. In our haste, we had not properly decoupled our business logic from our HTML generation code, but initially there were no obvious problems—the code worked, so we shipped it!

A few months later, someone new started working on the app, and immediately "helped" by renaming an innocuous spelling error in a class in the business layer. Unfortunately, the names of those classes had been used to generate our HTML code, so renaming the class caused the whole website to break in users' browsers! Suffice it to say, we made a concerted effort to apply the MVC pattern after that, and ensure we had a proper separation of concerns.

The examples shown in this chapter demonstrate the bulk of the Razor Pages functionality. It has additional features, such as the filter pipeline, that I'll cover later (chapter 13), and I'll discuss binding models in greater depth in chapter 6, but the overall behavior of the system is the same.

Similarly, in chapter 9, I'll discuss how the MVC design pattern applies when you're generating machine-readable responses using Web API controllers. The process is, for all intents and purposes, identical, apart from the final result generated.

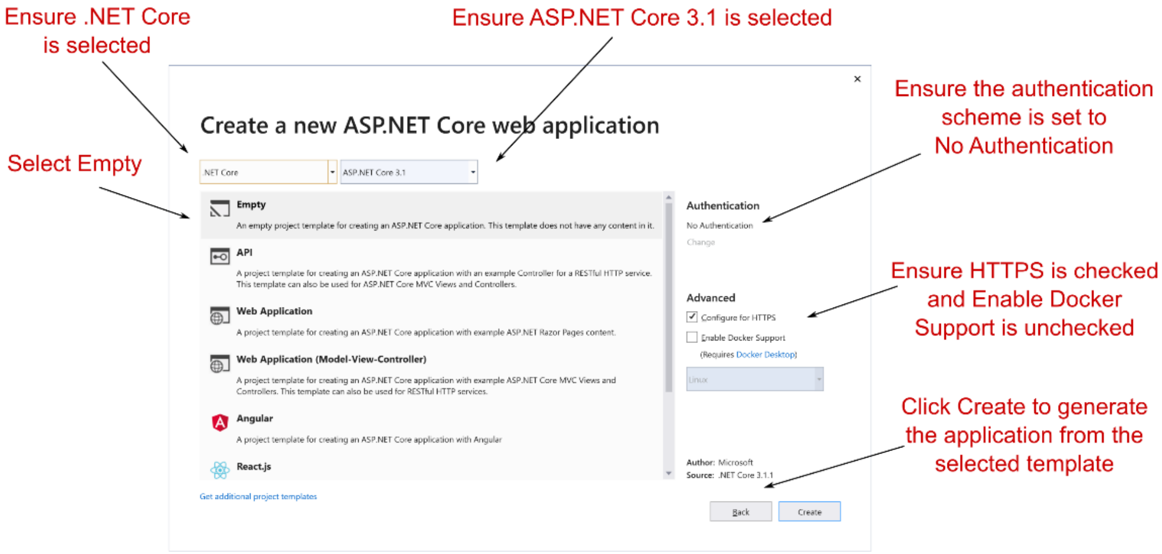
In the next section, you'll see how to add Razor Pages to your application. Some templates in Visual Studio and the .NET CLI will include Razor Pages by default, but you'll see how to add it to an existing application and explore the various options available.

4.1.4 Adding Razor Pages to your application

The MVC infrastructure, whether used by Razor Pages or MVC/API controllers, is a foundational aspect of all but the simplest ASP.NET Core applications, so virtually all templates include it configured by default in some way. But to make sure you're comfortable with adding Razor Pages to an existing project, I'll show how to start with a basic empty application and add Razor Pages to it from scratch.

The result of your efforts won't be exciting yet. We'll display "Hello World" on a web page, but it'll show how simple it is to convert an ASP.NET Core application to use Razor Pages. It also emphasizes the pluggable nature of ASP.NET Core—if you don't need the functionality provided by Razor Pages, then you don't have to use it. Here's how you add Razor Pages to your application:

1. In Visual Studio 2019, choose File > New > Project or choose Create a New Project from the splash screen
2. From the list of templates, choose ASP.NET Core Web Application, ensuring you select the C# language template.
3. On the next screen, enter a project name, Location, and a solution name, and click Create.
4. On the following screen create a basic template without MVC or Razor Pages by selecting the Empty Project template in Visual Studio, as shown in figure 4.8. You can create a similar empty project using the .NET CLI with the `dotnet new web` command.



Create a new ASP.NET Core web application

.NET Core | ASP.NET Core 3.1

Empty
An empty project template for creating an ASP.NET Core application. This template does not have any content in it.

API
A project template for creating an ASP.NET Core application with an example Controller for a RESTful HTTP service. This template can also be used for ASP.NET Core MVC Views and Controllers.

Web Application
A project template for creating an ASP.NET Core application with example ASP.NET Razor Pages content.

Web Application (Model-View-Controller)
A project template for creating an ASP.NET Core application with example ASP.NET Core MVC Views and Controllers. This template can also be used for RESTful HTTP services.

Angular
A project template for creating an ASP.NET Core application with Angular

React.js

Get additional project templates

Authentication
No Authentication
Change

Advanced
☑ Configure for HTTPS
□ Enable Docker Support
(Requires Docker Desktop)
Linux

Author: Microsoft
Source: .NET Core 3.1.1

Ensure .NET Core is selected

Ensure ASP.NET Core 3.1 is selected

Select Empty

Ensure the authentication scheme is set to No Authentication

Ensure HTTPS is checked and Enable Docker Support is unchecked

Click Create to generate the application from the selected template

Figure 4.8 Creating an empty ASP.NET Core template. The empty template will create a simple ASP.NET Core application that contains a small middleware pipeline without Razor Pages.

5. Add the necessary Razor Page services (in bold) in your Startup.cs file's `ConfigureServices` method:

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddRazorPages();
}
```

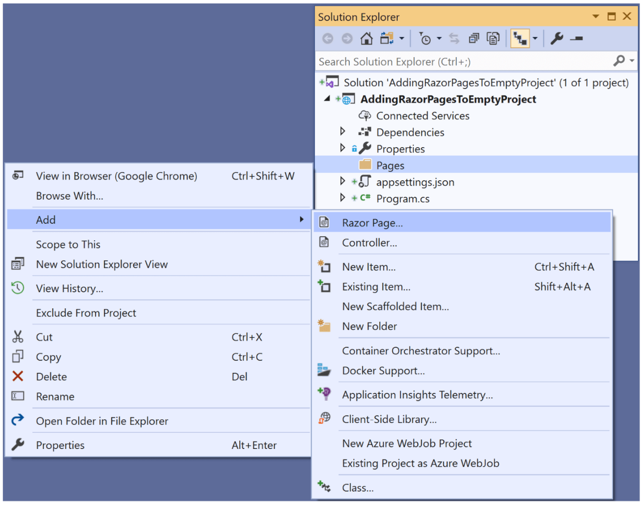
6. Replace the existing basic endpoint configured in the `EndpointMiddleware` at the end of your middleware pipeline with the `MapRazorPages()` extension method (in bold). For simplicity, also remove the existing error handler middleware from the `Configure` method of Startup.cs for now:

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    app.UseRouting();

    app.UseEndpoints(endpoints =>
    {
        endpoints.MapRazorPages();
    });
}
```

7. Right-click your project in Solution Explorer and choose Add > New Folder to add a new folder to the root of your project. Name the new folder Pages.

   You have now configured your project to use Razor Pages, but you don't have any pages yet. The following steps add a new Razor Page to your application. You can create a similar Razor Page using the .NET CLI by running `dotnet new page -n Index -o Pages/` from the project directory.

8. Right-click the new pages folder and choose Add > Razor Page, as shown in figure 4.9.



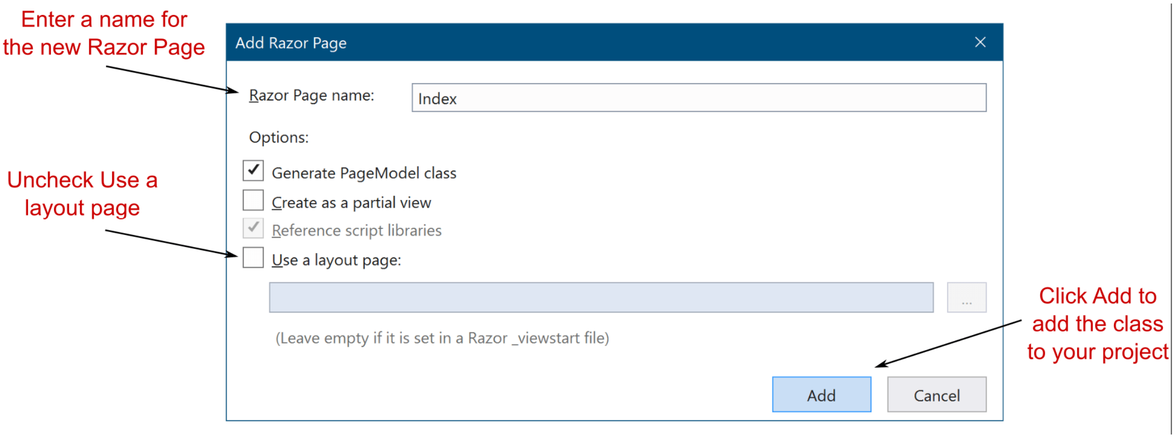
1. Right click on the Pages folder to bring up the context menu

2. Click Add to open the Add submenu

3. Choose Razor Page to add a Razor Page to your project

Figure 4.9 Adding a new Razor Page to your project

9. On the following page select Razor Page and click Add. In the following dialog box, name your page Index, uncheck the Use a layout page option, and click Add, as shown in figure 4.10. Leave all other checkboxes with their default values.



Add Razor Page

Razor Page name: Index

Options:

☑ Generate PageModel class

□ Create as a partial view

☑ Reference script libraries

□ Use a layout page:

(Leave empty if it is set in a Razor _viewstart file)

Enter a name for the new Razor Page

Uncheck Use a layout page

Click Add to add the class to your project

Figure 4.10 Creating a new Razor Page using the Add Razor Page dialog box

10. After Visual Studio has finished generating the file, open the Index.chtml file, and update the HTML to say `Hello World` by adding an `<h1>` element inside the `<body>` element (in bold):

```
@page
@model AddingRazorPagesToEmptyProject.IndexModel
@{
    Layout = null;
}

<!DOCTYPE html>

<html>
<head>
    <meta name="viewport" content="width=device-width" />
    <title>Index</title>
</head>
<body>
    <h1>Hello World!</h1>
</body>
</html>
```

Once you've completed all these steps, you should be able to restore, build, and run your application.

> **NOTE** You can run your project by pressing F5 from within Visual Studio (or by calling `dotnet run` at the command line from the project folder). This will restore any referenced NuGet packages, build your project,

and start your application. Visual Studio will automatically open a browser window to access your application's homepage.

When you make a request to the root "/" path, the application invokes the `OnGet` handler on the `IndexModel` due to the conventional way routing works for Razor Pages based on the file name. Don't worry about this for now; we'll go into it in detail in the next chapter.

The `OnGet` handler is a `void` method, which causes the Razor Page to render the associated Razor view and send it to the user's browser in the response.

Razor Pages rely on a number of internal services to perform their functions, which must be registered during application startup. This is achieved with the call to `AddRazorPages` in the `ConfigureServices` method of Startup.cs. Without this, you'll get exceptions when your app starts, reminding you that the call is required.

The call to `MapRazorPages` in `Configure` registers the Razor Page endpoints with the endpoint middleware. As part of this call, the routes that are used to map URL paths to a specific Razor Page handler are registered automatically.

NOTE I cover routing in detail in the next chapter.

The instructions in this section described how to add Razor Pages to your application, but it's not the only way to add HTML generation to your application. As I mentioned previously, Razor Pages builds on top of the ASP.NET Core MVC framework and shares many of the same concepts. In the next section, we take a brief look at MVC controllers, see how they compare to Razor Pages, and discuss when you should choose to use one approach over the other.

4.2 Razor Pages vs MVC in ASP.NET Core

In this book, I focus on Razor Pages, as that has become the recommended approach for building server-side rendered applications with ASP.NET Core. However, I also mentioned that Razor Pages uses the ASP.NET Core MVC framework behind the scenes, and that you can choose to use it directly if you wish. Additionally, if you're creating a Web API for working with mobile or client-side apps then you will almost certainly be using the MVC framework directly.

NOTE I look at how to build Web APIs in chapter 9.

So, what are the differences between Razor Pages and MVC, and when should you choose one or the other?

If you're new to ASP.NET Core, the answer is pretty simple—use Razor Pages for server-side rendered applications and use the MVC framework for building Web APIs. There are nuances I'll discuss in later sections, but that distinction will serve you very well initially.

If you're familiar with the previous version of ASP.NET or earlier versions of ASP.NET Core and are deciding whether to use Razor Pages, then this section should help you choose. Developers coming from those backgrounds often have misconceptions about Razor Pages initially (as I did!), incorrectly equating them to Web Forms and overlooking their underlying basis of the MVC framework.

Before we can get to comparisons though, we should take a brief look at the ASP.NET Core MVC framework itself. Understanding the similarities and differences between MVC and Razor Pages can be very useful, as and you'll likely find a use for MVC at some point, even if you use Razor Pages most of the time.

4.2.1 MVC controllers in ASP.NET Core

In section 4.1 we looked at the MVC design pattern, and how it applies to Razor Pages in ASP.NET Core. Perhaps unsurprisingly, you can use the ASP.NET Core MVC framework in almost exactly the same way. To demonstrate the difference between Razor Pages and MVC, we'll look at an MVC version of the Razor Page from Listing 4.1, which displays a list of to-do items for a given category.

Instead of a `PageModel` and page handler, MVC uses a concept of *controllers* and *action methods*. These are almost directly analogous to their Razor Page counterparts, as you can see in figure 4.7, which shows an MVC equivalent of figure 4.6. On the other hand, MVC controllers use explicit *view models* to pass data to a Razor view, rather than exposing the data as properties on itself (as Razor Pages do with Page Models).

> **DEFINITION** An *action* (or *action method*) is a method that runs in response to a request. An *MVC controller* is a class that contains a number of logically grouped action methods.

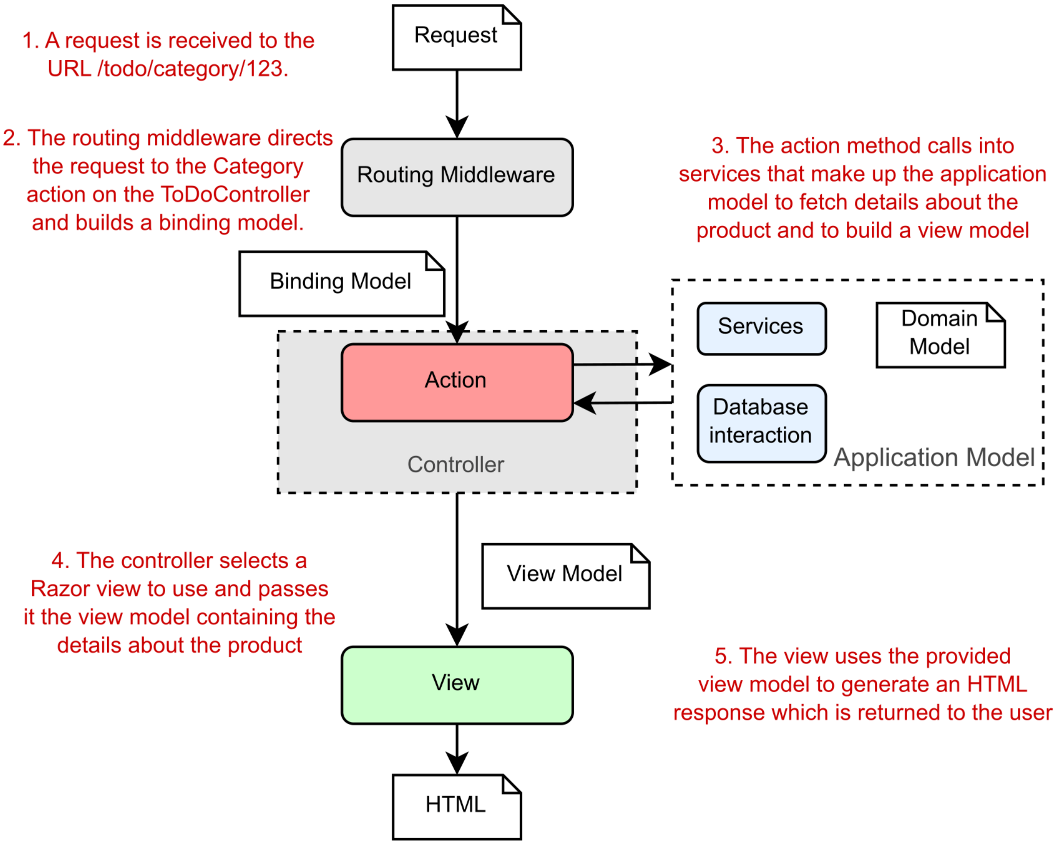

1. A request is received to the URL /todo/category/123.
Request
2. The routing middleware directs the request to the Category action on the ToDoController and builds a binding model.
Routing Middleware
3. The action method calls into services that make up the application model to fetch details about the product and to build a view model
Binding Model
Services
Domain Model
Action
Database interaction
Controller
Application Model
4. The controller selects a Razor view to use and passes it the view model containing the details about the product
View Model
5. The view uses the provided view model to generate an HTML response which is returned to the user
View
HTML

Figure 4.7 A complete MVC controller request for a category. The MVC controller pattern is almost identical to that of Razor Pages, shown in figure 4.6. The Controller is equivalent to a Razor Page, and the Action is equivalent to a page handler.

The listing below shows an example of how an MVC controller that provides the same functionality as the Razor Page in Listing 4.1 might look. In MVC, controllers are often used to aggregate similar actions together, so the controller in this case is called `ToDoController`, as it would typically contain additional action methods for working with to-do items, such as actions to view a specific item, or to create a new one.

Listing 4.2 An MVC controller for viewing all to-do items in a given category

```
public class ToDoController : Controller
{
    private readonly ToDoService _service;              #A
    public ToDoController(ToDoService service)          #A
    {
        _service = service;
    }

    public ActionResult Category(string id)              #B
    {
        var items = _service.GetItemsForCategory(id);    #C
        var viewModel = new CategoryViewModel(items);    #C

        return View(items);                              #D
    }

    public ActionResult Create(ToDoListModel model)      #E
    {                                                    #E
        // ...                                           #E
    }                                                    #E
}
```

#A The ToDoService is provided in the controller constructor using dependency injection.
#B The Category action method takes a parameter, id.
#C The action method calls out to the ToDoService to retrieve data and build a view model
#D Returns a ViewResult indicating the Razor view should be rendered, passing in the view model
#E MVC controllers often contain multiple action methods which respond to different requests

Aside from some naming differences, the `ToDoController` looks very similar to the Razor Page equivalent from Listing 4.1. Indeed, *architecturally*, Razor Pages and MVC are essentially equivalent, as they both use the MVC design pattern. The most obvious differences relate to *where the files are placed* in your project, as I discuss in the next section.

4.2.2 The benefits of Razor Pages

In the previous section I showed that the code for an MVC controller looks very similar to the code for a Razor Page `PageModel`. If that's the case, what benefit is there to using Razor Pages? In this section I discuss some of the pain points of MVC controllers and how Razor Pages attempts to address them.

Razor Pages are not web forms

A common argument I hear from existing ASP.NET developers against Razor Pages is "oh, they're just Web Forms". That sentiment misses the mark in many different ways, but it's common enough that it's worth addressing directly.

Web Forms was a web-programming model that was released as part of .NET Framework 1.0 in 2002. They attempted to provide a highly productive experience for developers moving from desktop development to the web for the first time.

Web Forms are much-maligned now, but their weakness only became apparent later. Web forms attempted to hide the complexities of the web away from you, to give you the "impression" of developing with a desktop app. That often resulted in apps that were slow, with lots of inter-dependencies, and were hard to maintain.

Web Forms provided a "page-based" programming model, which is why Razor Pages sometimes gets associated with them. However, as you've seen, Razor Pages is based on the MVC design pattern, and exposes the intrinsic features of the web without trying to hide them from you.

Razor Pages optimizes certain flows using conventions (some of which you've seen), but it's not trying to build a *stateful* application model over the top of a stateless web application, in the way that Web Forms did.

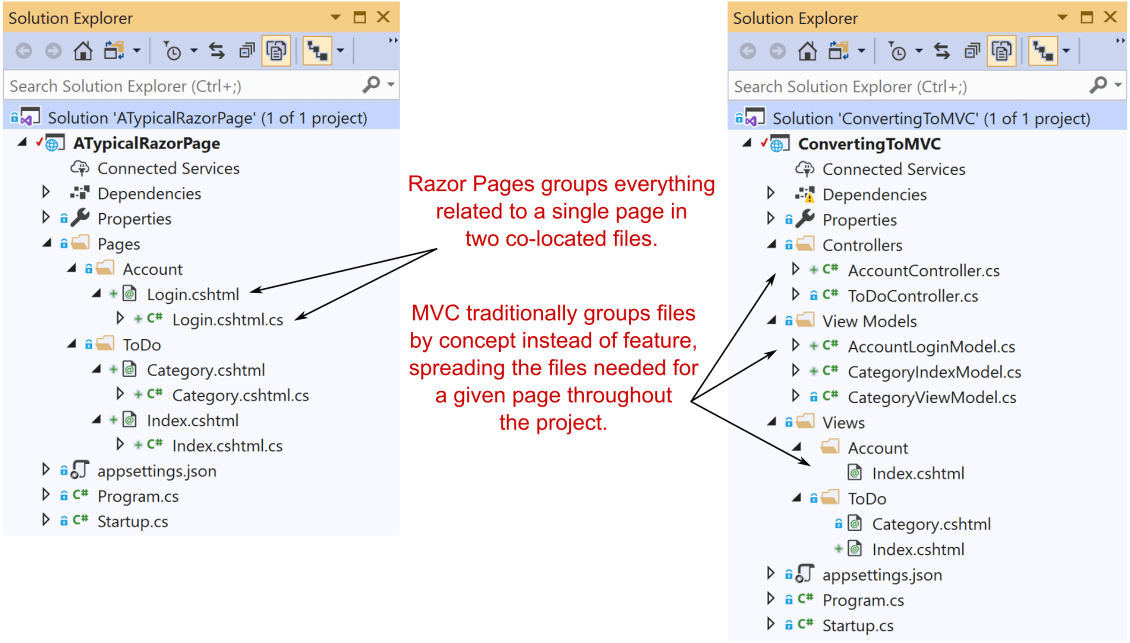
In MVC, a single controller can have multiple action methods. Each action handles a different request and generates a different response. The grouping of multiple actions in a controller is somewhat arbitrary, but is typically used to group actions related to a specific entity, to-do list items in this case. A more complete version of the `ToDoController` in Listing 4.2 might include action methods for listing all to-do items, for creating new items, and for deleting items, for example. Unfortunately, you can often find that your controllers become very large and bloated, with many dependencies.[15]

> **NOTE** You don't *have* to make your controllers very large like this, it's just a very common pattern. You could, for example, create a separate controller for every action instead.

Another pitfall of the MVC controllers are the way they're typically organized in your project. Most action methods in a controller will need an associated Razor view, and a view model for passing data to the view. The MVC approach traditionally groups classes by *type* (controller, view, view model), while the Razor Page approach groups by *function*—everything related to a specific page is co-located.

Figure 4.11 compares the file layout for a simple Razor Page project with the MVC equivalent. Using Razor Pages means much less scrolling up and down between the controller, views, and view model folders whenever you're working on a particular page. Everything you need is found in two files, the cshtml Razor view and the cshtml.cs `PageModel` file.

[15] Before moving to Razor Pages, the ASP.NET Core template that includes user login functionality contained two such controllers, each containing over 20 action methods, and over 500 lines of code!



Razor Pages groups everything related to a single page in two co-located files.

MVC traditionally groups files by concept instead of feature, spreading the files needed for a given page throughout the project.

Figure 4.11 Comparing the folder structure for an MVC project to the folder structure for a Razor Pages project.

There are additional differences between MVC and Razor Pages, which I'll highlight throughout the book, but this layout difference is really the biggest win. Razor Pages embraces the fact that you're building a page-based application and optimizes your workflow by keeping everything related to a single page together.

> **TIP** You can think of each Razor Page as a mini controller focused on a single page. Page handlers are functionally equivalent to MVC controller action methods.

This layout also has the benefit of making each page a separate class. This contrasts with the MVC approach of making each page an *action* on a given controller. Each Razor Page is cohesive for a particular *feature*, such as displaying a to-do item, for example. MVC controllers contain action methods which handle multiple different features for a more abstract *concept*, such as all the features related to to-do items.

Another important point is that Razor Pages doesn't lose any of the "separation-of-concerns" that MVC has. The view part of Razor Pages is still only concerned with rendering HTML and the handler is the "coordinator" that calls out to the application model. The only real difference is the lack of the explicit view model that you have in MVC, but it's perfectly possible to emulate this in Razor Pages if that's a deal breaker for you.

The benefits that Razor Pages bring are particularly noticeable when you have "content" websites, such as marketing websites, where you're mostly displaying static data, and there's no real logic. In that case, MVC adds complexity without any real benefits, as there's not really any logic in the controllers at all. Another great use case is when creating forms for users to submit data. Razor Pages is especially optimized for this scenario, as you'll see in later chapters.

Clearly, I'm a fan of Razor Pages, but that's not to say they're perfect for every situation. In the next section I discuss some of the cases when you might choose to use MVC controllers in your application. Bear in mind it's not an either-or choice—it's possible to use both MVC controllers and Razor Pages in the same application, and in many cases that may be the best option.

4.2.3 When to choose MVC controllers over Razor Pages

Razor Pages are great for building page-based server-side rendered applications. But not all applications fit that mold, and even some applications that *do* fall in that category might be best developed using MVC controllers instead of Razor Pages. Possible reasons include:

- *When you don't want to render views*. Razor Pages are best for page-based applications, where you're rending a view for the user. If you're building a Web API then you should use MVC controllers instead.
- *When you're converting an existing MVC application to ASP.NET Core*. If you already have an ASP.NET application that uses MVC, then it's probably not worth converting your existing MVC controllers to Razor Pages. It makes more sense to keep your existing code, and perhaps look at doing *new* development in the application with Razor Pages.
- *When you're doing a lot of partial page updates*. It's possible to use JavaScript in an application to avoid doing full page navigations, by only updating part of the page at a time. This approach, halfway between fully server-side rendered and a client-side application may be easier to achieve with MVC controllers than Razor Pages.

When not to use Razor Pages or MVC controllers

Typically, you'll use either Razor Pages or MVC controllers to write most of your application logic for an app. You'll use it to define the APIs and pages in your application, and to define how they interface with your business logic. Razor Pages and MVC provide an extensive framework (as you'll see over the next six chapters) that provide a great deal of functionality to help build your apps quickly and efficiently. But they're not suited to *every* app.

Providing so much functionality necessarily comes with a certain degree of performance overhead. For typical apps, the productivity gains from using MVC or Razor Pages strongly outweigh any performance impact. But if you're building small, lightweight apps for the cloud, then you might consider using custom middleware directly (see chapter 19). You might want to also consider *Microservices in .NET Core* by Christian Horsdal Gammelgaard (Manning, 2017).

Alternatively, if you're building an app with real-time functionality, you'll probably want to consider using WebSockets instead of traditional HTTP requests. ASP.NET Core SignalR can be used to add real-time functionality to your app by providing an abstraction over Web Sockets. SignalR also provides simple transport fallbacks and a remote procedure call (RPC) app model. For details, see the documentation at https://docs.microsoft.com/en-us/aspnet/core/signalr.

Another option introduced in ASP.NET Core 3.1 is Blazor. This framework allows you to build interactive client-side web applications by either leveraging the WebAssembly standard to run .NET code directly in your browser, or by using a stateful model with SignalR. See the documentation for details at https://docs.microsoft.com/en-us/aspnet/core/blazor/.

Hopefully by this point you’re sold on Razor Pages and their overall design. So far, all the Razor Pages we’ve looked at have used a single page handler. In the next section we’ll look in greater depth at page handlers, how to define them, how to invoke them, and how to use them to render Razor views.

4.3 Razor Pages and page handlers

In the first section of this chapter, I described the MVC design pattern and how it relates to ASP.NET Core. In the design pattern, the controller receives a request and is the entry point for UI generation. For Razor Pages, the entry point is a page handler that resides in a Razor Page’s `PageModel`. A page handler is a method that runs in response to a request.

By default, the path of a Razor Page on disk controls the URL path that the Razor Page responds to. For example, a request to the URL `/products/list` corresponds to the Razor Page at the path pages/Products/List.cshtml. Razor Pages can contain any number of page handlers, but only one runs in response to a given request.

> **NOTE** You’ll learn more about this process of selecting a Razor Page and handler, called *routing*, in the next chapter.

The responsibility of a page handler is generally threefold:

- Confirm the incoming request is valid.
- Invoke the appropriate business logic corresponding to the incoming request.
- Choose the appropriate *kind* of response to return.

A page handler doesn’t need to perform all these actions, but at the very least it must choose the kind of response to return. Page Handlers typically return one of 3 things:

- A `PageResult` object. This causes the associated Razor view to generate an HTML response.
- Nothing (the handler returns `void` or `Task`). This is the same as the previous case, causing the Razor view to generate an HTML response.
- A `RedirectToPageResult`. This indicates the user should be redirected to a different page in your application.

These are the most commonly used results for Razor Pages, but I describe some additional options in section 4.3.2.

It’s important to realize that an action method doesn’t generate a response directly; it selects the *type* of response and prepares the data for it. For example, returning a

PageResult doesn’t generate any HTML at that point, it merely indicates that a view *should* be rendered. This is in keeping with the MVC design pattern in which it’s the *view* that generates the response, not the *controller*.

> **TIP** The page handler is responsible for choosing what sort of response to send; the *view engine* in the MVC framework uses the result to generate the response.

It’s also worth bearing in mind that page handlers should generally not be performing business logic directly. Instead, they should call appropriate services in the application model to handle requests. If a page handler receives a request to add a product to a user’s cart, it shouldn’t directly manipulate the database or recalculate cart totals, for example. Instead, it should make a call to another class to handle the details. This approach of separating concerns ensures your code stays testable and maintainable as it grows.

4.3.1 Accepting parameters to page handlers

Some requests made to page handlers will require additional values with details about the request. If the request is for a search page, the request might contain details of the search term and the page number they’re looking at. If the request is posting a form to your application, for example a user logging in with their username and password, then those values must be contained in the request. In other cases, there will be no such values, such as when a user requests the homepage for your application.

The request may contain additional values from a variety of different sources. They could be part of the URL, the query string, headers, or in the body of the request itself. The middleware will extract values from each of these sources and convert them into .NET types.

> **DEFINITION** The process of extracting values from a request and converting them to .NET types is called *model binding*. I discuss model binding in chapter 6.

ASP.NET Core can bind two different targets in Razor Pages:

- *Method arguments*. If a page handler has method arguments, the values from the request are used to create the required parameters.
- *Properties marked with a* [BindProperty] *attribute*. Any properties marked with the attribute will be bound. By default, this attribute does nothing for GET requests.

Model bound values can be simple types, such as strings and integers, or they can be a complex type, as shown in the listing below. If any of the values provided in the request are *not* bound to a property or page handler argument, then the additional values will go unused.

Listing 4.3 Example Razor Page handlers

```
public class SearchModel : PageModel
{
    private SearchService _searchService;                #A
    public SearchModel(SearchService searchService)      #A
    {                                                    #A
        _searchService = searchService;                  #A
    }                                                    #A

    [BindProperty]                                       #B
    public BindingModel Input { get; set; }              #B
    public List<Product> Results { get; set; }           #C

    public void OnGet()                                  #D
    {                                                    #D
    }                                                    #D

    public IActionResult OnPost(int max)                  #E
    {
        if (ModelState.IsValid)                                        #F
        {                                                              #F
            Results = _searchService.Search (Input.SearchTerm, max);   #F
            return Page();                                             #F
        }                                                              #F
        return RedirectToPage("./Index");                                #G
    }                                                                  #F
}
```

#A The SearchService is provided to the SearchModel for use in page handlers.
#B Properties decorated with the [BindProperty] attribute will be model bound.
#C Undecorated properties will not be model bound.
#D The page handler doesn't need to check if the model is valid. Returning void will render the view.
#E The max parameter in this page handler will be model bound using the values in the request.
#E If the request is valid, a view model is set and a PageResult is returned to render the view.
#F If the request was not valid, the method indicates the user should be redirected to the Index page.

In this example, the `OnGet` handler doesn't require any parameters, and the method is simple—it returns `void`, which means the associated Razor view will be rendered. It could also have returned a `PageResult`; the effect would have been the same. Note that this handler is for HTTP `GET` requests, so the `Input` property decorated with `[BindProperty]` is not bound.

> **TIP To bind properties for `GET` requests too, use the `SupportsGet` property of the attribute, for example:** `[BindProperty(SupportsGet = true)]`.

The `OnPost` handler, conversely, accepts a parameter `max` as an argument. In this case it's a simple type, `int`, but it could also be a complex object. Additionally, as this handler corresponds to an HTTP `POST` request, the `Input` property is also model bound to the request.

When an action method uses model bound properties or parameters, it should always check that the provided model is valid using `ModelState.IsValid`. The `ModelState` property is exposed as a property on the base `PageModel` class and can be used to check that all the bound properties and parameters are valid. You'll see how the process works in chapter 6 when you learn about validation.

Once a page handler establishes that the method parameters provided to an action are valid, it can execute the appropriate business logic and handle the request. In the case of the

OnPost handler, this involves calling the provided SearchService and setting the result on the Results property. Finally, the handler returns a PageResult by calling the base method

```
return Page();
```

If the model wasn't valid, then you don't have any results to display! In this example, the action returns a RedirectToPageResult using the RedirectToPage helper method. When executed, this result will send a 302 redirect response to the user, which will cause their browser to navigate to the Index Razor Page.

Note that the OnGet method returns void in the method signature, whereas the OnPost method returns an IActionResult. This is required in the OnPost method in order to allow the C# to compile (as the Page and RedirectToPage helper methods return different types), but it doesn't change the final behavior of the methods. You could just as easily have called Page in the OnGet method and returned an IActionResult and the behavior would be identical.

> **TIP** **If you're returning more than one type of result from a page handler, you'll need to ensure your method returns an** IActionResult.

In the next section we look in more depth at action results and what they're used for.

4.3.2 Returning responses with ActionResults

In the previous section, I emphasized that page handlers only decide *what type* or response to return, but they don't generate the response themselves. It's the IActionResult returned by a page handler which, when executed by the Razor Pages infrastructure using the view engine, will generate the response.

This approach is key to following the MVC design pattern. It separates the decision of what sort of response to send from the generation of the response. This allows you to easily test your action method logic to confirm the right sort of response is sent for a given input. You can then separately test that a given IActionResult generates the expected HTML, for example.

ASP.NET Core has many different types of IActionResult:

- PageResult—Generates an HTML view for an associated page in Razor Pages.
- ViewResult—Generates an HTML view for a given Razor view when using MVC controllers.
- RedirectToPageResult—Sends a 302 HTTP redirect response to automatically send a user to another page.
- RedirectResult—Sends a 302 HTTP redirect response to automatically send a user to a specified URL (doesn't have to be a Razor Page).
- FileResult—Returns a file as the response.
- ContentResult—Returns a provided string as the response.

- StatusCodeResult—Sends a raw HTTP status code as the response, optionally with associated response body content.
- NotFoundResult—Sends a raw 404 HTTP status code as the response.

Each of these, when executed by Razor Pages, will generate a response to send back through the middleware pipeline and out to the user.

> **TIP** When you're using Razor Pages, you generally won't use some of these action results, such as ContentResult and StatusCodeResult. It's good to be aware of them though, as you will likely use them if you are building Web APIs with MVC controllers.

In this section I give a brief description of the most common IActionResult classes that you'll use with Razor Pages.

PAGERESULT AND REDIRECTTOPAGERESULT

When you're building a traditional web application with Razor Pages, most of the time you'll be using the PageResult, which generates an HTML response using Razor. We'll look at how this happens in detail in chapter 7.

You'll also commonly use the various redirect-based results to send the user to a new web page. For example, when you place an order on an e-commerce website you typically navigate through multiple pages, as shown in figure 4.12. The web application sends HTTP redirects whenever it needs you to move to a different page, such as when a user submits a form. Your browser automatically follows the redirect requests, creating a seamless flow through the checkout process.

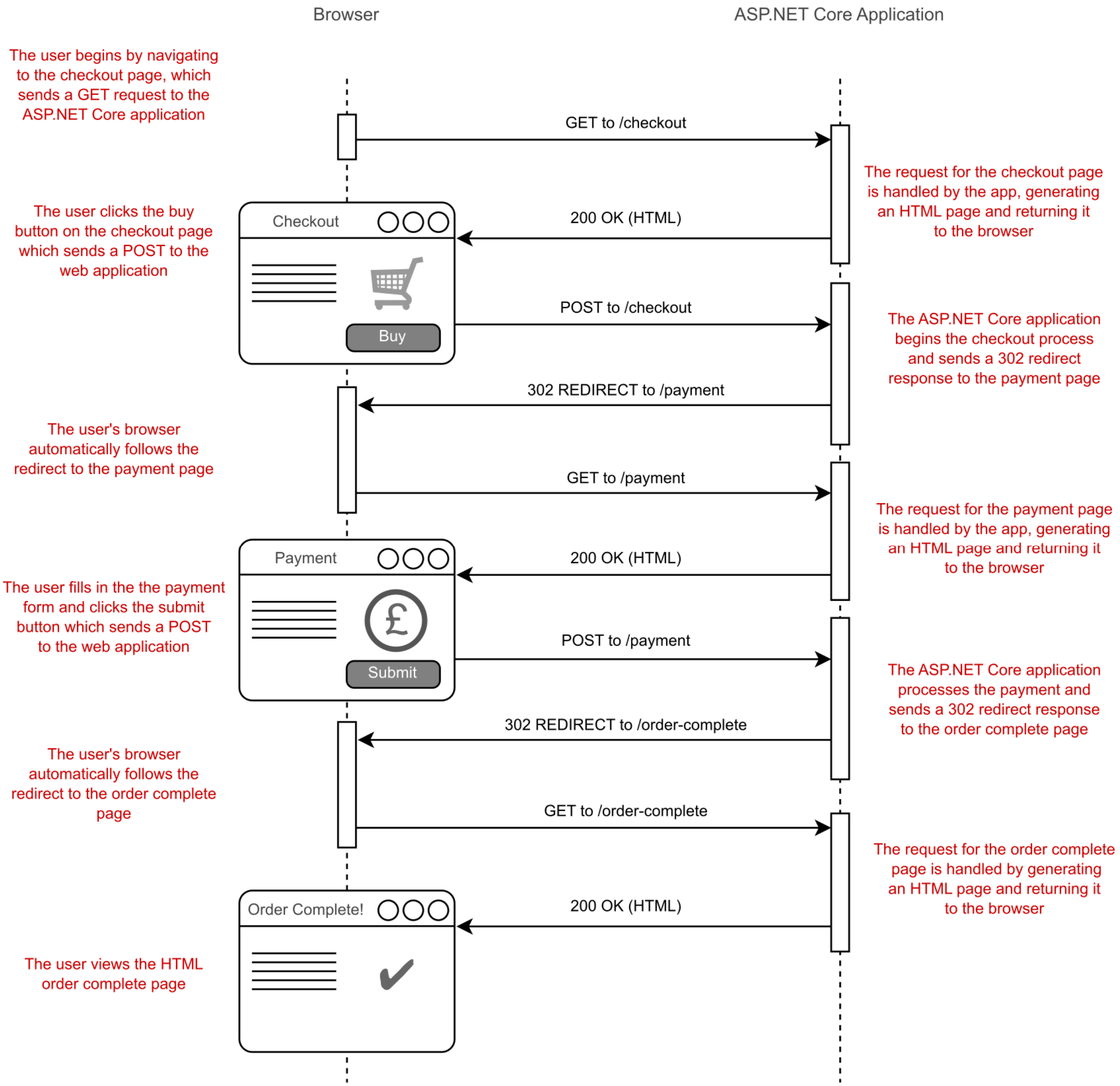

Browser
ASP.NET Core Application
The user begins by navigating to the checkout page, which sends a GET request to the ASP.NET Core application
GET to /checkout
The request for the checkout page is handled by the app, generating an HTML page and returning it to the browser
The user clicks the buy button on the checkout page which sends a POST to the web application
Checkout
Buy
200 OK (HTML)
POST to /checkout
The ASP.NET Core application begins the checkout process and sends a 302 redirect response to the payment page
302 REDIRECT to /payment
The user's browser automatically follows the redirect to the payment page
GET to /payment
The request for the payment page is handled by the app, generating an HTML page and returning it to the browser
Payment
£
Submit
200 OK (HTML)
The user fills in the the payment form and clicks the submit button which sends a POST to the web application
POST to /payment
The ASP.NET Core application processes the payment and sends a 302 redirect response to the order complete page
302 REDIRECT to /order-complete
The user's browser automatically follows the redirect to the order complete page
GET to /order-complete
The request for the order complete page is handled by generating an HTML page and returning it to the browser
Order Complete!
200 OK (HTML)
The user views the HTML order complete page

Figure 4.12 A typical POST, REDIRECT, GET flow through a website. A user sends their shopping basket to a checkout page, which validates its contents and redirects to a payment page without the user having to manually change the URL.

In this flow, whenever you return HTML you use a PageResult; when you redirect to a new page, you use a RedirectToPageResult.

NOTFOUNDRESULT AND STATUSCODERESULT

As well as HTML and redirect responses, you'll occasionally need to send specific HTTP status codes. If you request a page for viewing a product on an e-commerce application, and that product doesn't exist, a 404 HTTP status code is returned to the browser and you'll typically see a "Not found" web page. Razor Pages can achieve this behavior by returning a NotFoundResult, which will return a raw 404 HTTP status code. You could achieve a similar result using the StatusCodeResult and setting the status code returned explicitly to 404.

Note that the NotFoundResult doesn't generate any HTML; it only generates a raw 404 status code and returns it through the middleware pipeline. But, as discussed in the previous chapter, you can use the StatusCodePagesMiddleware to intercept this raw 404 status code after it's been generated and provide a user-friendly HTML response for it.

CREATING ACTIONRESULT CLASSES USING HELPER METHODS

ActionResult classes can be created and returned using the normal new syntax of C#:

```
return new PageResult()
```

However, the Razor Pages PageModel base class also provides a number of helper methods for generating responses. It's common to use the Page method to generate an appropriate PageResult, the RedirectToPage method to generate a RedirectToPageResult, or the NotFound method to generate a NotFoundResult.

> **TIP** **Most ActionResult classes have a helper method on the base PageModel class. They're typically named Type, and the result generated is called TypeResult. For example, the StatusCode method returns a StatusCodeResult instance.**

As discussed earlier, the act of *returning* an IActionResult doesn't immediately generate the response—it's the *execution* of an IActionResult by the Razor Pages infrastructure, which occurs outside the action method. After producing the response, Razor Pages returns it to the middleware pipeline. From there, it passes through all the registered middleware in the pipeline, before the ASP.NET Core web server finally sends it to the user.

By now, you should have an overall understanding of the MVC design pattern and how it relates to ASP.NET Core and Razor Pages. The page handler methods on a Razor Page are invoked in response to given requests and are used to select the type of response to generate by returning an IActionResult.

It's important to remember that the MVC and Razor Pages infrastructure in ASP.NET Core runs as part of the EndpointMiddleware pipeline, as you saw in the previous chapter. Any response generated, whether a PageResult or a RedirectToPageResult, will pass back through the middleware pipeline, giving a potential opportunity for middleware to observe the response before the web server sends it to the user.

An aspect I've only vaguely touched on is how the `RoutingMiddleware` decides which Razor Page and handler to invoke for a given request. If you had to have a Razor Page for *every* URL in an app, it would be difficult to have, for example, a different page per product in an e-shop—every product would need its own Razor Page! Handling this and other scenarios is the role of the routing infrastructure and is a key part of ASP.NET Core. In the next chapter, you'll see how to define routes, how to add constraints to your routes, and how they deconstruct URLs to match a single Razor Page handler.

4.4 Summary

- The MVC design pattern allows for a separation of concerns between the business logic of your application, the data that's passed around, and the display of data in a response.
- Razor Pages are built on the ASP.NET Core MVC framework and use many of the same primitives. They use conventions and a different project layout to optimize for page-based scenarios.
- MVC *controllers* contain multiple *action methods,* typically grouped around a high-level entity. Razor Pages groups all the *page handlers* for a single page in one place, grouping around a page/feature instead of an entity.
- Each Razor Page is equivalent to a mini controller focused on a single page, and each Razor Page handler corresponds to a separate action method.
- Razor Pages should inherit from the `PageModel` base class.
- A single Razor Page handler is selected based on the incoming request's URL, the HTTP verb, and the request's query string, in a process called *routing*.
- Page handlers should generally delegate to services to handle the business logic required by a request, instead of performing the changes themselves. This ensures a clean separation of concerns that aids testing and improves application structure.
- Page handlers can have parameters whose values are taken from properties of the incoming request in a process called *model binding*. Properties decorated with `[BindProperty]` can also be bound to the request.
- By default, properties decorated with `[BindProperty]` are not bound for GET requests. To enable binding, use `[BindProperty(SupportsGet = true)]`.
- Page Handlers can return a `PageResult` or `void` to generate an HTML response.
- You can send users to a new Razor Page using a `RedirectToPageResult`.
- The `PageModel` base class exposes many helper methods for creating an `ActionResult`.

5

Mapping URLs to Razor Pages using routing

This chapter covers

- **Mapping URLs to Razor Pages**
- **Using constraints and default values to match URLs**
- **Generating URLs from route parameters**

In chapter 4, you learned about the MVC design pattern, and how ASP.NET Core uses it to generate the UI for an application using Razor Pages. Razor Pages contain page handlers which act as "mini controllers" for a request. The page handler calls the application model to retrieve or save data. The handler then passes data from the application model to the Razor view, which generates an HTML response.

Although not part of the MVC design pattern per-se, one crucial part of Razor Pages is selecting which Razor Page to invoke in response for a given request. This process is called *routing* and is the focus of this chapter.

This chapter begins by identifying the need for routing and why it's useful. You'll learn about the endpoint routing system introduced in ASP.NET Core 3.0, see several examples of routing techniques, and explore the separation routing can bring between the layout of your Razor Page files and the URLs you expose.

The bulk of this chapter focuses on how to use routing with Razor Pages to create dynamic URLs, so that a single Razor Page can handle requests to multiple URLs. I'll show how to build powerful route templates and give you a taste of the available options.

In section 5.5, I describe how to use the routing system to *generate* URLs, which you can use to create links and redirect requests for your application. One of the benefits of using a routing system is that it decouples your Razor Pages from the underlying URLs that are used to execute them. You can use URL generation to avoid littering your code with hardcoded URLs like `/Product/View/3`. Instead, you can generate the URLs at runtime, based on the routing system. The benefit of this is that it makes changing the URL configuration for a Razor Page easier. Instead of having to hunt down everywhere you used the Razor Page's URL, the URLs will be automatically updated for you, with no other changes required.

I finish the chapter by describing how you can customize the conventions Razor Pages uses, giving you complete control over the URLs your application uses. You'll see how to change the built-in conventions, such as using lowercase for your URLs, as well as how to write your own convention and apply it globally to your application.

By the end of this chapter, you should have a much clearer understanding of how an ASP.NET Core application works. You can think of routing as the glue that ties the middleware pipeline to Razor Pages and the MVC framework. With middleware, Razor Pages, and routing under your belt, you'll be writing web apps in no time!

5.1 What is routing?

In this section, I teach about routing. Routing is the process of mapping an incoming request to a method that will handle it. You can use routing to control the URLs you expose in your application. You can also use routing to enable powerful features like mapping multiple URLs to the same Razor Page, and automatically extracting data from a request's URL.

In chapter 3, you saw that an ASP.NET Core application contains a middleware pipeline, which defines the behavior of your application. Middleware is well suited to handling both cross-cutting concerns, such as logging and error handling, and narrowly focused requests, such as requests for images and CSS files.

To handle more complex application logic, you'll typically use the `EndpointMiddleware` at the end of your middleware pipeline as you saw in chapter 4. This middleware can handle an appropriate request by invoking a method, known as a page handler on a Razor Page or an action method on an MVC controller, and using the result to generate a response.

One aspect that I glossed over in chapter 4 was *how* to select which Razor Page or action method to execute when you receive a request. What makes a request "appropriate" for a given Razor Page handler? The process of mapping a request to a handler is called *routing*.

> **DEFINITION** ***Routing*** **in ASP.NET Core is the process of mapping an incoming HTTP request to a specific handler. In Razor Pages, the handler is a page handler method in a Razor Page. In MVC, the handler is an action method.**

At this point you've already seen several simple applications built with Razor Pages in previous chapters, and so you've already seen routing in action, even if you didn't realize it at the time. Even a simple URL path—for example, `/Index`—uses routing to determine that Index.cshtml Razor Page should be executed, as shown in figure 5.1.

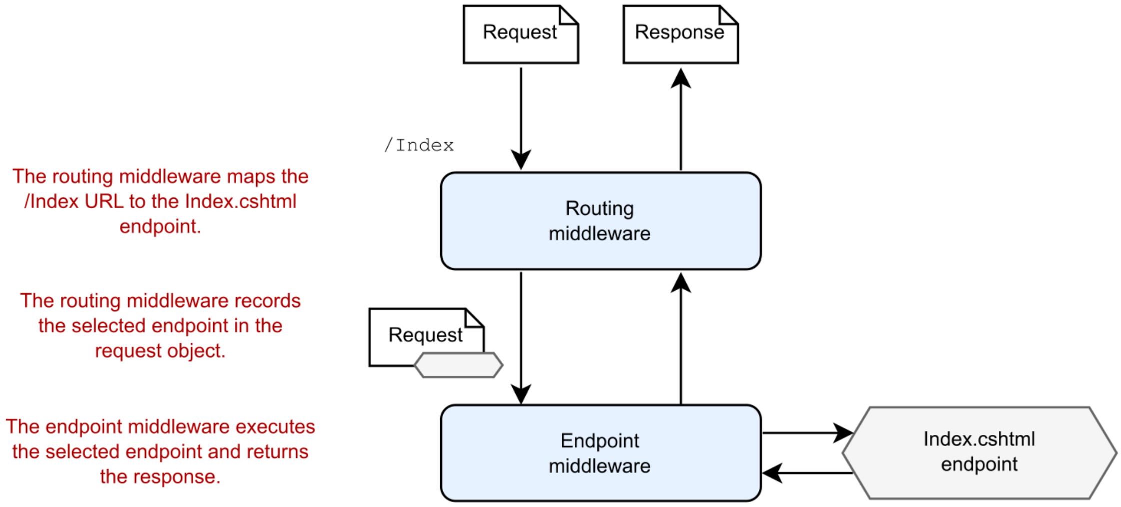

Request
Response
/Index
The routing middleware maps the /Index URL to the Index.cshtml endpoint.
Routing middleware
The routing middleware records the selected endpoint in the request object.
Request
The endpoint middleware executes the selected endpoint and returns the response.
Endpoint middleware
Index.cshtml endpoint

Figure 5.1 The router compares the request URL against a list of configured route templates to determine which action method to execute.

On the face of it, that seems pretty simple. You may be wondering why I need a whole chapter to explain that obvious mapping. The simplicity of the mapping in this case belies how powerful routing can be. If this "file layout-based" approach were the only one available, you'd be severely limited in the applications you could feasibly build.

For example, consider an eCommerce application that sells multiple products. Each product needs to have its own URL, so if you were using a purely file layout-based routing system, you'd only have two options:

- *Use a different Razor Page for every product in your product range.* That would be completely unfeasible for almost *any* realistically sized product range.
- Use a single Razor Page and use the query string to differentiate between products. This is much more practical, but would end up with somewhat ugly URLs, like `"/product?name=big-widget"`, or `"/product?id=12"`.

DEFINITION **The *query string* is part of a URL that contains additional data that doesn't fit in the path. It isn't used by the routing infrastructure for identifying which action to execute, but can be used for model binding, as you'll see in chapter 6.**

With routing, you can have a *single* Razor Page that can handle *multiple* URLs, without having to resort to ugly query strings. From the point of the view of the Razor Page, the query string and routing approaches are very similar—the Razor Page dynamically displays the results for the correct product as appropriate. The difference is that with routing, we can completely customize the URLs, as shown in figure 5.2. This gives much more flexibility and can be important in real life applications for search engine optimization (SEO) reasons[16].

[16] Importantly, you can properly encode the hierarchy of your site in your URLs, as described in Google's SEO starter guide: https://support.google.com/webmasters/answer/7451184

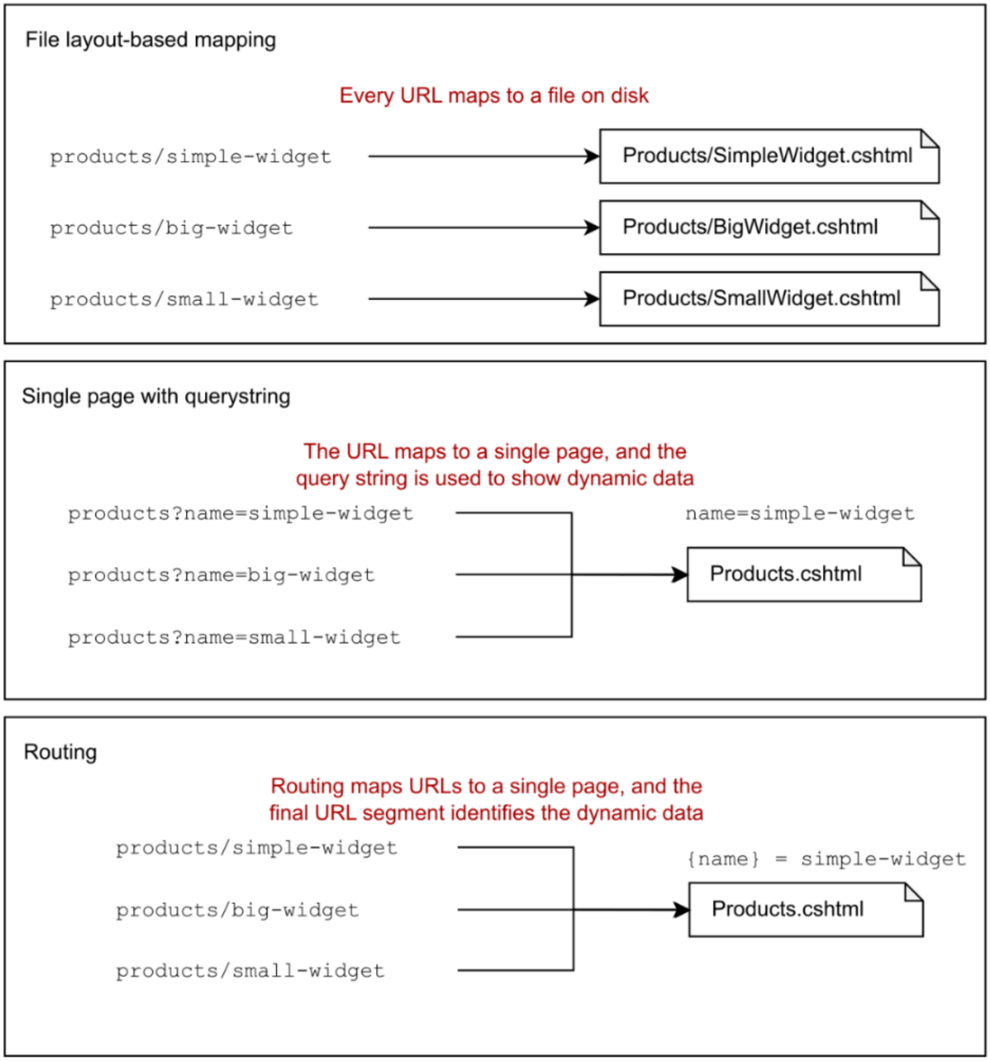

File layout-based mapping
Every URL maps to a file on disk
products/simple-widget
products/big-widget
products/small-widget
Products/SimpleWidget.cshtml
Products/BigWidget.cshtml
Products/SmallWidget.cshtml
Single page with querystring
The URL maps to a single page, and the query string is used to show dynamic data
products?name=simple-widget
products?name=big-widget
products?name=small-widget
name=simple-widget
Products.cshtml
Routing
Routing maps URLs to a single page, and the final URL segment identifies the dynamic data
products/simple-widget
products/big-widget
products/small-widget
{name} = simple-widget
Products.cshtml

Figure 5.2 If you use file-layout based mapping, you need a different Razor Page for every product in your product range. With routing, multiple URLs map to a single Razor Page, and a dynamic parameter captures the difference in the URL.

As well as enabling dynamic URLs, routing fundamentally decouples the URLs in your application from the file names of your Razor Pages. For example, say you had a currency converter application, with a Razor Page in your project located at the path Pages/Rates/View.cshtml, which is used to view the exchange rate for a currency, say USD. By default, this might correspond to the `/rates/view/1` URL for users. This would work fine, but it doesn't tell users much—which currency will this show? Will it be a historical view or the current rate?

Luckily, with routing it's easy to modify your exposed URLs without having to change your Razor Page file names or locations. Depending on your routing configuration, you could set the URL pointing to the View.chstml Razor Page to any of the following:

- `/rates/view/1`
- `/rates/view/USD`
- `/rates/current-exchange-rate/USD`
- `/current-exchange-rate-for-USD`

I know which of these I'd most like to see in the URL bar of my browser, and which I'd be most likely to click! This level of customization isn't often necessary, and the default URLs are normally the best option in the long run, but it's very useful to have the capability to customize the URLs when you need it.

In the next section we'll look at how routing works in practice in ASP.NET Core.

5.2 Routing in ASP.NET Core

In this section we look at:

- The endpoint routing system introduced in ASP.NET Core 3.0.
- The two supported routing approaches: convention-based routing and attribute routing.
- How routing works with Razor Pages.

Routing has been a part of ASP.NET Core since its inception, but in ASP.NET Core 3.0 it went through some big changes. In ASP.NET Core 2.0 and 2.1, routing was restricted to Razor Pages and the ASP.NET Core MVC framework. There was no dedicated routing middleware in your middleware pipeline—routing happened only within Razor Pages or MVC components.

Given that most of the logic of your application is implemented in Razor Pages, only using routing for Razor Pages was fine for the most part. Unfortunately, restricting routing to the MVC infrastructure made some things a bit messy. It meant some cross-cutting concerns, like authorization, were restricted to the MVC infrastructure and were hard to use from other middleware in your application. That restriction caused inevitable duplication, which wasn't ideal.

In ASP.NET Core 3.0, a new routing system was introduced, *endpoint routing*. Endpoint routing makes the routing system a more fundamental feature of ASP.NET Core, and no longer ties it to the MVC infrastructure. Razor Pages and MVC still rely on endpoint routing, but now other middleware can use it too.

In this section I cover

- How endpoint routing works in ASP.NET Core
- The two types of routing available: convention-based routing and attribute routing
- How routing works for Razor Pages

At the end of this section you should have a good overview of how routing in ASP.NET Core works with Razor Pages.

5.2.1 Using endpoint routing in ASP.NET Core

Endpoint routing is fundamental to all but the simplest ASP.NET Core apps. It’s implemented using two pieces of middleware, which you’ve seen previously:

- `EndpointMiddleware`. You use this middleware to *register* the “endpoints” in routing the system when you start your application. The middleware *executes* one of the endpoints at runtime.
- `EndpointRoutingMiddleware`. This middleware chooses *which* of the endpoints registered by the `EndpointMiddleware` should execute for a given request at runtime. To make it easier to distinguish between the two types of middleware, I’ll be referring to this middleware as the `RoutingMiddleware` throughout this book.

The `EndpointMiddleware` is where you configure all the *endpoints* in your system. This is where you register your Razor Pages and MVC controllers, but you can also register additional handlers that fall outside of the MVC framework, such as health-check endpoints that confirm your application is still running.

> **DEFINITION** An *endpoint* in ASP.NET Core is some handler that returns a response. Each endpoint is associated with a URL pattern. Razor Page handlers and MVC controller action methods typically make up the bulk of the endpoints in an application, but you can also use simple middleware as an endpoint, or a health-check endpoint.

To register endpoints in your application, call `UseEndpoints` in the `Configure` method of Startup.cs. This method takes a configuration lambda action that defines the endpoints in your application, as shown in the following listing. You can automatically register all the Razor Pages in your application using extensions such as `MapRazorPages`. Additionally, you can register other endpoints explicitly using methods such as `MapGet`.

Listing 5.1 Registering multiple endpoints in Startup.Configure

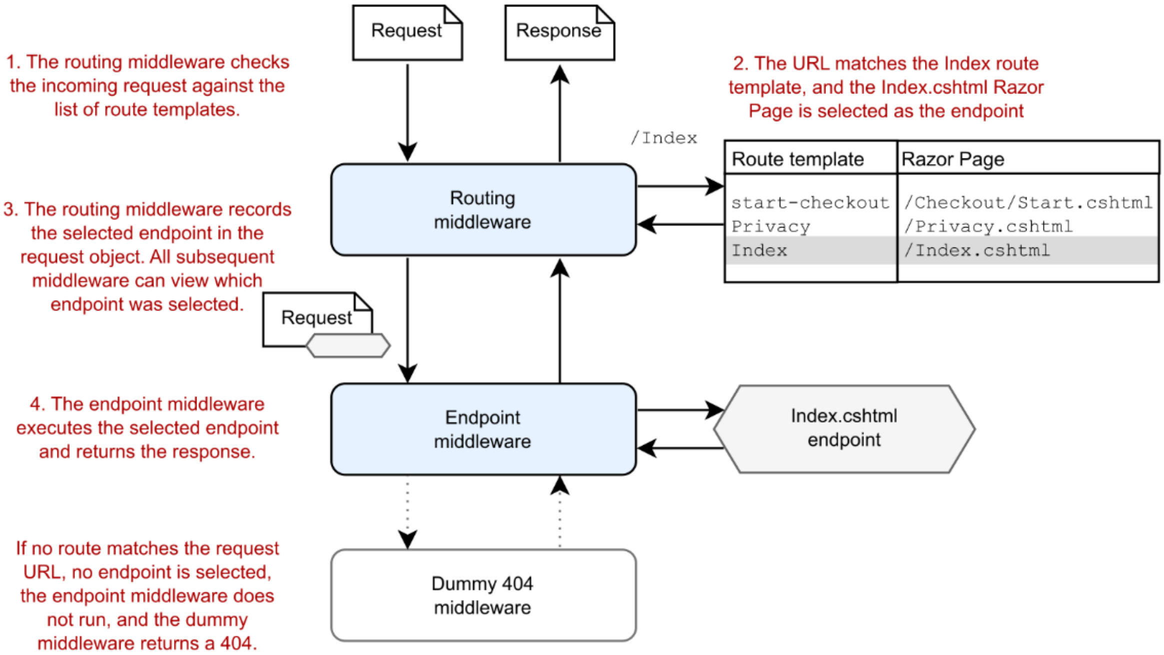
```
public void Configure(IApplicationBuilder app)
{
    app.UseRouting();                                             #A

    app.UseEndpoints(endpoints =>                                 #B
    {
        endpoints.MapRazorPages();                                #C
        endpoints.MapHealthChecks("/healthz");                    #D
        endpoints.MapGet("/test", async context =>                #E
        {                                                         #E
            await context.Response.WriteAsync("Hello World!");    #E
        });                                                       #E
    });
}
```

#A Add the EndpointRoutingMiddleware to the middleware pipeline
#B Add the EndpointMiddleware to the pipeline and provide a configuration lambda
#C Register all the Razor Pages in your application as an endpoint
#D Register a health check endpoint at the route /healthz
#E Register an endpoint inline that returns “Hello World!” at the route /test

Each endpoint is associated with a *route template* that defines which URLs the endpoint should match. You can see two route templates, `"/healthz"` `and` `"/test"`, in the previous listing.

> **DEFINITION** A *route template* is a URL pattern that is used to match against request URLs. They’re strings of fixed values, like `"/test"` in the previous listing. They can also contain placeholders for variables, as you’ll see in section 5.3.

The `EndpointMiddleware` stores the registered routes and endpoints in a dictionary, which it shares with the `RoutingMiddleware`. At runtime, the `RoutingMiddleware` compares an incoming request to the routes registered in the dictionary. If the `RoutingMiddleware` finds a matching endpoint, then it makes a note of which endpoint was selected and attaches that to the request’s `HttpContext` object. It then calls the next middleware in the pipeline. When the request reaches the `EndpointMiddleware`, the middleware checks to see which endpoint was selected, and executes it, as shown in figure 5.3.



Route template	Razor Page
start-checkout	/Checkout/Start.cshtml
Privacy	/Privacy.cshtml
Index	/Index.cshtml

1. The routing middleware checks the incoming request against the list of route templates.

2. The URL matches the Index route template, and the Index.cshtml Razor Page is selected as the endpoint

3. The routing middleware records the selected endpoint in the request object. All subsequent middleware can view which endpoint was selected.

4. The endpoint middleware executes the selected endpoint and returns the response.

If no route matches the request URL, no endpoint is selected, the endpoint middleware does not run, and the dummy middleware returns a 404.

Figure 5.3 Endpoint routing uses a two-step process. The `RoutingMiddleware` selects which endpoint to execute, and the `EndpointMiddleware` executes it. If the request URL doesn't match a route template, the endpoint middleware will not generate a response.

If the request URL *doesn't* match a route template, then the `RoutingMiddleware` doesn't select an endpoint, but the request still continues down the middleware pipeline. As no endpoint is selected, the `EndpointMiddleware` silently ignores the request, and passes it to the next middleware in the pipeline. The `EndpointMiddleware` is typically the final middleware in the pipeline, so the "next" middleware is normally the "dummy" middleware that always returns a `404 Not Found` response, as you saw in chapter 3.

> **TIP** **If the request URL does not match a route template, no endpoint is selected or executed. The whole middleware pipeline is still executed, but typically a 404 response is returned when the request reaches the "dummy" 404 middleware.**

The advantage of having two separate pieces of middleware to handle this process might not be obvious at first blush. Figure 5.3 hinted at the main benefit—all middleware placed after the `RoutingMiddleware` can see which endpoint is *going* to be executed before it is.

> **NOTE** **Only middleware placed *after* the `RoutingMiddleware` can detect which endpoint is going to be executed.**

Figure 5.4 shows a more realistic middleware pipeline, where middleware is placed both *before* the `RoutingMiddleware` and *between* the `RoutingMiddleware` and the `EndpointMiddleware`.

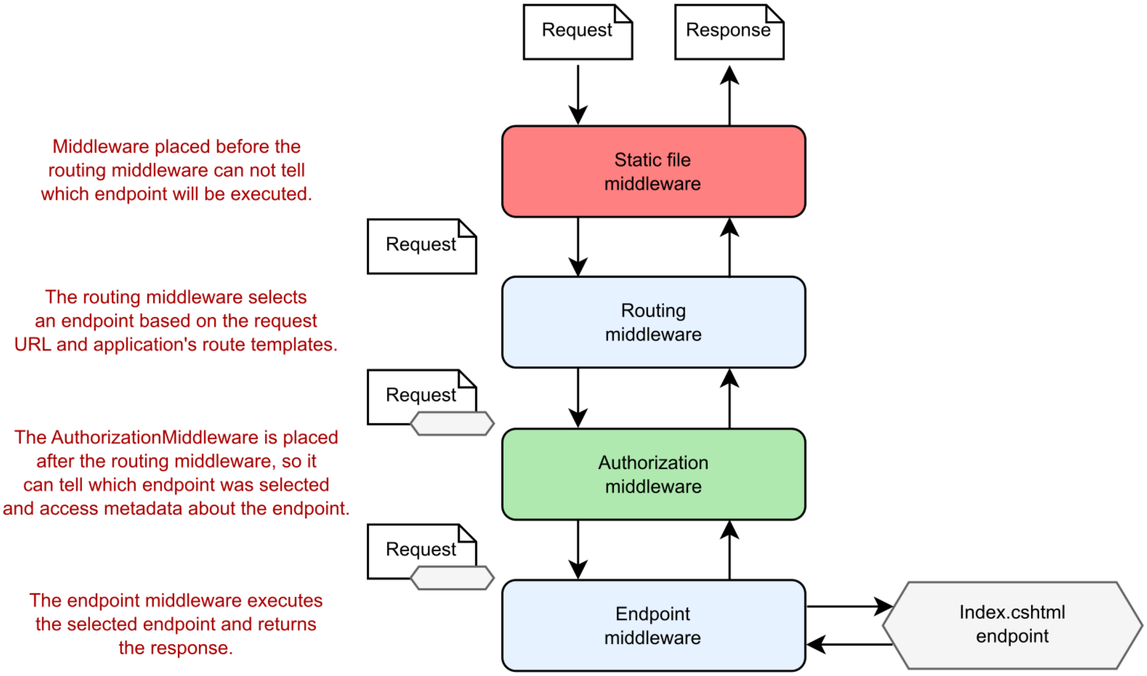

Request
Response
Middleware placed before the routing middleware can not tell which endpoint will be executed.
Static file middleware
Request
The routing middleware selects an endpoint based on the request URL and application's route templates.
Routing middleware
Request
The AuthorizationMiddleware is placed after the routing middleware, so it can tell which endpoint was selected and access metadata about the endpoint.
Authorization middleware
Request
The endpoint middleware executes the selected endpoint and returns the response.
Endpoint middleware
Index.cshtml endpoint

Figure 5.4 Middleware placed before the routing middleware doesn't know which endpoint the routing middleware will select. Middleware placed between the routing middleware and the endpoint middleware can see the selected endpoint.

The `StaticFileMiddleware` in figure 5.4 is placed *before* the `RoutingMiddleware`, so it executes before an endpoint is selected. Conversely, the `AuthorizationMiddleware` is placed *after* the `RoutingMiddleware`, so it can tell that the Index.cshtml Razor Page endpoint will be executed eventually. In addition, it can access certain metadata about the endpoint, such as its name and what the required permissions are to access the Razor Page.

> **TIP** **The** `AuthorizationMiddleware` **needs to know which endpoint will be executed, so it must be placed *after* the** `RoutingMiddleware` **and *before* the** `EndpointMiddleware` **in your middleware pipeline. I discuss authorization in more detail in chapter 15.**

It's important to remember the different roles of the two types of routing middleware when building your application. If you have a piece of middleware that needs to know which endpoint (if any) a given request will execute, then you need to make sure you place it after the `RoutingMiddleware` and before the `EndpointMiddleware`.

We've covered how the `RoutingMiddleware` and `EndpointMiddleware` interact to provide routing capabilities in ASP.NET Core, but we haven't yet looked at *how* the `RoutingMiddleware` matches the request URL to an endpoint. In the next section we look at the two different approaches used in ASP.NET Core.

5.2.2 Convention-based routing vs attribute routing

Routing is a key part of ASP.NET Core, as it maps the incoming request's URL to a specific endpoint to execute. You have two different ways to define these URL-endpoint mappings in your application:

- Using global, convention-based routing.
- Using attribute routing.

Which approach you use will typically depend on whether you're using Razor Pages or MVC controllers, and whether you're building an API or a website (using HTML). These days, I lean heavily towards attribute routing, as you'll see shortly.

Convention-based routing is defined globally for your application. You can use convention-based routes to map endpoints (MVC controller actions) in your application to URLs, but your MVC controllers must adhere strictly to the conventions you define. Traditionally, applications using MVC controllers to generate HTML tend to use this approach to routing. The downside to this approach is it makes customizing the URLs for a subset of controllers and actions more difficult.

Alternatively, you can use attribute-based routes to tie a given URL to a specific endpoint. For MVC controllers, this involves placing `[Route]` attributes on the action methods themselves, hence the term *attribute-routing*. This provides a lot more flexibility, as you can explicitly define what the URL for each action method should be. This approach is generally more verbose than the convention-based approach, as it requires applying attributes to *every* action method in your application. Despite this, the additional flexibility it provides can be very useful, especially when building Web APIs.

Somewhat confusingly, Razor Pages uses *conventions* to generate *attribute routes*! In many ways this combination gives the best of both worlds—you get the predictability and terseness of convention-based routing with the easy customization of attribute routing. There are trade-offs to each of the approaches, as shown in table 5.1.

Table 5.1 The advantages and disadvantages of the routing styles available in ASP.NET Core

Routing style	Typical use	Advantages	Disadvantages
Convention-based routes	HTML generating MVC controllers	Very terse definition in one location in your application. Forces a consistent layout of MVC	Routes are defined in different place to your controllers. Overriding the route conventions

		controllers.	can be tricky and error prone. Adds an extra layer of indirection when routing a request.
Attribute routes	Web API MVC controllers	Gives complete control over route templates for every action. Routes are defined next to the action they execute.	Verbose compared to convention-based routing Can be easy to over-customize route templates Route templates are scattered throughout your application, rather than in one location.
Convention-based generation of attribute routes	Razor Pages	Encourages consistent set of exposed URLs. Terse when you stick to the conventions Easily override the route template for a single page Customize conventions globally to change exposed URLs	Possible to over-customize route templates You must calculate what the route template for a page is, rather than it being explicitly defined in your app

So which approach should you use? My opinion is that convention-based routing is not worth the effort in 99% of cases, and that you should stick to attribute routing. If you're following my advice of using Razor Pages, then you're already using attribute routing under the covers. Also, if you're creating APIs using MVC controllers, then attribute routing is the best option, and is the recommended approach.

The only scenario where convention-based routing is used traditionally is if you're using MVC controllers to generate HTML. But if you are following my advice from chapter 4, you'll be using Razor Pages for HTML generating applications, and only falling back to MVC controllers when completely necessary. For consistency, in that scenario I would still stick with attribute routing.

> **NOTE** For the reasons above, this book focuses on attribute routing. Virtually of the features described in this section also apply to convention-based routing. For details on convention-based routing see the documentation: https://docs.microsoft.com/en-us/aspnet/core/mvc/controllers/routing.

Whichever technique you use, you'll define your application's expected URLs using *route templates*. These define the pattern of the URL you're expecting, with placeholders for the parts that may vary.

> **DEFINITION** *Route templates* define the structure of known URLs in your application. They're strings with placeholders for variables that can contain optional values.

A single route template can match many different URLs. For example, the `/customer/1` and `/customer/2` URLs would both be matched by the `"customer/{id}"` route template. The route template syntax is powerful and contains many different features that are controlled by splitting a URL into multiple *segments*.

> **DEFINITION** **A *segment* is a small contiguous section of a URL. It's separated from other URL segments by at least one character, often by the `/` character. Routing involves matching the segments of a URL to a route template.**

For each route template, you can define

- Specific, expected strings
- Variable segments of the URL
- Optional segments of a URL
- Default values when an optional segment isn't provided
- Constraints on segments of a URL, for example, ensuring that it's numeric

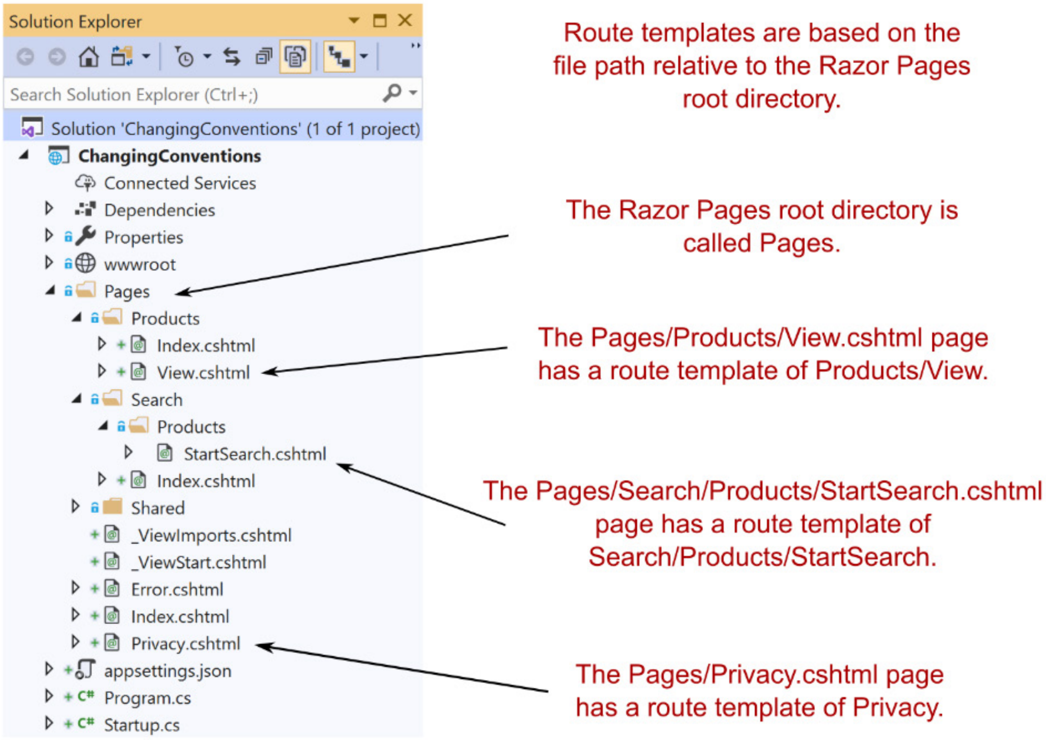
Most applications will use a variety of these features, but you often only use one or two features here and there. For the most part, the default convention-based attribute route templates generated by Razor Pages will be all you need. In the next section we look at those conventions, and how routing maps a request's URL to a Razor Page in detail.

5.2.3 Routing to Razor Pages

As I mentioned in the section 5.2.2, Razor Pages uses attribute routing by creating route templates based on conventions. ASP.NET Core creates a route template for every Razor Page in your app during app startup, when you call `MapRazorPages` in the `Configure` method of Startup.cs:

```
app.UseEndpoints(endpoints =>
{
    endpoints.MapRazorPages();
});
```

For every Razor Page in your application, the framework uses the path of the Razor Page file relative to the Razor Pages root directory (Pages/), excluding the file extension (cshtml). For example, if you have a Razor Page located at the path Pages/Products/View.cshtm, the framework creates a route template with the value `"Products/View"`, as shown in figure 5.5.



Route templates are based on the file path relative to the Razor Pages root directory.

The Razor Pages root directory is called Pages.

The Pages/Products/View.cshtml page has a route template of Products/View.

The Pages/Search/Products/StartSearch.cshtml page has a route template of Search/Products/StartSearch.

The Pages/Privacy.cshtml page has a route template of Privacy.

Figure 5.5 By default, route templates are generated for Razor Pages based on the path of the file relative to the root directory, Pages.

Requests to the URL `/products/view` match the route template `"Products/View"`, which in turn corresponds to the View.cshtml Razor Page. The `RoutingMiddleware` selects the View.cshtml Razor Page as the endpoint for the request, and the `EndpointMiddleware` executes the page's handler once the request reaches it in the middleware pipeline.

> **TIP** **Routing is not case sensitive, so the request URL does not need to have the same URL casing as the route template to match.**

In chapter 4, you learned that Razor Page handlers are the methods that are invoked on a Razor Page. When we say, "a Razor Page is executed" we really mean "an instance of the Razor Page's `PageModel` is created, and a page handler on the model is invoked". Razor Pages can have multiple page handlers, so once the `RoutingMiddleware` selects a Razor Page, the `EndpointMiddleware` still needs to choose which handler to execute. You'll learn how the framework selects which page handler to invoke in section 5.6.

By default, each Razor Page creates a single route template based on its file path. The exception to this rule is for Razor Pages that are called Index.cshtml. Index.cshtml pages create *two* route templates, one ending with `"Index"`, the other without an ending. For example, if you have a Razor Page at the path Pages/ToDo/Index.cshtml, that will generate two route templates:

- `"ToDo"`
- `"ToDo/Index"`

When either of these routes are matched, the same Index.cshtml Razor Page is selected. For example, if your application is running at the URL https://example.org, you can view the page by executing https://example.org/ToDo or https://example.org/ToDo/Index.

As a final example, consider the Razor Pages created by default when you create a Razor Pages application using Visual Studio or by running `dotnet new web` using the .NET CLI, as we did in chapter 2. The standard template includes three Razor Pages in the Pages directory:

- Pages/Error.cshtml
- Pages/Index.cshtml
- Pages/Privacy.cshtml

That creates a collection of four routes for the application, defined by the following templates:

- `""` maps to Index.cshtml
- `"Index"` maps to Index.cshtml
- `"Error"` maps to Error.cshtml
- `"Privacy"` maps to Privacy.cshtml

At this point, routing probably feels laughably trivial, but this is just the basics that you get "for free" with the default Razor Pages conventions, which is often sufficient for a large portion of any website. At some point though, you'll find you need something more dynamic, such as an ecommerce site where you want each product to have its own URL, but which maps to a single Razor Page. This is where route templates and route data come in and show the real power of routing.

5.3 Customizing Razor Page route templates

The route templates for a Razor Page are based on the file path by default, but you're also able to customize the final template for each page, or even to replace it entirely. In this section I show how to customize the route templates for individual pages, so you can customize your application's URLs, and map multiple URLs to a single Razor Page.

Route templates have a rich, flexible syntax, but a simple example is shown in figure 5.6.

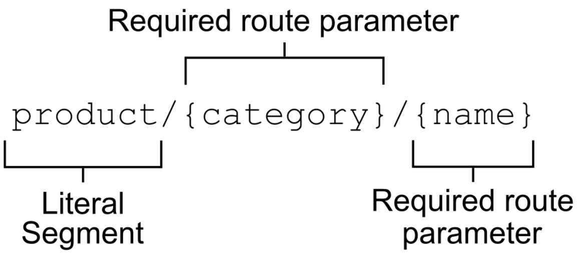


Figure 5.6 A simple route template showing a literal segment and two required route parameters

The routing middleware parses a route template by splitting it into a number of *segments*. A segment is typically separated by the `/` character, but it can be any valid character. Each segment is either

- *A literal value*—For example, `product` in figure 5.6
- *A route parameter*—For example, `{category}` and `{name}` in figure 5.6

Literal values must be matched exactly (ignoring case) by the request URL. If you need to match a particular URL exactly, you can use a template consisting only of literals. This is the default case for Razor Pages, as you saw in section 5.2.3; each Razor Page consists of a series of literal segments, for example "`ToDo/Index`".

Imagine you have a contact page in your application at the path Pages/About/Contact.cshtml. The route template for this page is "`About/Contact`". This route template consists of only literal values, and so only matches the exact URL. None of the following URLs would match this route template:

- `/about`
- `/about-us/contact`
- `/about/contact/email`
- `/about/contact-us`

Route parameters are sections of a URL that may vary, but will still be a match for the template. They are defined by giving them a name, and placing them in braces, such as `{category}` or `{name}`. When used in this way, the parameters are required, so there must be a segment in the request URL that they correspond to, but the value can vary.

> **TIP** Some words can't be used as names for route parameters: `area`, `action`, `controller`, `handler`, and `page`.

The ability to use route parameters gives you great flexibility. For example, the simple route template "`{category}/{name}`" could be used to match all the product-page URLs in an ecommerce application, such as:

- /bags/rucksack-a—Where category=bags and name=rucksack-a
- /shoes/black-size9—Where category=shoes and name=black-size-9

But note that this template would *not* map the following URLs:

- /socks/—No name parameter specified
- /trousers/mens/formal—Extra URL segment, formal, not found in route template

When a route template defines a route parameter, and the route matches a URL, the value associated with the parameter is captured and stored in a dictionary of values associated with the request. These *route values* typically drive other behavior in the Razor Page, such as model binding.

> **DEFINITION** ***Route values*** **are the values extracted from a URL based on a given route template. Each route parameter in a template will have an associated route value and is stored as a string pair in a dictionary. They can be used during model binding, as you'll see in chapter 6.**

Literal segments and route parameters are the two cornerstones of ASP.NET Core route templates. With these two concepts, it's possible to build all manner of URLs for your application. But how can you customize a Razor Page to use one of these patterns?

5.3.1 Adding a segment to a Razor Page route template

To customize the Razor Page route template, you update the @page directive at the top of the Razor Page's cshtml file. This directive must be the first thing in the Razor Page file for the page to be registered correctly.

> **NOTE You must include the @page directive at the top of a Razor Page's cshtml file. Without it, ASP.NET Core will not treat the file as a Razor Page, and you will not be able to view the page.**

To add an additional segment to a Razor Page's route template, add a space followed by the desired route template, after the @page statement. For example, to add "Extra" to a Razor Page's route template, use

```
@page "Extra"
```

This *appends* the provided route template to the default template generated for the Razor Page. For example, the default route template for the Razor Page at Pages/Privacy.html is "Privacy". With the directive above, the new route template for the page would be "Privacy/Extra".

> **NOTE The route template provided in the @page directive is *appended* to the end of the default template for the Razor Page.**

The most common reason for customizing a Razor Page's route template like this is to add a *route parameter*. For example, you could have a single Razor Page for displaying the products in an ecommerce site at the path Pages/Products.cshtml, and use a route parameter in the `@page` directive

```
@page "{category}/{name}"
```

This would give a final route template of `Products/{category}/{name}` which would match all of the following URLs:

- `/products/bags/white-rucksack`
- `/products/shoes/black-size9`
- `/Products/phones/iPhoneX`

It's very common to *add* route segments to the Razor Page template like this, but what if that's not enough? Maybe you don't want to have the `/products` segment at the start of the above URLs, or you want to use a completely custom URL for a page. Luckily that's just as easy to achieve.

5.3.2 Replacing a Razor Page route template completely

You'll be most productive working with Razor Pages if you can stick to the default routing conventions where possible, adding additional segments for route parameters where necessary. But sometimes you just need more control. That's often the case for "important" pages in your application, such as the checkout page for an ecommerce application, or even the product pages, as you saw in the previous section.

To specify a custom route for a Razor Page, prefix the route with `/` in the `@page` directive. For example, to remove the `"product/"` prefix from the route templates in the previous section, use the directive:

```
@page "/{category}/{name}"
```

Note that this directive includes the `"/"` at the start of the route, indicating that this is a *custom* route template, instead of an *addition*. The route template for this page will be `"{category}/{name}"`, no matter which Razor Page it is applied to.

Similarly, you can create a "static" custom template for a page by starting the template with a `"/"` and using only literal segments. For example:

```
@page "/checkout"
```

Wherever your place your checkout Razor Page within the Pages folder, using this directive ensures it always has the route template `"checkout"`, so it will always match the request URL `/checkout`.

It's important to note that when you customize the route template for a Razor Page, both when appending to the default and when replacing it with a custom route, the *default template is no longer valid*. For example, if you use the `"checkout"` route template above on a Razor

Page located at Pages/Payment.cshtml, you can *only* access it using the URL `/checkout`; the URL `/Payment` is no longer valid and will not execute the Razor Page.

> **TIP** **Customizing the route template for a Razor Page using the `@page` directive *replaces* the default route template for the page. In section 5.7 I show how you can add additional routes while preserving the default route template.**

In this section you learned how to customize the route template for a Razor Page. In the next section we look in more depth at the route template syntax and some of the other features available.

5.4 Exploring the route template syntax

As well as the basic elements of literals and route parameter segments, route templates have extra features that give you more control over your application's URLs. These features let you have optional URL segments, provide default values when a segment isn't specified, or can place additional constraints on the value's that are valid for a given route parameter. This section takes a look at these features, and ways you can apply them.

5.4.1 Using optional and default values

In the previous section, you saw a simple route template with a literal segment and two required routing parameters. In figure 5.7, you can see a more complex route that uses a number of additional features.

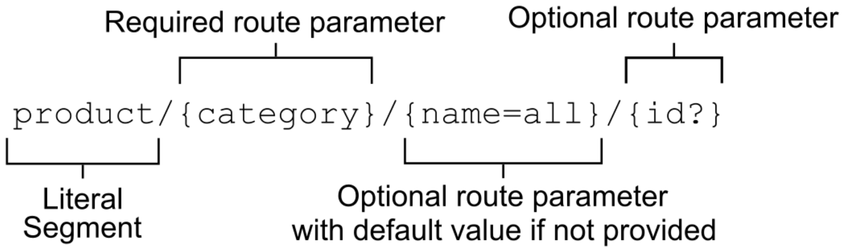

Required route parameter
Optional route parameter
product/{category}/{name=all}/{id?}
Literal Segment
Optional route parameter with default value if not provided

Figure 5.7 A more complex route template showing literal segments, named route parameters, optional parameters, and default values

The literal `product` segment and the required `{category}` parameter are the same as you saw in figure 5.6. The `{name}` parameter looks *similar*, but it has a default value specified for it using `=all`. If the URL doesn't contain a segment corresponding to the `{name}` parameter, then the router will use the `all` value instead.

The final segment of figure 5.7, `{id?}`, defines an optional route parameter called `id`. This segment of the URL is optional—if present, the router will capture the value for the `{id}` parameter; if it isn't there, then it won't create a route value for `id`.

You can specify any number of route parameters in your templates, and these values will be available to you when it comes to model binding. The complex route template of figure 5.7 allows you to match a greater variety of URLs by making `{name}` and `{id}` optional, and providing a default for `{name}`. Table 5.2 shows some of the possible URLs this template would match, and the corresponding route values the router would set.

Table 5.2 URLs that would match the template of figure 5.7 and their corresponding route values

URL	Route values
/product/shoes/formal/3	category=shoes, name=formal, id=3
/product/shoes/formal	category=shoes, name=formal
/product/shoes	category=shoes, name=all
/product/bags/satchels	category=bags, name=satchels
/product/phones	category=phones, name=all
/product/computers/laptops/ABC-123	category=computes, name=laptops, id=ABC-123

Note that there's no way to specify a value for the optional `{id}` parameter without also specifying the `{category}` and `{name}` parameters. You can *only* put an optional parameter (that doesn't have a default) at the *end* of a route template. For example, imagine your route template had an optional `{category}` parameter:

```
{category?}/{name}
```

Now try to think of a URL that would specify the `{name}` parameter, but not the `{category}`. It can't be done! Patterns like this won't cause errors per-se, the category parameter is just essentially required, even though you've marked is as optional.

Using default values allows you to have multiple ways to call the same URL, which may be desirable in some cases. For example, using the route template in figure 5.7 the two URLs below are equivalent:

- `/product/shoes`
- `/product/shoes/all`

Both of these URLs will execute the same Razor Page, with the same route values of `category=shoes` and `name=all`. Using default values allows you to use shorter and more memorable URLs in your application for common URLs, but still have the flexibility to match a variety of routes in a single template.

5.4.2 Adding additional constraints to route parameters

By defining whether a route parameter is required or optional, and whether it has a default value, you can match a broad range of URLs with a pretty terse template syntax. Unfortunately, in some cases this can end up being a little *too* broad. Routing only matches URL segments to route parameters; it doesn't know anything about the data that you're expecting those route parameters to contain. If you consider a template similar to that in figure 5.7, "`{category}/{name=all}/{id?}`, the following URLs would all match:

- `/shoes/sneakers/test`
- `/shoes/sneakers/123`
- `/Account/ChangePassword`
- `/ShoppingCart/Checkout/Start`
- `/1/2/3`

These URLs are all perfectly valid given the template's syntax, but some might cause problems for your application. These URLs all have two or three segments, and so the router happily assigns route values and matches the template when you might not want it to! The route values assigned are:

- `/shoes/sneakers/test—category=shoes, name=sneakers, id=test`
- `/shoes/sneakers/123—category=shoes, name=sneakers, id=123`
- `/Account/ChangePassword—category=Account, name=ChangePassword`
- `/Cart/Checkout/Start—category=Cart, name=Checkout, id=Start`
- `/1/2/3—category=1, name=2, id=3`

Typically, the router passes route values to Razor Pages through a process called model binding which you saw briefly in chapter 4 (and which we'll discuss in detail in the next chapter). For example, a Razor Page with the handler `public void OnGet(int id)` would obtain the `id` argument from the `id` route value. If the `id` route parameter ends up assigned a *non-integer* value from the URL, then you'll get an exception when it's bound to the *integer* `id` parameter.

To avoid this problem, it's possible to add additional *constraints* to a route template that must be satisfied for a URL to be considered a match. Constraints can be defined in a route template for a given route parameter using : (a colon). For example, `{id:int}` would add the `IntRouteConstraint` to the `id` parameter. For a given URL to be considered a match, the value assigned to the `id` route value must be convertible to an integer.

You can apply a large number of route constraints to route templates to ensure that route values are convertible to appropriate types. You can also check more advanced constraints, for example, that an integer value has a particular minimum value, or that a string value has a maximum length. Table 5.3 describes a number of the possible constraints available, but you can find a more complete list online at http://mng.bz/U11Q.

Table 5.3 A few route constraints and their behavior when applied

Constraint	Example	Match examples	Description
`int`	`{qty:int}`	`123, -123, 0`	Matches any `integer`
`Guid`	`{id:guid}`	`d071b70c-a812-4b54-87d2-7769528e2814`	Matches any `Guid`
`decimal`	`{cost:decimal}`	`29.99, 52, -1.01`	Matches any `decimal` value
`min(value)`	`{age:min(18)}`	`18, 20`	Matches `integer` values of 18 or greater
`length(value)`	`{name:length(6)}`	`andrew,123456`	Matches `string` values with a length of 6
`optional int`	`{qty:int?}`	`123, -123, 0, null`	Optionally matches any `integer`
`optional int max(value)`	`{qty:int:max(10)?}`	`3, -123, 0, null`	Optionally matches any `integer` of 10 or less

TIP As you can see from table 5.3, you can also combine multiple constraints; place a colon between them or use an optional mark (`?`) at the end.

Using constraints allows you to narrow down the URLs that a given route template will match. When the routing middleware matches a URL to a route template, it interrogates the constraints to check that they're all valid. If they aren't valid, then the route template isn't considered a match, and the Razor Page won't be executed.

WARNING Don't use route constraints to validate general input, for example to check that an email address is valid. Doing so will result in 404 "Page not found" errors, which will be confusing for the user.

Constraints are best used sparingly, but they can be useful when you have strict requirements on the URLs used by the application, as they can allow you to work around some otherwise tricky combinations.

Constraints and ordering in attribute routing

If you have a well-designed set of URLs for your application, then you will probably find that you don't really need to use route constraints. Route constraints really come in useful when you have "overlapping" route templates.

For example, imagine you have a Razor Page with the route template `"{number}/{name}"`, and another with the template `"{product}/{id}"`. When a request with the URL `/shoes/123` arrives, which template is chosen? They *both* match, so the routing middleware panics and throws an exception. Not ideal.

Using conventions can fix this. For example, if you update the first template to `"{number:int}/{name}"`, then the integer constraint means the URL is no longer a match, and the routing middleware can choose correctly. Note however, that the URL `/123/shoes` *does* still match both route templates, so you're not out of the woods.

Generally, you should avoid overlapping route templates like these, as they're often confusing and more trouble than they're worth.

Attribute routing (used by Razor Pages and MVC controllers for building APIs) allows you to explicitly control the *order* the routing middleware looks at your route templates, which can also be used to resolve issues like the one above. However, if you find yourself needing to manually control the order, this is a very strong indicator that your URLs are confusing.[17]

If your route templates are well defined such that each URL only maps to a single template, ASP.NET Core routing will work without any difficulties. Sticking to the built-in conventions as far as possible is the best way to stay on the happy path!

We're coming to the end of our look at route templates, but before we move on there's one more type of parameter to think about: the catch-all parameter.

5.4.3 Matching arbitrary URLs with the catch-all parameter

You've already seen how route templates take URL segments and attempt to match them to parameters or literal strings. These segments normally split around the slash character, `/`, so the route parameters themselves won't contain a slash. What do you do if you need them to contain a slash, or you don't know how many segments you're going to have?

Imagine you are building a currency-converter application that shows the exchange rate from one currency to one or more other currencies. You're told that the URLs for this page should contain all the currencies as separate segments. Here are some examples:

- `/USD/convert/GBP`—Show USD with exchange rate to GBP
- `/USD/convert/GBP/EUR`—Show USD with exchange rate to GBP and EUR
- `/USD/convert/GBP/EUR/CAD`—Show USD with exchange rate for GBP, EUR, and CAD

If you want to support showing *any* number of currencies as the URLs above do, then you need a way of capturing *everything* after the `convert` segment. You could achieve this for the

[17] If you're really sure you do need to control route template ordering, see the documentation at https://docs.microsoft.com/en-us/aspnet/core/razor-pages/razor-pages-conventions?route-order. Note that you can only control the order for additional routes added using conventions, as you'll see in section 5.7

Pages/Convert.cshtml Razor Page by using a catch-all parameter in the `@page` directive, as shown in figure 5.8.

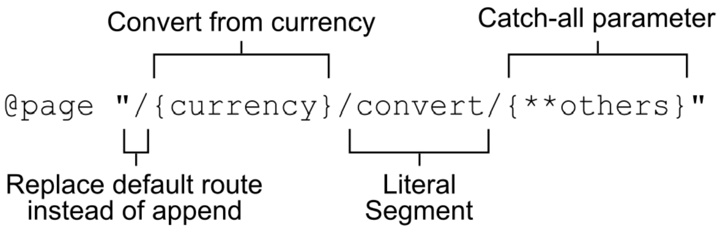

Convert from currency
Catch-all parameter
@page "/{currency}/convert/{**others}"
Replace default route instead of append
Literal Segment

Figure 5.8 You can use catch-all parameters to match the remainder of a URL. Catch-all parameters may include the "/" character or may be an empty string.

Catch-all parameters can be declared using either one or two asterisks inside the parameter definition, like `{*others}` or `{**others}`. These will match the remaining unmatched portion of a URL, including any slashes or other characters that aren't part of earlier parameters. They can also match an empty string. For the `USD/convert/GBP/EUR` URL, the value of the route value `others` would be the single string `"GBP/EUR"`.

> **TIP** Catch-all parameters are greedy and will capture the whole unmatched portion of a URL. Where possible, to avoid confusion, avoid defining route templates with catch-all parameters that "overlap" other route templates.

The one- and two-asterisk versions of the catch-all parameter behave identically when routing an incoming request to a Razor Page. The difference only comes when you're *generating* URLs (which we'll cover in the next section): the one-asterisk version URL encodes forward slashes, and the two-asterisk version doesn't. The "round-trip" behavior of the two-asterisk version is typically what you want.[18]

You read that correctly—mapping URLs to Razor Pages is only half of the responsibilities of the routing system in ASP.NET Core. It's also used to *generate* URLs so that you can easily reference your Razor Pages from other parts of your application.

[18] For details and examples of this behaviour, see the documentation https://docs.microsoft.com/en-us/aspnet/core/fundamentals/routing

5.5 Generating URLs from route parameters

In this section, we look at the other half of routing—generating URLs. You'll learn how to generate URLs as a string you can use in your code, and how to automatically send redirect URLs as a response from your Razor Pages.

One of the by-products of using the routing infrastructure in ASP.NET Core is that your URLs can be somewhat fluid. If you rename a Razor Page, then the URL associated with that page will also change. For example, renaming the Pages/Cart.cshtml page to Pages/Basket/View.cshtml would cause the URL used to access the page to change from `/Cart` to `/Basket/View`.

Trying to manually manage these links within your app would be a recipe for heartache, broken links, and 404s. If your URLs were hardcoded, then you'd have to remember to do a find-and-replace with every rename!

Luckily, you can use the routing infrastructure to generate appropriate URLs dynamically at runtime instead, freeing you from the burden. Conceptually, this is almost an exact reverse of the process of mapping a URL to a Razor Page, as shown in figure 5.9. In the "routing" case, the routing middleware takes a URL, matches it to a route template, and splits it into route values. In the "URL generation" case, the generator takes in the *route values* and combines them with a route template to build a URL.

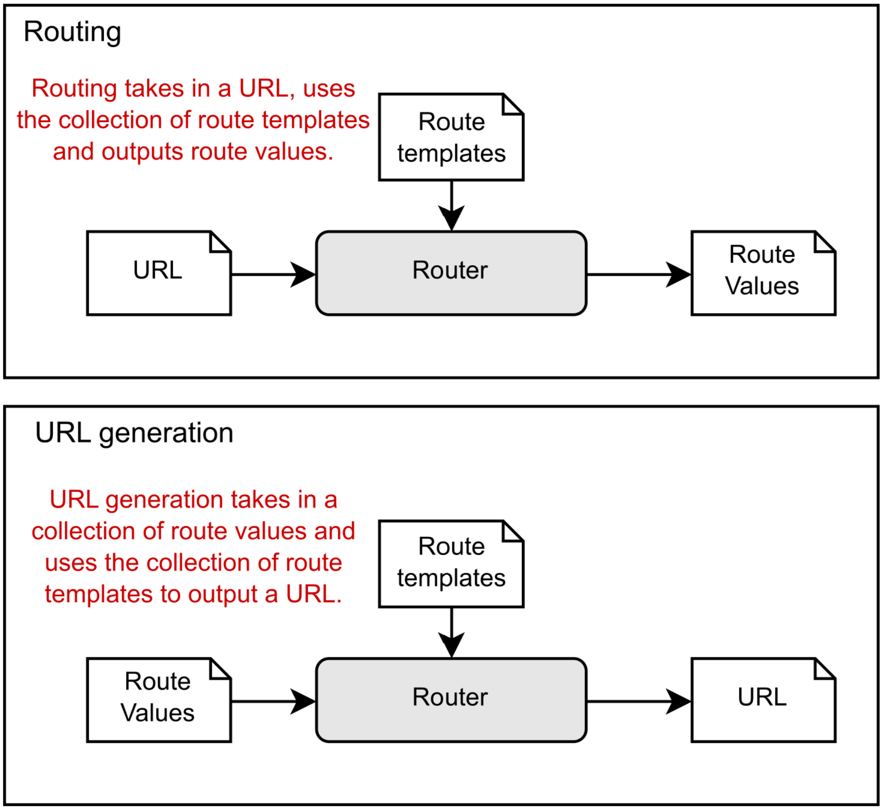

Routing
Routing takes in a URL, uses the collection of route templates and outputs route values.
Route templates
URL
Router
Route Values
URL generation
URL generation takes in a collection of route values and uses the collection of route templates to output a URL.
Route templates
Route Values
Router
URL

Figure 5.9 A comparison between routing and URL generation. Routing takes in a URL and generates route values, but URL generation uses route values to generate a URL.

5.5.1 Generating URLs for a Razor Page

You will need to generate URLs in various places in your application, and one common location is in your Razor Pages and MVC controllers. The following listing shows how you could generate a link to the Pages/Currency/View.cshtml Razor Page, using the `Url` helper from the `PageModel` base class.

Listing 5.2 Generating a URL using `IUrlHelper` and the Razor Page name

```
public class IndexModel : PageModel                                 #A
{
    public void OnGet()
    {
        var url = Url.Page("Currency/View", new { code = "USD" });  #B
    }
}
```

#A Deriving from PageModel gives access to the Url property.
#B You provide the relative path to the Razor Page, along with any additional route values.

The Url property is an instance of IUrlHelper that allows you to easily generate URLs for your application by referencing other Razor Pages by their file path. It exposes a Page method to which you pass the name of the Razor Page and any additional route data. The route data is packaged as key-value pairs into a single C# anonymous object. If you need to pass more than one route value, you can add additional properties to the anonymous object. The helper will then generate a URL based on the referenced page's route template.

> **TIP You can provide the *relative* file path to the Razor Page, as shown in Listing 5.2. Alternatively, you can provide the *absolute* file path (relative to the Pages folder) by starting the path with a "/", for example "/Currency/View".**

The IUrlHelper has several different overloads of the Page method. Some of these methods allow you to specify a specific page handler, others let you generate an absolute URL instead of a relative URL, and some let you pass in additional route values.

In listing 5.2, as well as providing the file path, I passed in an anonymous object, new { code = "USD" }. This object provides additional route values when generating the URL, in this case setting the code parameter to "USD".

If a selected route explicitly includes the defined route value in its definition, such as in the "Currency/View/{code}" route template, then the route value will be used in the URL path, giving /Currency/View/GBP.

If a route doesn't contain the route value explicitly, for example in the "Currency/View" template, then the route value is appended as additional data as part of the query string, for example /Currency/View?code=GBP.

Generating URLs based on the page you want to execute is convenient, and the usual approach taken in most cases. If you're using MVC controllers for your APIs then the process is much the same as for Razor Pages, though the methods are slightly differently.

5.5.2 Generating URLs for an MVC controller

Generating URLs for MVC controllers is very similar to Razor Pages. The main difference is that you use the Action method on the IUrlHelper, and you provide an MVC controller name and action name instead of a page path. The following listing shows an MVC controller generating a link from one action method to another, using the Url helper from the Controller base class.

Listing 5.3 Generating a URL using IUrlHelper and the action name

```
public class CurrencyController : Controller                  #A
{
    [HttpGet("currency/index")]
    public IActionResult Index()
    {
        var url = Url.Action("View", "Currency",                 #B
            new { code = "USD" });                               #B
        return Content($"The URL is {url}");                      #C
    }

    [HttpGet("currency/view/{code}")
    public IActionResult View(string code)                        #D
    {
         /* method implementation*/
    }
}
```

#A Deriving from Controller gives access to the Url property.
#B You provide the controller and action name, along with any additional route values.
#C This will return "The URL is /Currency/View/USD".
#D The URL generated will route to the View action method.

You can call the `Action` and `Page` methods on `IUrlHelper` from both Razor Pages and MVC controllers, so you can generate links back and forth between them if you need to. The important question is: what is the *destination* of the URL? If the URL you need refers to a Razor Page, use the `Page` method. If the destination is an MVC action, use the `Action` method.

> **TIP** **Instead of using strings for the name of the action method, use the C# 6** `nameof` **operator to make the value refactor-safe, for example,** `nameof(View)`**.**

If you're routing to an action in the same controller, you can use a different overload of `Action` that omits the controller name when generating the URL. The `IUrlHelper` uses *ambient values* from the current request and overrides these with any specific values you provide.

> **DEFINITION** **Ambient values are the route values for the current request. They include** `controller` **and** `action` **when called from an MVC controller but can also include additional route values that were set when the action or Razor Page was initially located using routing. See the documentation for further details: https://docs.microsoft.com/en-us/aspnet/core/fundamentals/routing.**

Generating URLs using the `Url` property doesn't tend to be very common in practice. Instead, it's more common to generate URLs implicitly with an `ActionResult`.

5.5.3 Generating URLs with ActionResults

In this section you've seen how to generate a string containing a URLs for both Razor Pages and MVC actions. This is useful if you need to display the URL to a user, or to include the URL in an API response for example. However, you don't need to display URLs very often. More commonly, you want to *automatically redirect* a user to a URL. For that situation you can use an `ActionResult` to handle the URL generation instead.

The listing below shows how you can generate a URL that automatically redirects a user to a different Razor Pages using an `ActionResult`. The `RedirectToPage` method takes the path to a Razor Page and any required route parameters, and generates a URL in the same way as the `Url.Page` method. The framework automatically sends the generated URL as the response, so you never "see" the URL in your code. The user's browser then reads the URL from the response, and automatically redirects to the new page.

Listing 5.4 Generating a redirect URL from an `ActionResult`

```
public class CurrencyModel : PageModel
{
    public IActionResult OnGetRedirectToPage()
    {
        return RedirectToPage("Currency/View", new { id = 5 });  #A
    }
}
```

#A The RedirectToPage method generates a RedirectToPageResult with the generated URL.

You can use a similar method, `RedirectToAction`, to automatically redirect to an MVC action instead. Just as with the `Page` and `Action` methods, it is the *destination* that controls whether you need to use `RedirectToPage` or `RedirectToAction`. `RedirectToAction` is only necessary if you're using MVC controllers to generate HTML instead of Razor Pages.

> **TIP** I recommend you use Razor Pages instead of MVC controllers for HTML generation. For a discussion on the benefits of Razor Pages, refer to chapter 4.

As well as generating URLs from your Razor Pages and MVC controllers, you'll often find you need to generate URLs when building HTML in your views. This is necessary in order to provide navigation links in your web application. You'll see how to achieve this when we look at Razor Tag Helpers in chapter 8.

If you need to generate URLs from parts of your application outside of the Razor Page or MVC infrastructure, then you won't be able to use the `IUrlHelper` helper or an `ActionResult`. Instead, you can use the `LinkGenerator` class.

5.5.4 Generating URLs from other parts of your application

If you're writing your Razor Pages and MVC controllers following the advice from chapter 4, then you should be trying to keep your Razor Pages relatively simple. That requires you to execute your application's business and domain logic in separate classes and services.

For the most part, the URLs your application uses *shouldn't* be part of your domain logic. That makes it easier for your application to evolve over time, or even change completely. For example, you may want to create a mobile application that reuses the same business logic for an ASP.NET Core app. In that case, using URLs in the business logic wouldn't make sense, as they wouldn't be correct when the logic is called from the mobile app!

> **TIP** Where possible, try to keep knowledge of the "front-end" application design out of your business logic. This pattern is known generally as the Dependency Inversion principle.[19]

Unfortunately, sometimes that separation is not possible, or it makes things significantly more complicated. One example might be when you're creating emails in a background service—it's likely you'll need to include a link to your application in the email. The `LinkGenerator` class lets you generate that URL, so that it updates automatically if the routes in your application change.

The `LinkGenerator` class is available in any part of your application, so you can use it inside middleware and any other services. You can use it from Razor Pages and MVC too if you wish, but the `IUrlHelper` available is typically easier and hides some details of using the `LinkGenerator`.

`LinkGenerator` has various methods for generating URLs, such as `GetPathByPage`, `GetPathByAction`, and `GetUriByPage` as shown in the listing below. There are some subtleties to using these methods, especially in complex middleware pipelines, so stick to the `IUrlHelper` where possible, and be sure to consult the documentation[20] if you have problems.

Listing 5.5 Generating URLs using the LinkGeneratorClass

```
public class CurrencyModel : PageModel
{
    private readonly LinkGenerator _link;                     #A
    public CurrencyModel(LinkGenerator linkGenerator)         #A
    {                                                         #A
        _link = linkGenerator;                                #A
    }                                                         #A

    public void OnGet ()
    {
        var url1 = Url.Page("Currency/View", new { id = 5 }); #B
        var url3 = _link.GetPathByPage(                       #C
                       HttpContext,                           #C
                       "/Currency/View",                      #C
                       values: new { id = 5 });               #C
        var url2= _link.GetPathByPage(                        #D
                      "/Currency/View",                       #D
                      values: new { id = 5 });                #D
        var url4 = _link.GetUriByPage(                        #E
                       page: "/Currency/View",                #E
                       handler: null,                         #E
                       values: new { id = 5 },                #E
```

[19] Steve Smith maintains a project template that applies this pattern rigorously, called the Clean Architecture. You can find the template, along with many useful links and books on the topic here: https://github.com/ardalis/CleanArchitecture.

[20] https://docs.microsoft.com/en-us/aspnet/core/fundamentals/routing#url-generation-with-linkgenerator

```
                        scheme: "https",                          #E
                        host: new HostString("example.com"));     #E
    }
}
```

#A LinkGenerator can be accessed using dependency injection
#B Url can generate relative paths to using Url.Page. You can use relative or absolute Page paths.
#C GetPathByPage is equivalent to Url.Page when you pass in HttpContext. Can't use relative paths
#D Other overloads don't require an HttpContext
#E GetUriByPage generates an absolute URL instead of a relative URL

Whether you're generating URLs using the `IUrlHelper` or `LinkGenerator` you need to be careful when using the route generation methods. Make sure you provide the correct Razor Page path, and any necessary route parameters. If you get something wrong—have a type in your path or forgot to include a required route parameter, for example—then the URL generated will be `null`. It's worth checking the generated URL for `null` explicitly, just to be sure there's not problems!

So far in this chapter we've looked extensively at how incoming requests are routed to Razor Pages, but we haven't really seen where page handlers come into it. In the next section we look at page handlers and how your can have multiple handlers on a Razor Page.

5.6 Selecting a page handler to invoke

At the start of this chapter I said routing was about mapping URLs to a *handler*. For Razor Pages, that means a *page handler*, but so far, we've only been talking about routing based on a Razor Page's route template. In this section you'll learn how the `EndpointMiddleware` selects which page handler to invoke when it executes a Razor Page.

You learned about page handlers in chapter 4, and their role within Razor Pages, but we haven't discussed how a page handler is *selected* for a given request. Razor Pages can have multiple handlers, so if the `RoutingMiddleware` selects a Razor Page, the `EndpointMiddleware` still needs to know a way to choose which handler to execute.

Consider the Razor Page `PageModel` shown in the listing below. This Razor Page has three handlers `OnGet`, `OnPostAsync`, and `OnPostCustomSearch`. The body of the handler methods aren't shown, as, at this point, we're only interested in how the `RoutingMiddleware` chooses which handler to invoke.

Listing 5.6 Razor Page with multiple page handlers

```
public class SearchModel : PageModel
{
    public void OnGet()                  #A
    {
        // Handler implementation
    }

    public Task OnPostAsync()             #B
    {
        // Handler implementation
    }
    public void OnPostCustomSearch()      #C
    {
        // Handler implementation
    }
}
```

#A Handles GET requests.
#B Handles POST requests. The async suffix is optional, and is ignored for routing purposes.
#C Handles POST requests where the handler route value has the value CustomSearch

Razor Pages can contain any number of page handlers, but only one runs in response to a given request. When the `EndpointMiddleware` executes a selected Razor Page, it selects a page handler to invoke based on two variables:

- The HTTP verb used in the request (for example `GET`, `POST`, or `DELETE`)
- The value of the `handler` route value.

The `handler` route value typically comes from a query string value in the request URL, for example `/Search?handler=CustomSearch`. If you don't like the look of query strings (I don't!) you can include the `{handler}` route parameter in your Razor Page's route template. For example, for the Search page in listing 5.6, you could update the page's directive to

```
@page "{handler}"
```

This would give a complete route template something like `"Search/{handler}"`, which would match URLs such as `/Search/CustomSearch`.

The `EndpointMiddleware` uses the handler route value and the HTTP verb together with a standard naming convention to identify which page handler to execute, as shown in figure 5.10. The handler parameter is optional, and typically provided as part of the request's query string or as a route parameter, as described above. The async suffix is also optional and is often used when the handler uses asynchronous programming constructs such as `Task` or `async`/`await`[21].

[21] The async suffix naming convention is suggested by Microsoft, though it is unpopular with some developers. NServiceBus provide a reasoned argument against it here (along with Microsoft's advice): https://docs.particular.net/nservicebus/upgrades/5to6/async-suffix.

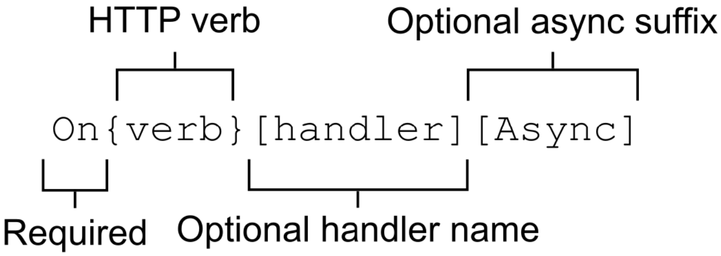


Figure 5.10 Razor Page handlers are matched to a request based on the HTTP verb and the optional handler parameter.

Based on this convention, we can now identify what type of request each page handler in listing 5.6 corresponds to:

- `OnGet`—Invoked for `GET` requests that don’t specify a `handler` value.
- `OnPostAsync`—Invoked for `POST` requests that don’t specify a `handler` value. Returns a `Task` so uses the `Async` suffix, which is ignored for routing purposes.
- `OnPostCustomSearch`—Invoked for `POST` requests that specify a `handler` value of `"CustomSearch"`.

The Razor Page in listing 5.6 specifies three handlers, so it can handle only three verb-handler pairs. But what happens if you get a request that doesn’t match these? Such as a request using the `DELETE` verb, a `GET` request with a non-blank `handler` value, or a `POST` request with an unrecognized `handler` value?

For all these cases, the `EndpointMiddleware` executes an *implicit* page handler instead. Implicit page handlers contain no logic, they just render the Razor view. For example, if you sent a `DELETE` request to the Razor Page in listing 5.6, an implicit handler would be executed. The implicit page handler is equivalent to the following handler code:

```
public void OnDelete() { }
```

> **DEFINITION** If a page handler does not match a request’s HTTP verb and handler value, an *implicit* page handler is executed which renders the associated Razor view. Implicit page handlers take part in model binding and use page filter but execute no logic.

There’s one exception to the implicit page handler rule: if a request uses the `HEAD` verb, and there is no corresponding `OnHead` handler, Razor Pages will execute the `OnGet` handler instead (if it exists).[22]

[22] HEAD requests are typically sent automatically by the browser, and don’t return a response body. They’re often used for security purposes, as you’ll see in chapter 18.

At this point we’ve covered mapping request URLs to Razor Pages, and generating URLs using the routing infrastructure, but most of the URLs we’ve been using have been kind of ugly. If seeing capital letters in your URLs bothers you, then the next section is for you. In the next section we customize the conventions your application uses to generate route templates.

5.7 Customizing conventions with Razor Pages

Razor Pages is built on a series of conventions that are designed to reduce the amount of boilerplate code you need to write. In this section you’ll see some of the ways you can customize those conventions. By customizing the conventions Razor Pages uses in your application you get full control over your application’s URLs without having to manually customize every Razor Page’s route template.

By default, ASP.NET Core generates URLs that match the file names of your Razor Pages very closely. For example, the Razor Page located at the path Pages/Products/ProductDetails.cshtml, would correspond to the route template `Products/ProductDetails`.

These days, it’s not very common to see capital letters in URLs. Similarly, words in URLs are usually separated using “kebab-case” rather than “PascalCase”, for example `product-details` instead of `ProductDetails`. Finally, it’s also common to ensure your URLs always end with a trailing slash, for example `/product-details/` instead of `/product-details`. Razor Pages gives you complete control over the conventions your application uses to generate route templates, but these are two common changes I make.

The following listing shows how to ensure URLs are always lowercase, and that they always have a trailing slash. You can change these conventions by configuring a `RouteOptions` object in Startup.cs. This object contains configuration for the whole ASP.NET Core routing infrastructure, so any changes you make will apply to both Razor Pages and MVC. You’ll learn more about configuring options in chapter 10.

Listing 5.7 Configuring routing conventions using `RouteOptions` in Startup.cs

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddRazorPages();                              #A
    services.Configure<RouteOptions>(options =>            #B
    {
        options.AppendTrailingSlash = true;                #C
        options.LowercaseUrls = true;                      #C
        options.LowercaseQueryStrings = true;              #C
    });
}
```

#A Add the standard Razor Pages services
#B Configure the RouteOptions object after by providing a configuration method
#C You can change the conventions used to generate URLs. By default, these properties are false.

To use kebab-case for your application, annoyingly you must create a custom parameter transformer. This is a somewhat advanced topic, but it’s relatively simple to implement in this case. The listing below shows how you can create a parameter transformer that uses a Regular Expression to replace PascalCase values in a generated URL with kebab-case

Listing 5.8 Creating a kebab-case parameter transformer

```
public class KebabCaseParameterTransformer                  #A
    : IOutboundParameterTransformer                         #A
{
    public string TransformOutbound(object value)
    {
        if (value == null) return null;                      #B

        return Regex.Replace(value.ToString(),               #C
            "([a-z])([A-Z])", "$1-$2").ToLower();            #C
    }
}
```

#A Create a class that implements the parameter transformer interface
#B Guard against null values to avoid runtime exceptions
#C The regular expression replaces PascalCase patterns with kebab-case

You can register the parameter transformer in your application with the `AddRazorPagesOptions` extension method in Startup.cs. This method is chained after the `AddRazorPages` method and can be used to completely customize the conventions used by Razor Pages. The listing below shows how to register the kebab-case transformer. It also shows how to add an extra page route convention for a given Razor Page.

Listing 5.9 Registering a parameter transformer using `RazorPagesOptions`

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddRazorPages()
        .AddRazorPagesOptions(opts =>                                  #A
        {
            opts.Conventions.Add(                                      #B
                new PageRouteTransformerConvention(                    #B
                    new KebabCaseParameterTransformer()));             #B
            opts.Conventions.AddPageRoute(                             #C
                "/Search/Products/StartSearch", "/search-products");   #C
        });
}
```

#A AddRazorPagesOptions can be used to customize the conventions used by Razor Pages.
#B Registers the parameter transformer as a convention used by all Razor Pages.
#C AddPageRoute adds an additional route template to Pages//Search/Products/StartSearch.cshtml.

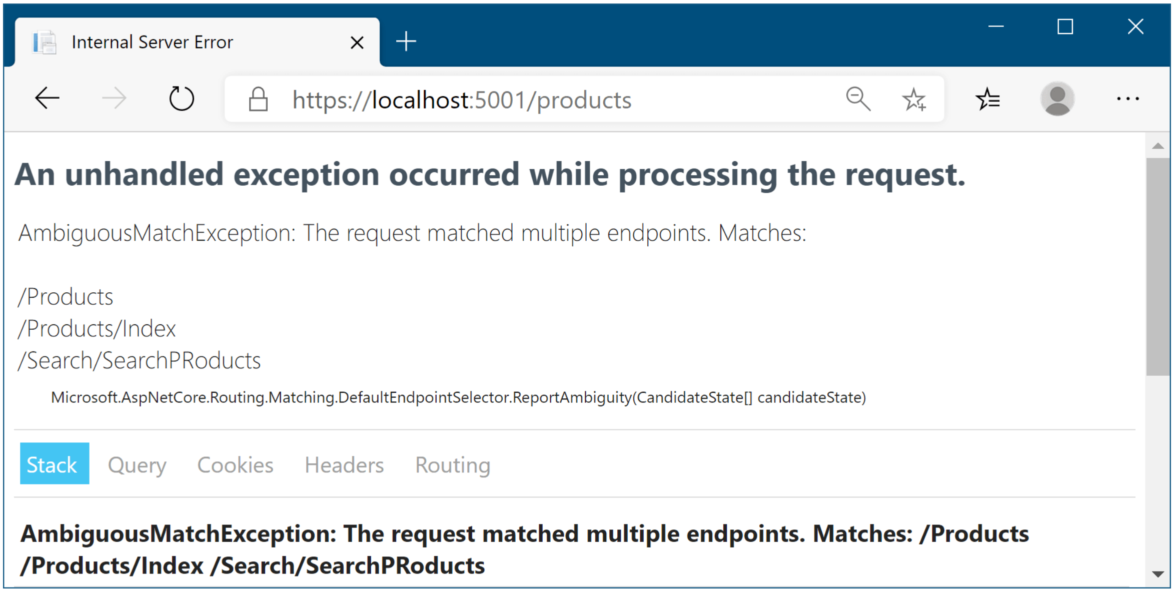
The `AddPageRoute` convention adds an alternative way to execute a single Razor Page. Unlike when you customize the route template for a Razor Page using the `@page` directive, using `AddPageRoute` *adds an extra route template* to the page instead of replacing the default. That means there are two route templates that can access the page.

There are many other ways you can customize the conventions for your Razor Pages applications, but most of the time that's not necessary. If you do find you need to customize all the pages in your application in some way, for example to add an extra header to every page's response, you can use a custom convention. The documentation contains details on everything that's available: https://docs.microsoft.com/en-us/aspnet/core/razor-pages/razor-pages-conventions.

Conventions are a key feature of Razor Pages and you should lean on them whenever you can. While you *can* manually override the route templates for individual Razor Pages, as you've seen in previous sections, I advise against it where possible. In particular:

- **Avoid** replacing the route template with an absolute path in a page's `@page` directive.
- **Avoid** adding literal segments to the `@page` directive. Rely on the file hierarchy instead.
- **Avoid** adding additional route templates to a Razor Page with the `AddPageRoute` convention. Having multiple ways to access a page can sometimes be confusing.
- **Do** add route parameters to the `@page` directive to make your routes dynamic, for example `@page {name}`.
- **Do** consider using global conventions when you want to change the route templates for all your Razor Pages, for example using kebab-case as you saw in the previous section.

In a nutshell, these rules amount to "stick to the conventions". The danger, if you don't, is that you accidentally create two Razor Pages that have overlapping route templates. Unfortunately, if you end up in that situation, you won't get an error at compile time. Instead, you'll get an exception at runtime when your application receives a request that matches multiple route template, as shown in figure 5.11.



An unhandled exception occurred while processing the request.

AmbiguousMatchException: The request matched multiple endpoints. Matches:

/Products
/Products/Index
/Search/SearchPRoducts

Microsoft.AspNetCore.Routing.Matching.DefaultEndpointSelector.ReportAmbiguity(CandidateState[] candidateState)

AmbiguousMatchException: The request matched multiple endpoints. Matches: /Products /Products/Index /Search/SearchPRoducts

Figure 5.11 If multiple Razor Pages are registered with overlapping route templates, you'll get an exception at runtime when the router can't work out which one to select.

Congratulations, you’ve made it all the way through this detailed discussion on routing! Routing is one of those topics that people often get stuck on when they come to building an application, which can be frustrating. You’ll revisit routing again when I describe how to create Web APIs in chapter 9, but rest assured, you’ve already covered all the tricky details in this chapter!

In chapter 6, we’ll dive into model binding. You’ll see how the route values generated during routing are bound to your action method parameters, and perhaps more importantly, how to validate the values you’re provided.

5.8 Summary

- Routing is the process of mapping an incoming request URL to a Razor Page that will execute to generate a response. You can use routing to decouple your URLs from the files in your project and to have multiple URLs map to the same Razor Page.
- ASP.NET Core uses two pieces of middleware for routing. The `EndpointRoutingMiddleware` is added in Startup.cs by calling `UseRouting()` and the `EndpointMiddleware` is added by calling `UseEndpoints()`.
- The `EndpointRoutingMidleware` selects which endpoint should be executed by using routing to match the request URL. The `EndpointMiddleware` executes the endpoint.
- Any middleware placed between the calls to `UseRouting()` and `UseEndpoints()` can tell which endpoint will be executed for the request.
- Route templates define the structure of known URLs in your application. They’re strings with placeholders for variables that can contain optional values and map to Razor Pages or to MVC controller actions.
- Route parameters are variable values extracted from a request’s URL.
- Route parameters can be optional and can have default values used when they’re missing.
- Route parameters can have constraints that restrict the possible values allowed. If a route parameter doesn’t match its constraints, the route isn’t considered a match.
- Don’t use route constraints as general input validators. Use them to disambiguate between two similar routes.
- Use a catch-all parameter to capture the remainder of a URL into a route value.
- You can use the routing infrastructure to generate internal URLs for your application.
- The `IUrlHelper` can be used to generate URLs as a string based on an action name or Razor Page.
- You can use the `RedirectToAction` and `RedirectToPage` methods to generate URLs while also generating a redirect response.
- The `LinkGenerator` can be used to generate URLs from other services in your application, where you don’t have access to an `HttpContext` object.
- When a Razor Page is executed, a single page handler is invoked based on the HTTP verb of the request, and the value of the `handler` route value.

- If there is no page handler for a request, an implicit page handler is used that renders the Razor view.
- You can control the routing conventions used by ASP.NET Core by configuring the `RouteOptions` object, for example to force all URLs to be lowercase, or to always append a trailing slash.
- You can add additional routing conventions for Razor Pages by calling `AddRazorPagesOptions()` after `AddRazorPages()` in Startup.cs. These conventions can control how route parameters are displayed or can add additional route templates for specific Razor Pages.
- Where possible, avoid customizing the route templates for a Razor Page and rely on the conventions instead.

6

The binding model: retrieving and validating user input

This chapter covers

- **Using request values to create binding models**
- **Customizing the model binding process**
- **Validating user input using `DataAnnotations` attributes**

In chapter 5, I showed you how to define a route with parameters—perhaps for the day in a calendar or the unique ID for a product page. But say a user requests a given product page—what then? Similarly, what if the request includes data from a form, to change the name of the product, for example? How do you handle that request and access the values the user provided?

In the first half of this chapter, we look at using *binding models* to retrieve those parameters from the request so that you can use them in your Razor Pages. You'll see how to take the data posted in the form or in the URL and *bind* them to C# objects. These objects are passed to your Razor Page handlers as method parameters or are set as properties on your Razor Page `PageModel`. When your page handler executes, it can use these values to do something useful—return the correct diary entry or change a product's name, for instance.

Once your code is executing in a page handler method, you might be forgiven for thinking that you can happily use the binding model without any further thought. Hold on now, where did that data come from? From a user—you know they can't be trusted! The second half of the chapter focuses on how to make sure that the values provided by the user are valid and make sense for your app.

You can think of the binding models as the *input* to a Razor Page, taking the user's raw HTTP request and making it available to your code by populating "plain old CLR objects"

(POCOs). Once your page handler has run, you're all set up to use the *output* models in ASP.NET Core's implementation of MVC—the view models and API models. These are used to generate a response to the user's request. We'll cover them in chapters 7 and 9.

Before we go any further, let's recap the MVC design pattern and how binding models fit into ASP.NET Core.

6.1 Understanding the models in Razor Pages and MVC

In this section I describe how *binding models* fit into the MVC design pattern we covered in chapter 4. I describe the difference between binding models and the other "model" concepts in the MVC pattern, and how they're each used in ASP.NET Core.

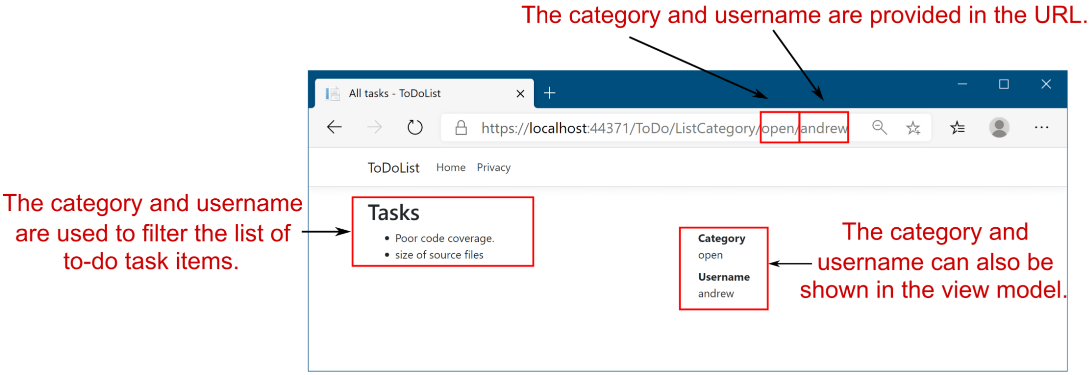
MVC is all about the separation of concerns. The premise is that by isolating each aspect of your application to focus on a single responsibility, it reduces the interdependencies in your system. This separation makes it easier to make changes without affecting other parts of your application.

The classic MVC design pattern has three independent components:

- *Controller*—Calls methods on the model and selects a view.
- *View*—Displays a representation of data that makes up the model.
- *Model*—The data to display and the methods for updating itself.

In this representation, there's only one model, the application model, which represents all the business logic for the application, as well as how to update and modify its internal state. ASP.NET Core has multiple models, which takes the single responsibility principle one step further than some views of MVC.

In chapter 4, we looked at an example of a to-do list application that can show all the to-do items for a given category and username. With this application, you make a request to a URL that's routed using `todo/listcategory/{category}/{username}`. This returns a response showing all the relevant to-do items, as shown in figure 6.1.



https://localhost:44371/ToDo/ListCategory/open/andrew

Tasks

- Poor code coverage.
- size of source files

Category
open

Username
andrew

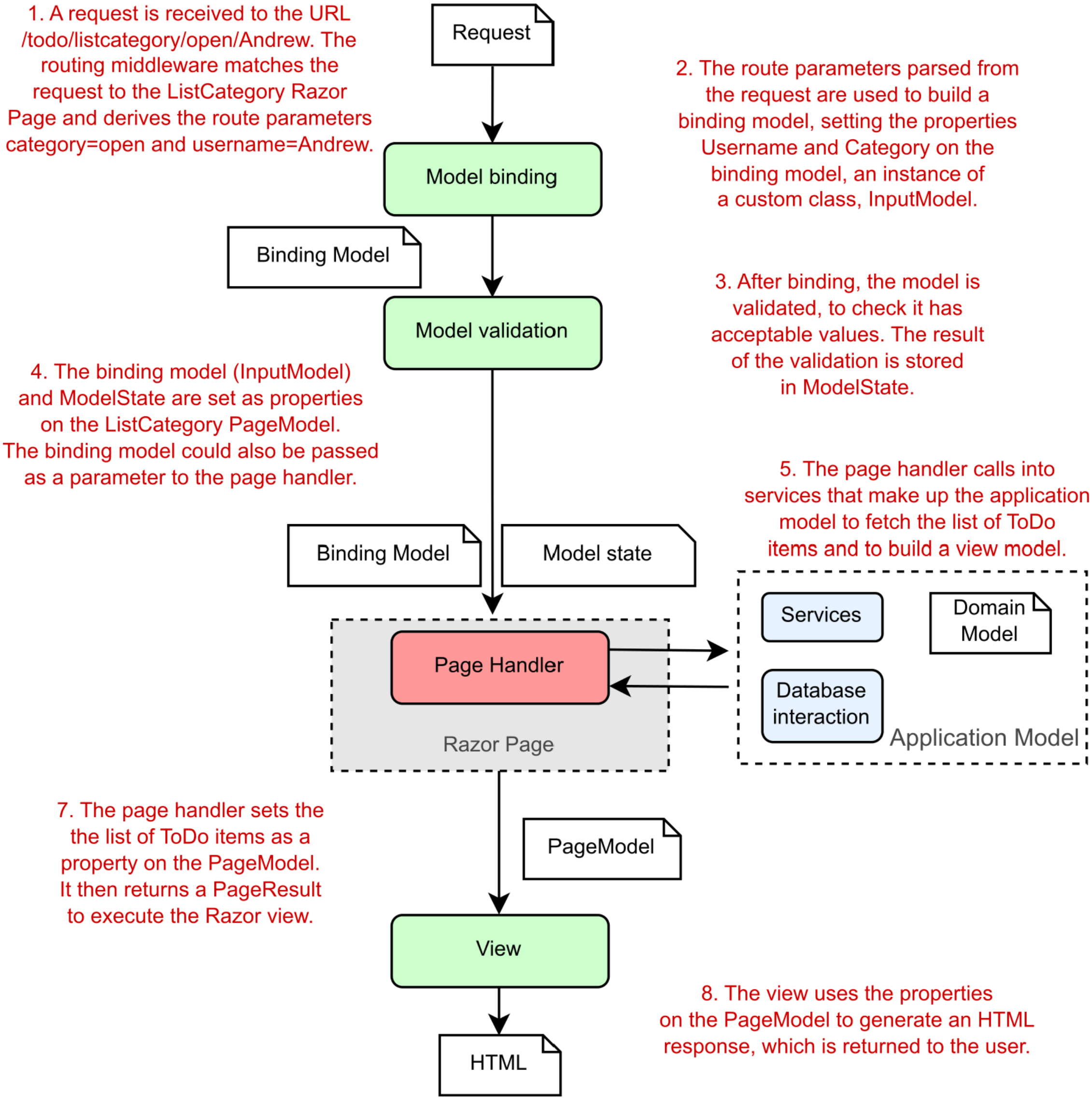
The category and username are provided in the URL.

The category and username are used to filter the list of to-do task items.

The category and username can also be shown in the view model.

Figure 6.1 A basic to-do list application that displays to-do list items. A user can filter the list of items by changing the `category` and `username` parameters in the URL.

The application uses the same MVC constructs you've already seen, such as routing to a Razor Page handler, as well as a number of different *models*. Figure 6.2 shows how a request to this application maps to the MVC design pattern and how it generates the final response, including additional details around the model binding and validation of the request.



1. A request is received to the URL /todo/listcategory/open/Andrew. The routing middleware matches the request to the ListCategory Razor Page and derives the route parameters category=open and username=Andrew.

2. The route parameters parsed from the request are used to build a binding model, setting the properties Username and Category on the binding model, an instance of a custom class, InputModel.

3. After binding, the model is validated, to check it has acceptable values. The result of the validation is stored in ModelState.

4. The binding model (InputModel) and ModelState are set as properties on the ListCategory PageModel. The binding model could also be passed as a parameter to the page handler.

5. The page handler calls into services that make up the application model to fetch the list of ToDo items and to build a view model.

7. The page handler sets the the list of ToDo items as a property on the PageModel. It then returns a PageResult to execute the Razor view.

8. The view uses the properties on the PageModel to generate an HTML response, which is returned to the user.

Figure 6.2 The MVC pattern in ASP.NET Core handling a request to view a subset of items in a to-do list Razor Pages application.

ASP.NET Core Razor Pages uses several different models, most of which are POCOs, and the application model, which is more of a concept around a collection of services. Each of the models in ASP.NET Core is responsible for handling a different aspect of the overall request:

- *Binding model*—The binding model is all the information that's provided by the user when making a request, as well as additional contextual data. This includes things like route parameters parsed from the URL, the query string, and form or JSON data in the request body. The binding model itself is one or more POCO objects that you define. Binding models in Razor Pages are typically defined by creating a public property on the page's `PageModel` and decorating it with the `[BindProperty]` attribute. They can also be passed to a page handler as parameters.

  For this example, the binding model would include the name of the category, `open`, and the username, `Andrew`. The Razor Pages infrastructure inspects the binding model before the page handler executes to check whether the provided values are valid, though the page handler will execute even if they're not, as you'll see when we discuss validation in section 6.3

- *Application model*—The application model isn't really an "ASP.NET Core model" at all. It's typically a whole group of different services and classes, and is more of a "concept"—anything needed to perform some sort of business action in your application. It may include the domain model (which represents the thing your app is trying to describe) and database models (which represent the data stored in a database), as well as any other, additional services.

  In the to-do list application, the application model would contain the complete list of to-do items, probably stored in a database, and would know how to find only those to-do items in the `open` category assigned to `Andrew`.

  Modeling your domain is a huge topic, with many different possible approaches, so it's outside the scope of this book, but we'll touch briefly on creating database models in chapter 11.

- *Page model—The* `PageModel` *of a Razor Page serves two main functions: it acts as the controller for the application by exposing page handler methods, and it acts as the view model for a Razor view. All the data* required for the view to generate a response is exposed on the `PageModel`, such as the list of to-dos in the `open` category assigned to `Andrew`*.*

  The `PageModel` base class that you derive your Razor Pages from contains various helper properties and methods. One of these, the `ModelState` property, contains the result of the model validation as a series of key-value pairs. You'll learn more about validation and the `ModelState` property in section 6.3.

These models make up the bulk of any Razor Pages application, handling the input, business logic, and output of each page handler. Imagine you have an e-commerce application that allows users to search for clothes by sending requests to the URL `/search/{query}` URL, where `{query}` holds their search term:

- *Binding model*—Would take the `{query}` route parameter from the URL and any values posted in the request body (maybe a sort order, or number of items to show), and bind them to a C# class, which typically acts as a "throwaway" data transport class. This would be set as a property on the `PageModel` when the page handler is invoked.

- *Application model*—The services and classes that perform the logic. When invoked by the page handler, this would load all the clothes that match the query, applying the necessary sorting and filters, and return the results back to the controller.
- *Page model*—The values provided by the application model would be set as properties on the Razor Page's `PageModel`, along with other metadata, such as the total number of items available, or whether the user can currently check out. The Razor view would use this data to render the Razor view to HTML.

The important point about all these models is that their responsibilities are well-defined and distinct. Keeping them separate and avoiding reuse helps to ensure your application stays agile and easy to update.

The obvious exception to this separation is the `PageModel`, as it is where the binding models are defined, where the page handlers are defined, and it also holds the data required for rendering the view. Some people may consider the apparent lack of separation to be sacrilege, but in reality, it's not generally an issue. The lines of demarcation are pretty apparent, so as long as you don't try to, for example, invoke a page handler from inside a Razor view then you shouldn't run into any problems!

Now that you've been properly introduced to the various models in ASP.NET Core, it's time to focus on how to use them. This chapter looks at the binding models that are built from incoming requests—how are they created, and where do the values come from?

6.2 From request to model: making the request useful

In this section you will learn

- How ASP.NET Core creates binding models from a request.
- How to bind simple types, like `int` and `string`, as well as complex classes.
- How to choose which parts of a request are used in the binding model.

By now, you should be familiar with how ASP.NET Core handles a request by executing a page handler on a Razor Page. You've also already seen several page handlers, such as

```
public void OnPost(ProductModel product)
```

Page handlers are normal C# methods, so the ASP.NET Core framework needs to be able to call them in the usual way. When page handlers accept parameters as part of their method signature, such as `product` in the preceding example, the framework needs a way to generate those objects. Where exactly do they come from, and how are they created?

I've already hinted that in most cases, these values come from the request itself. But the HTTP request that the server receives is a series of strings—how does ASP.NET Core turn that into a .NET object? This is where *model binding* comes in.

DEFINITION *Model binding* extracts values from a request and uses them to create .NET objects. These objects are passed as method parameters to the page handler being executed or are set as properties of the `PageModel` that are marked with the `[BindProperty]` attribute.

The model binder is responsible for looking through the request that comes in and finding values to use. It then creates objects of the appropriate type and assigns these values to your model in a process called *binding*.

NOTE Model binding in Razor Pages and MVC is a one-way population of objects from the request, not the two-way databinding that desktop or mobile development sometimes uses.

Any properties on your Razor Page's `PageModel` (in the cshtml.cs file for your Razor Page), that are decorated with the `[BindProperty]` attribute, are created from the incoming request using model binding, as shown in the listing below. Similarly, if your page handler method has any parameters, these are also created using model binding.

Listing 6.1 Model binding requests to properties in a Razor Page

```
public class IndexModel: PageModel
{
    [BindProperty]                                 #A
    public string Category { get; set; }           #A

    [BindProperty(SupportsGet = true)]             #B
    public string Username { get; set; }           #B

    public void OnGet()
    {
    }

    public void OnPost(ProductModel model)     #C
    {
    }
}
```

#A Properties decorated with [BindProperty] take part in model binding
#B Properties are not model bound for GET requests, unless you use SupportsGet
#C Parameters to page handlers are also model bound when that handler is selected

As shown in the previous listing, `PageModel` properties are *not* model bound for `GET` requests, even if you add the `[BindProperty]` attribute. For security reasons, only requests using verbs like `POST` and `PUT` are bound. If you *do* want to bind `GET` requests, then you can set the `SupportsGet` property on the `[BindProperty]` attribute to opt-in to model binding.

TIP To bind `PageModel` properties for `GET` requests, use the `SupportsGet` property of the attribute, for example `[BindProperty(SupportsGet = true)]`.

Which part is the binding model

Listing 6.1 shows a Razor Page that uses multiple "binding models": the `Category` property, the `Username` property, and the `ProductModel` property (in the `OnPost` handler) are all model bound.

Using multiple models in this way is fine, but I prefer to use an approach that keeps all the model binding in a single, nested, class, which I often call `InputModel`. With this approach, the Razor Page in listing 6.1 could be written as:

```
public class IndexModel: PageModel
{
    [BindProperty]
    public InputModel Input { get; set; }
    public void OnGet()
    {
    }

    public class InputModel
    {
        public string Category { get; set; }
        public string Username { get; set; }
    }
}
```

This approach has some organizational benefits that you'll learn more about in section 6.4.

ASP.NET Core automatically populates your binding models for you using properties of the request, such as the request URL, any headers sent in the HTTP request, any data explicitly POSTed in the request body, and so on.

By default, ASP.NET Core uses three different *binding sources* when creating your binding models. It looks through each of these in order and takes the first value it finds (if any) that matches the name of the binding model:

- *Form values*—Sent in the body of an HTTP request when a form is sent to the server using a POST.
- *Route values*—Obtained from URL segments or through default values after matching a route, as you saw in chapter 5.
- *Query string values*—Passed at the end of the URL, not used during routing.

The model binding process is shown in figure 6.3. The model binder checks each binding source to see if it contains a value that could be set on the model. Alternatively, the model can also choose the specific source the value should come from, as you'll see in section 6.2.3. Once each property is bound, the model is validated and is set as a property on the `PageModel` or is passed as a parameter to the page handler. You'll learn about the validation process in the second half of this chapter.

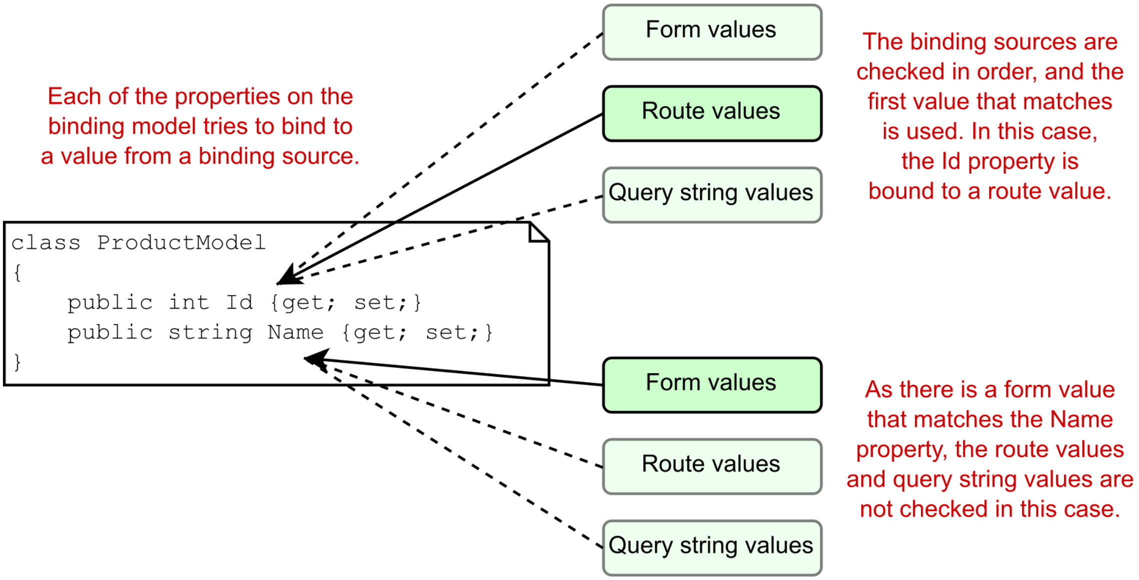

Each of the properties on the binding model tries to bind to a value from a binding source.
class ProductModel
{
public int Id {get; set;}
public string Name {get; set;}
}
Form values
Route values
Query string values
The binding sources are checked in order, and the first value that matches is used. In this case, the Id property is bound to a route value.
Form values
Route values
Query string values
As there is a form value that matches the Name property, the route values and query string values are not checked in this case.

Figure 6.3 Model binding involves mapping values from binding sources, which correspond to different parts of a request.

`PageModel` properties or page handler parameters?

There are two different ways to use model binding in Razor Pages:

- Decorate properties on your `PageModel` with the `[BindProperty]` attribute.
- Add parameters to your page handler method.

Which of these approaches should you choose?

This answer to this question is largely a matter of taste. Setting properties on the `PageModel` and marking them with `[BindProperty]` is the approach you'll see most often in examples. If you use this approach, you'll be able to access the binding model when the view is rendered, as you'll see in chapters 7 and 8.

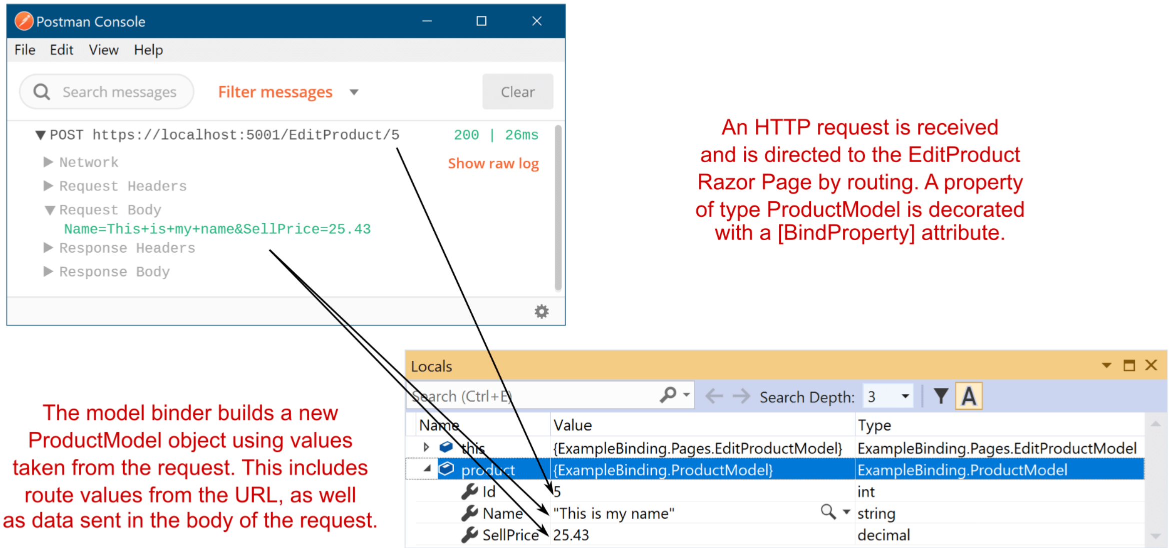
The alternative approach, adding parameters to page handler methods, provides more separation between the different MVC stages, because you won't be able to access the parameters outside of the page handler. On the downside, if you *do* need to display those values in the Razor view, you'll have to manually copy the parameters across to properties that *can* be accessed in the view.

The approach I choose tends to depend on the specific Razor Page I'm building. If I'm creating a form, I will favor the `[BindProperty]` approach, as I typically need access to the request values inside the Razor view. For simple pages, where the binding model is a product ID for example, I tend to favor the page handler parameter approach for its simplicity, especially if the handler is for a `GET` request. I give some more specific advice on my approach in section 6.4.

Figure 6.4 shows an example of a request creating the `ProductModel` method argument using model binding for the example shown at the start of this section:

```
public void OnPost(ProductModel product)
```

The `Id` property has been bound from a URL route parameter, but the `Name` and `SellPrice` properties have been bound from the request body. The big advantage of using model binding is that you don't have to write the code to parse requests and map the data yourself. This sort of code is typically repetitive and error-prone, so using the built-in conventional approach lets you focus on the important aspects of your application: the business requirements.



```
▼POST https://localhost:5001/EditProduct/5          200 | 26ms
   ▼Request Body
     Name=This+is+my+name&SellPrice=25.43
```

Name	Value	Type
this	{ExampleBinding.Pages.EditProductModel}	ExampleBinding.Pages.EditProductModel
product	{ExampleBinding.ProductModel}	ExampleBinding.ProductModel
Id	5	int
Name	"This is my name"	string
SellPrice	25.43	decimal

An HTTP request is received and is directed to the EditProduct Razor Page by routing. A property of type ProductModel is decorated with a [BindProperty] attribute.

The model binder builds a new ProductModel object using values taken from the request. This includes route values from the URL, as well as data sent in the body of the request.

Figure 6.4 Using model binding to create an instance of a model that's used to execute a Razor Page.

TIP **Model binding is great for reducing repetitive code. Take advantage of it whenever possible and you'll rarely find yourself having to access the** `Request` **object directly.**

If you need to, the capabilities are there to let you completely customize the way model binding works, but it's relatively rare that you'll find yourself needing to dig too deep into this. For the majority of cases it works as-is, as you'll see in the remainder of this section.

6.2.1 Binding simple types

You'll start your journey into model binding by considering a simple Razor Page handler. The next listing shows a simple Razor Page that takes one number as a method parameter and squares it by multiplying the number by itself.

Listing 6.2 A Razor Page accepting a simple parameter

```
public class CalculateSquareModel : PageModel
{
    public void OnGet(int number)                 #A
    {
        Square = number * number;                 #B
    }

    public int Square { get; set; }               #C

}
```

#A The method parameter is the binding model.
#B A more complex example would do this work in an external service, in the application model.
#C The result is exposed as a property, and is used by the view to generate a response.

In the last chapter, you learned about routing, and how it selects a Razor Page to execute. You can update the route template for the Razor Page to be "`CalculateSquare/{number}`" by adding a `{number}` segment to the Razor Page's `@page` directive in the cshtml file, as we discussed in chapter 5:

```
@page "{number}"
```

When a client requests the URL `/CalculatorSquare/5`, the Razor Page framework uses routing to parse it for route parameters. This produces the route value pair:

```
number=5
```

The Razor Page's `OnGet` page handler contains a single parameter—an integer called `number`—which is your binding model. When ASP.NET Core executes this page handler method, it will spot the expected parameter, flick through the route values associated with the request, and find the `number=5` pair. It can then bind the `number` parameter to this route value and execute the method. The page handler method itself doesn't care about where this value came from; it goes along its merry way, calculating the square of the value, and setting it on the `Square` property.

The key thing to appreciate is that you didn't have to write any extra code to try to extract the `number` from the URL when the method executed. All you needed to do was create a method parameter (or public property) with the right name and let model binding do its magic.

Route values aren't the only values the model binder can use to create your binding models. As you saw previously, the framework will look through three default *binding sources* to find a match for your binding models:

- Form values
- Route values
- Query string values

Each of these binding sources store values as name-value pairs. If none of the binding sources contain the required value, then the binding model is set to a new, default, instance of the type instead. The exact value the binding model will have in this case depends on the type of the variable:

- For value types, the value will be `default(T)`. For an `int` parameter this would be `0`, and for a `bool` it would be `false`.
- For reference types, the type is created using the default constructor. For custom types like `ProductModel`, that will create a new object. For nullable types like `int?` or `bool?`, the value will be `null`.
- For string types, the value will be `null`.

> **WARNING** **It's important to consider the behavior of your page handler when model binding fails to bind your method parameters. If none of the binding sources contain the value, the value passed to the method could be `null`, or have an unexpected default value.**

Listing 6.2 showed how to bind a *single* method parameter. Let's take the next logical step and look at how you'd bind *multiple* method parameters.

In the previous chapter, we discussed routing for building a currency converter application. As the next step in your development, your boss asks you to create a method in which the user provides a value in one currency and you must convert it to another. You first create a Razor Page called Convert.cshtml, and customize the route template for the page using the `@page` directive to use an absolute path containing two route values:

```
@page "/{currencyIn}/{ currencyOut}"
```

You then create a page handler that accepts the three values you need, as shown in the listing below.

Listing 6.3 A Razor Page handler accepting multiple binding parameters

```
public class ConvertModel : PageModel
{
    public void OnGet(
        string currencyIn,
        string currencyOut,
        int qty
)
    {
        /* method implementation */
    }
}
```

As you can see, there are three different parameters to bind. The question is, where will the values come from and what will they be set to? The answer is, it depends! Table 6.1 shows a whole variety of possibilities. All these examples use the same route template and page handler, but depending on the data sent, different values will be bound. The actual values might differ from what you expect, as the available binding sources offer conflicting values!

Table 6.1 Binding request data to page handler parameters from multiple binding sources

URL (route values)	HTTP body data (form values)	Parameter values bound

/GBP/USD		currencyIn=GBP
		currencyOut=USD qty=0

/GBP/USD?currencyIn=CAD	QTY=50	currencyIn=GBP
		currencyOut=USD qty=50

/GBP/USD?qty=100	qty=50	currencyIn=GBP
		currencyOut=USD qty=50

/GBP/USD?qty=100	currencyIn=CAD&
	currencyOut=EUR& qty=50
		currencyIn=CAD
		currencyOut=EUR qty=50

For each example, be sure you understand *why* the bound values have the values that they do. In the first example, the qty value isn't found in the form data, in the route values, or in the query string, so it has the default value of 0. In each of the other examples, the request contains one or more duplicated values; in these cases, it's important to bear in mind the order in which the model binder consults the binding sources. By default, form values will take precedence over other binding sources, including route values!

> **NOTE** **The default model binder isn't case sensitive, so a binding value of** QTY=50 **will happily bind to the** qty **parameter.**

Although this may seem a little overwhelming, it's relatively unusual to be binding from all these different sources at once. It's more common to have your values all come from the request body as form values, maybe with an ID from URL route values. This scenario serves as more of a cautionary tale about the knots you can twist yourself into if you're not sure how things work under the hood!

In these examples, you happily bound the qty integer property to incoming values, but as I mentioned earlier, the values stored in binding sources are all strings. What types can you convert a string to? The model binder will convert pretty much any primitive .NET type such as int, float, decimal (and string obviously), plus anything that has a TypeConverter.[23] There are a few other special cases that can be converted from a string, such as Type, but thinking of it as primitives only will get you a long way there!

[23] TypeConverters can be found in the System.ComponentModel.TypeConverter package. You can read more about them here: https://docs.microsoft.com/en-us/dotnet/standard/base-types/type-conversion#the-typeconverter-class.

6.2.2 Binding complex types

If it seems like only being able to bind simple primitive types is a bit limiting, then you're right! Luckily, that's not the case for the model binder. Although it can only convert strings *directly* to those primitive types, it's also able to bind complex types by traversing any properties your binding models expose.

In case this doesn't make you happy straight off the bat, let's look at how you'd have to build your page handlers if simple types were your only option. Imagine a user of your currency converter application has reached a checkout page and is going to exchange some currency. Great! All you need now is to collect their name, email, and phone number. Unfortunately, your page handler method would have to look something like this:

```
public IActionResult OnPost(string firstName, string lastName, string phoneNumber, string
       email)
```

Yuck! Four parameters might not seem that bad right now, but what happens when the requirements change and you need to collect other details? The method signature will keep growing. The model binder will bind the values quite happily, but it's not exactly clean code. Using the `[BindProperty]` approach doesn't really help either—we still have to clutter up our `PageModel` with lots of properties and attributes!

SIMPLIFYING METHOD PARAMETERS BY BINDING TO COMPLEX OBJECTS

A common pattern for any C# code when you have many method parameters is to extract a class that encapsulates the data the method requires. If extra parameters need to be added, you can add a new property to this class. This class becomes your binding model and might look something like this.

Listing 6.4 A binding model for capturing a user's details

```
public UserBindingModel
{
    public string FirstName { get; set; }
    public string LastName { get; set; }
    public string Email { get; set; }
    public string PhoneNumber { get; set; }
}
```

With this model, you can now update your page handler's method signature to

```
public IActionResult OnPost(UserBindingModel user)
```

Or alternatively, using the `[BindProperty]` approach, create a property on the `PageModel`:

```
[BindProperty]
public UserBindingModel User { get; set; }
```

And simplify the page handler signature even further:

```
public IActionResult OnPost()
```

Functionally, the model binder treats this new complex type a little differently. Rather than looking for parameters with a value that matches the parameter name (`user`, or `User` for the property), the model binder create a new instance of the model using `new UserBindingModel()`.

> **NOTE** You don't have to use custom classes for your methods; it depends on your requirements. If your page handler needs only a single integer, then it makes more sense to bind to the simple parameter.

Next, the model binder loops through all the properties your binding model has, such as `FirstName` and `LastName` in listing 6.4, For each of these properties, it consults the collection of binding sources and attempts to find a name-value pair that matches. If it finds one, it sets the value on the property and moves on to the next.

> **TIP** Although the name of the model isn't necessary in this example, the model binder will also look for properties prefixed with the name of the property, such as `user.FirstName` and `user.LastName` for a property called `User`. You can use this approach when you have multiple complex parameters to a page handler, or multiple complex `[BindProperty]` properties. In general, for simplicity, you should avoid this situation if possible.

Once all the properties that can be bound on the binding model are set, the model is passed to the page handler (or the `[BindProperty]` property is set), and the handler is executed as usual. The behavior from this point is identical to when you have lots of individual parameters—you'll end up with the same values set on your binding model—but the code is cleaner and easier to work with.

> **TIP** For a class to be model-bound, it must have a default public constructor. You can only bind properties which are public and settable.

With this technique you can bind complex hierarchical models, whose properties are *themselves* complex models. As long as each property exposes a type that can be model-bound, the binder can traverse it with ease.

BINDING COLLECTIONS AND DICTIONARIES

As well as ordinary custom classes and primitives, you can bind to collections, lists, and dictionaries. Imagine you had a page in which a user selected all the currencies they were interested in; you'd display the rates for all those selected, as shown in figure 6.5.

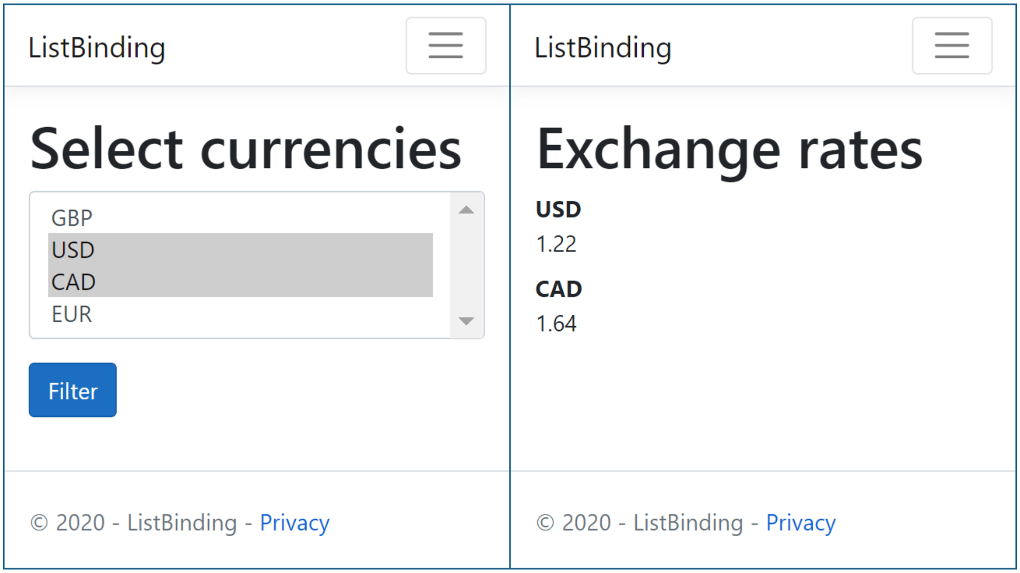


Figure 6.5 The select list in the currency converter application will send a list of selected currencies to the application. Model binding can bind the selected currencies and customize the view for the user to show the equivalent cost in the selected currencies.

To achieve this, you could create a page handler that accepts a `List<string>` type such as:

```
public void OnPost(List<string> currencies);
```

You could then `POST` data to this method by providing values in several different formats:

- `currencies[index]`—Where `currencies` is the name of the parameter to bind and `index` is the index of the item to bind, for example, `currencies[0]=GBR&currencies[1]=USD`.
- `[index]`—If you're only binding to a single list (as in this example), you can omit the name of the parameter, for example, `[0]=GBR&[1]=USD`.
- `currencies`—Alternatively, you can omit the `index` and send `currencies` as the key for every value, for example, `currencies=GBR&currencies=USD`.

The key values can come from route values and query values, but it's far more common to `POST` them in a form. Dictionaries can use similar binding, where the dictionary key replaces the index both when the parameter is named and when it's omitted.

If this all seems a bit confusing, don't feel too alarmed. If you're building a traditional web application, and using Razor views to generate HTML, then the framework will take care of generating the correct names for you. As you'll see in chapter 8, the Razor view will ensure that any form data you `POST` will be generated in the correct format.

BINDING FILE UPLOADS WITH IFORMFILE

A common feature of many websites is the ability to upload files. This could be a relatively infrequent activity, for example if a user uploads a profile picture for their Stack Overflow profile, or it may be integral to the application, like uploading photos to Facebook.

Letting users upload files to your application

Uploading files to websites is a pretty common activity, but you should carefully consider whether your application *needs* that ability. Whenever files can be uploaded by users the road is fraught with danger.

You should be careful to treat the incoming files as potentially malicious, don't trust the filename provided, take care of large files being uploaded, and don't allow the files to be executed on your server.

Files also raise questions as to where the data should be stored—should they go in a database, in the filesystem, or some other storage? None of these questions has a straightforward answer and you should think hard about the implications of choosing one over the other. Better yet, if you can avoid it, don't let users upload files!

ASP.NET Core supports uploading files by exposing the `IFormFile` interface. You can use this interface as your binding model, either as a method parameter to your page handler, or using the `[BindProperty]` approach, and it will be populated with the details of the file upload:

```
public void OnPost(IFormFile file);
```

You can also use an `IEnumerable<IFormFile>` if your need to accept multiple files:

```
public void OnPost(IEnumerable<IFormFile> file);
```

The `IFormFile` object exposes several properties and utility methods for reading the contents of the uploaded file, some of which are shown here:

```
public interface IFormFile
{
    string ContentType { get; }
    long Length { get; }
    string FileName { get; }
    Stream OpenReadStream();
}
```

As you can see, this interface exposes a `FileName` property, which returns the filename that the file was uploaded with. But you know not to trust users, right? You should *never* use the filename directly in your code—always generate a new filename for the file before you save it anywhere.

> **WARNING** Never use posted filenames in your code. Users can use them to attack your website and access files they shouldn't be able to.

The `IFormFile` approach is fine if users are only going to be uploading small files. When your method accepts an `IFormFile` instance, the whole content of the file is buffered in memory and on disk before you receive it. You can then use the `OpenReadStream` method to read the data out.

If users post large files to your website, you may find you start to run out of space in memory or on disk, as it buffers each of the files. In that case, you may need to stream the files directly to avoid saving all the data at once. Unfortunately, unlike the model binding approach, streaming large files can be complex and error-prone, so it's outside the scope of this book. For details, see the documentation at http://mng.bz/SH7X.

> **TIP** **Don't use the `IFormFile` interface to handle large file uploads as you may see performance issues. Be aware that you can't rely on users *not* to upload large files, so better yet, avoid file uploads entirely!**

For the vast majority of Razor Pages, the default configuration of model binding for simple and complex types works perfectly well, but you may find some situations where you need to take a bit more control. Luckily, that's perfectly possible, and you can completely override the process if necessary, by replacing the `ModelBinders` used in the guts of the framework.

However, it's rare to need that level of customization—I've found it's more common to want to specify which *binding source* to use for a page's binding model instead.

6.2.3 Choosing a binding source

As you've already seen, by default the ASP.NET Core model binder will attempt to bind your binding models from three different binding sources: form data, route data, and the query string.

Occasionally, you may find it necessary to specifically declare which binding source to bind to. In other cases, these three sources won't be sufficient at all. The most common scenarios are when you want to bind a method parameter to a request header value, or when the body of a request contains JSON-formatted data that you want to bind to a parameter. In these cases, you can decorate your binding models with attributes that say where to bind from, as shown in the listing below.

Listing 6.5 Choosing a binding source for model binding

```
public class PhotosModel: PageModel
{
    public void OnPost(
        [FromHeader] string userId,                  #A
        [FromBody] List<Photo> photos)               #B
    {
        /* method implementation */
    }
}
```

#A The userId will be bound from an HTTP header in the request.
#B The list of photos will be bound to the body of the request, typically in JSON format.

In this example, a page handler updates a collection of photos with a user ID. There are method parameters for the ID of the user to tag in the photos, `userId`, and a list of `Photo` objects to tag, `photos`.

Rather than binding these method parameters using the standard binding sources, I've added attributes to each parameter, indicating the binding source to use. The `[FromHeader]` attribute has been applied to the `userId` parameter. This tells the model binder to bind the value to an HTTP request header value called `userId`.

We're also binding a list of photos to the body of the HTTP request by using the `[FromBody]` attribute. This will read JSON from the body of the request and will bind it to the `List<Photo>` method parameter.

> **WARNING** **Developers familiar with the previous version of ASP.NET should take note that the `[FromBody]` attribute is explicitly required when binding to JSON requests in Razor Pages. This differs from previous ASP.NET behavior, in which no attribute was required.**

You aren't limited to binding JSON data from the request body—you can use other formats too, depending on which `InputFormatter`s you configure the framework to use. By default, only a JSON input formatter is configured. You'll see how to add an XML formatter in chapter 9, when I discuss Web APIs.

You can use a few different attributes to override the defaults and to specify a binding source for each binding model (or each property on the binding model):

- `[FromHeader]`—Bind to a header value
- `[FromQuery]`—Bind to a query string value
- `[FromRoute]`—Bind to route parameters
- `[FromForm]`—Bind to form data posted in the body of the request
- `[FromBody]`—Bind to the request's body content

You can apply each of these to any number of handler method parameters or properties, as you saw in listing 6.5, with the exception of the `[FromBody]` attribute—only one value may be decorated with the `[FromBody]` attribute. Also, as form data is sent in the body of a request, the `[FromBody]` and `[FromForm]` attributes are effectively mutually exclusive.

> **TIP** **Only one parameter may use the `[FromBody]` attribute. This attribute will consume the incoming request as HTTP request bodies can only be safely read once.**

As well as these attributes for specifying binding sources, there are a few other attributes for customizing the binding process even further:

- [BindNever]—The model binder will skip this parameter completely.[24]
- [BindRequired]—If the parameter was not provided, or was empty, the binder will add a validation error.
- [FromServices]—Used to indicate the parameter should be provided using dependency injection (see chapter 10 for details).

In addition, you have the [ModelBinder] attribute, which puts you into "God mode" with respect to model binding. With this attribute, you can specify the exact binding source, override the name of the parameter to bind to, and specify the type of binding to perform. It'll be rare that you need this one, but when you do, at least it's there!

By combining all these attributes, you should find you're able to configure the model binder to bind to pretty much any request data your page handler wants to use. In general, though, you'll probably find you rarely need to use them; the defaults should work well for you in most cases.

That brings us to the end of this section on model binding. If all has gone well, your page handler should have access to a populated binding model, and it's ready to execute its logic. It's time to handle the request, right? Nothing to worry about?

Not so fast! How do you know that the data you received was valid? That you haven't been sent malicious data attempting a SQL injection attack, or a phone number full of letters?

The binder is relatively blindly assigning values sent in a request, which you're happily going to plug into your own methods? What's to stop nefarious little Jimmy from sending malicious values to your application?

Except for basic safeguards, there's nothing stopping him, which is why it's important that you *always* validate the input coming in. ASP.NET Core provides a way to do this in a declarative manner out of the box, which is the focus of the second half of this chapter.

6.3 Handling user input with model validation

In this section I discuss:

- What is validation, and why do you need it?
- Using DataAnnotation attributes to describe the data you expect
- How to validate your binding models in page handlers

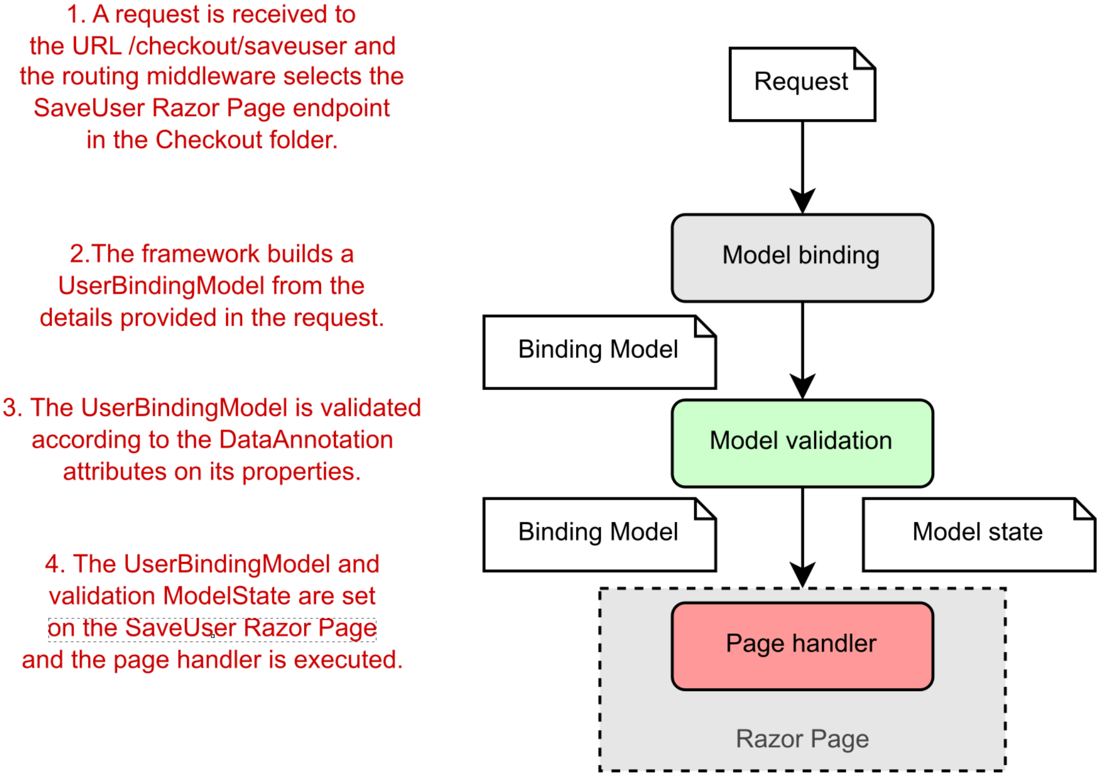
Validation in general is a pretty big topic, and one that you'll need to consider in every app you build. ASP.NET Core makes it relatively easy to add validation to your applications by making it an integral part of the framework.

[24] You can use the [BindNever] attribute to prevent mass assignment, as discussed in these two posts: http://mng.bz/QvfG and https://andrewlock.net/preventing-mass-assignment-or-over-posting-with-razor-pages-in-asp-net-core/.

6.3.1 The need for validation

Data can come from many different sources in your web application—you could load it from files, read it from a database, or you could accept values that a user typed into a form in requests. Although you might be inclined to trust that the data already on your server is valid (though this is sometimes a dangerous assumption!), you *definitely* shouldn't trust the data sent as part of a request.

Validation occurs in the Razor Pages framework after model binding, but before the page handler executes, as you saw in figure 6.2. Figure 6.6 shows a more compact view of where model validation fits in this process, demonstrating how a request to a checkout page that requests a user's personal details is bound and validated.



1. A request is received to the URL /checkout/saveuser and the routing middleware selects the SaveUser Razor Page endpoint in the Checkout folder.

2.The framework builds a UserBindingModel from the details provided in the request.

3. The UserBindingModel is validated according to the DataAnnotation attributes on its properties.

4. The UserBindingModel and validation ModelState are set on the SaveUser Razor Page and the page handler is executed.

Figure 6.6 Validation occurs after model binding but before the page handler executes. The page handler executes whether or not validation is successful.

You should always validate data provided by users before you use it in your methods. You have no idea what the browser may have sent you. The classic example of "little Bobby

Tables" (https://xkcd.com/327/) highlights the need to always validate any data sent by a user.

Validation isn't only to check for security threats, though; it's also needed to check for non-malicious errors, such as:

- Data should be formatted correctly (email fields have a valid email format).
- Numbers might need to be in a particular range (you can't buy -1 copies of this book!).
- Some values may be required but others are optional (name may be required for a profile but phone number is optional).
- Values must conform to your business requirements (you can't convert a currency to itself, it needs to be converted to a difference currency).

It might seem like some of these can be dealt with easily enough in the browser—for example, if a user is selecting a currency to convert to, don't let them pick the same currency; and we've all seen the "please enter a valid email address" messages.

Unfortunately, although this *client-side validation* is useful for users, as it gives them instant feedback, you can never rely on it, as it will *always* be possible to bypass these browser protections. It's always necessary to validate the data as it arrives at your web application, using *server-side validation*.

WARNING **Always validate user input on the server-side of your application.**

If that feels a little redundant, like you'll be duplicating logic and code, then I'm afraid you're right. It's one of the unfortunate aspects of web development; the duplication is a necessary evil. Thankfully, ASP.NET Core provides several features to try to reduce this burden.

TIP **Blazor, the new C# SPA framework promises to solve some of these issues, but it's out of the scope of this book. For details, see https://dotnet.microsoft.com/apps/aspnet/web-apps/blazor and *Blazor in Action* by Chris Sainty (Manning, 2021)**

If you had to write this validation code fresh for every app, it would be tedious and likely error prone. Luckily, you can simplify your validation code significantly using a set of attributes provided by .NET Core.

6.3.2 Using DataAnnotations attributes for validation

Validation attributes, or more precisely `DataAnnotations` attributes, allow you to specify the rules that your binding model should conform to. They provide *metadata* about your model by describing the *sort* of data the binding model should contain, as opposed to the data itself.

DEFINITION ***Metadata*** **describes other data, specifying the rules and characteristics the data should adhere to.**

You can apply DataAnnotations attributes directly to your binding models to indicate the type of data that's acceptable. This allows you to, for example, check that required fields have been provided, that numbers are in the correct range, and that email fields are valid email addresses.

As an example, let's consider the checkout page for your currency converter application. You need to collect details about the user before you can continue, so you ask them to provide their name, email and, optionally, a phone number. The following listing shows the UserBindingModel decorated with validation attributes that represent the validation rules for the model. This expands on the example you saw in listing 6.4.

Listing 6.6 Adding DataAnnotations to a binding model to provide metadata

```
public class UserBindingModel
{
    [Required]                                      //#A
    [StringLength(100)]                             //#B
    [Display(Name = "Your name")]                   //#C
    public string FirstName { get; set; }

    [Required]                                      //#A
    [StringLength(100)]                             //#B
    [Display(Name = "Last name")]                   //#C
    public string LastName { get; set; }

    [Required]                                      //#A
    [EmailAddress]                                  //#D
    public string Email { get; set; }

    [Phone]
    [Display(Name = "Phone number")]                //#C
    public string PhoneNumber { get; set; }
}
```

#A Values marked Required must be provided.
#B The StringLengthAttribute sets the maximum length for the property.
#C Customizes the name used to describe the property
#D Validates the value of Email is a valid email address

Suddenly your binding model contains a whole wealth of information where previously it was pretty sparse on details. For example, you've specified that the FirstName property should always be provided, that it should have a maximum length of 100 characters, and that when it's referred to (in error messages, for example) it should be called "Your name" instead of "FirstName".

The great thing about these attributes is that they clearly declare the *expected* state of the model. By looking at these attributes, you know what the properties will/should contain. They also provide hooks for the ASP.NET Core framework to validate that the data set on the model during model binding is valid, as you'll see shortly.

You've got a plethora of attributes to choose from when applying DataAnnotations to your models. I've listed some of the common ones here, but you can find more in the

System.ComponentModel.DataAnnotations namespace. For a more complete list, I recommend using IntelliSense in Visual Studio/Visual Studio Code, or you can always look at the source code directly on GitHub (https://github.com/dotnet/runtime/tree/master/src/libraries/System.ComponentModel.Annotations).

- [CreditCard]—Validates that a property has a valid credit card format.
- [EmailAddress]—Validates that a property has a valid email address format.
- [StringLength(max)]—Validates that a string has at most max number of characters.
- [MinLength(min)]—Validates that a collection has at least the min number of items.
- [Phone]—Validates that a property has a valid phone number format.
- [Range(min, max)]—Validates that a property has a value between min and max.
- [RegularExpression(regex)]—Validates that a property conforms to the regex regular expression pattern.
- [Url]—Validates that a property has a valid URL format.
- [Required]—Indicates the property must not be null.
- [Compare]—Allows you to confirm that two properties have the same value (for example, Email and ConfirmEmail).

> **WARNING** **The [EmailAddress] and other attributes only validate that the *format* of the value is correct. They don't validate that the email address exists.**[25]

The DataAnnotations attributes aren't a new feature—they have been part of the .NET Framework since version 3.5—and their usage in ASP.NET Core is almost the same as in the previous version of ASP.NET.

They're also used for other purposes, in addition to validation. Entity Framework Core (among others) uses DataAnnotations to define the types of columns and rules to use when creating database tables from C# classes. You can read more about Entity Framework Core in chapter 12, and in Jon P Smith's *Entity Framework Core in Action, Second Edition* (Manning, 2021).

If the DataAnnotation attributes provided out of the box don't cover everything you need, then it's also possible to write custom attributes by deriving from the base ValidationAttribute. You'll see how to create a custom attribute for your currency converter application in chapter 19.

Alternatively, if you're not a fan of the attribute-based approach, ASP.NET Core is flexible enough that you can completely replace the validation infrastructure with your preferred technique. For example, you could use the popular FluentValidation library

[25] The phone number attribute is particularly lenient in the formats it allows. For an example of this, and how to do more rigorous phone number validation, see this post https://www.twilio.com/blog/validating-phone-numbers-effectively-with-c-and-the-net-frameworks.

(https://github.com/JeremySkinner/FluentValidation) in place of the DataAnnotations attributes if you prefer.

> **TIP** DataAnnotations **are good for input validation of properties in isolation, but not so good for validating business rules. You'll most likely need to perform this validation outside the** DataAnnotations **framework.**

Whichever validation approach you use, it's important to remember that these techniques don't protect your application by themselves. The Razor Pages framework will ensure that validation occurs, but it doesn't automatically do anything if validation fails. In the next section, we look at how to check the validation result on the server and handle the case where validation has failed.

6.3.3 Validating on the server for safety

Validation of the binding model occurs before the page handler executes, but note that the handler *always* executes, whether the validation failed or succeeded. It's the responsibility of the page handler to check the result of the validation.

> **NOTE Validation happens automatically but handling validation failures is the responsibility of the page handler.**

The Razor Pages framework stores the output of the validation attempt in a property on the PageModel called ModelState. This property is a ModelStateDictionary object, which contains a list of all the validation errors that occurred after model binding, as well as some utility properties for working with it.

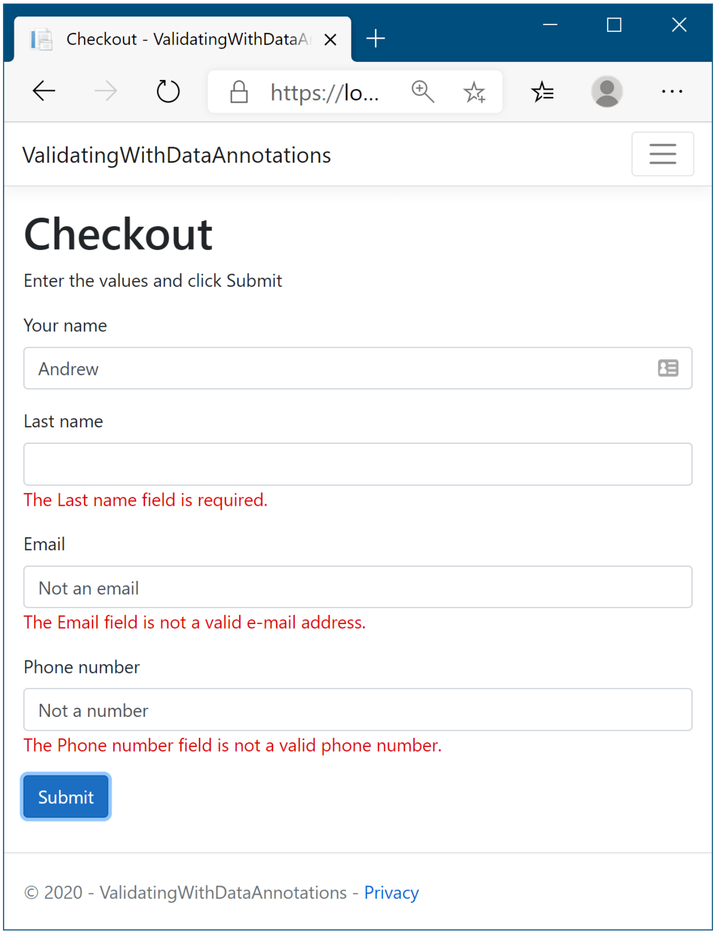
As an example, the listing below shows the OnPost page handler for the Checkout.cshtml Razor Page. The Input property is marked for binding, and uses the UserBindingModel type shown previously in listing 6.6. This page handler doesn't do anything with the data currently, but the pattern of checking ModelState early in the method is the key takeaway here.

Listing 6.7 Checking model state to view the validation result

```
public class CheckoutModel : PageModel                           #A
{
    [BindProperty]                                               #B
    public UserBindingModel Input { get; set; }                  #B

    public IActionResult OnPost()                                 #C
    {
        if (!ModelState.IsValid)                                  #D
        {
            return Page();                                        #E
        }

        /* Save to the database, update user, return success */    #F

        return RedirectToPage("Success");
    }
}
```

#A The ModelState property is available on the PageModel base class.
#B The Input property contains the model-bound data.
#C The binding model is validated before the page handler is executed.
#D If there were validation errors, IsValid will be false.
#E Validation failed, so redisplay the form with errors, and finish the method early.
#F Validation passed, so it’s safe to use the data provided in model.

If the `ModelState` indicates an error occurred, the method immediately calls the `Page` helper method. This returns a `PageResult` that will ultimately generate HTML to return to the user, as you saw in chapter 4. The view uses the (invalid) values provided in the `Input` property to repopulate the form when it’s displayed, as shown in figure 6.7. Also, helpful messages for the user are added automatically using the validation errors in the `ModelState`.



ValidatingWithDataAnnotations

Checkout

Enter the values and click Submit

Your name

Andrew

Last name

The Last name field is required.

Email

Not an email

The Email field is not a valid e-mail address.

Phone number

Not a number

The Phone number field is not a valid phone number.

Submit

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Figure 6.7 When validation fails, you can redisplay the form to display `ModelState` validation errors to the user. Note the "Your name" field has no associated validation errors, unlike the other fields.

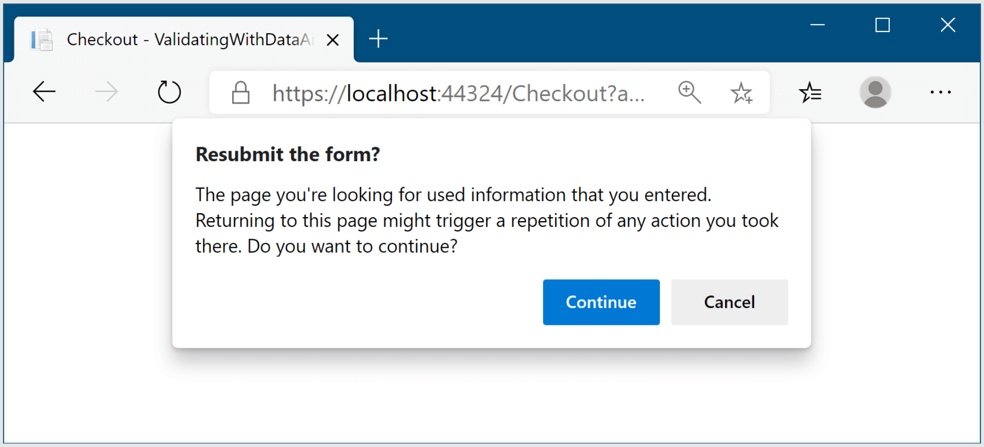
If the request is successful, the page handler returns a `RedirectToPage` result that redirects the user to the Success.cshtml Razor Page. This pattern of returning a redirect response after a successful POST is called the POST-REDIRECT-GET pattern.

> **NOTE** **The error messages displayed on the form are the default values for each validation attribute. You can customize the message by setting the `ErrorMessage` property on any of the validation attributes. For example, you could customize a `[Required]` attribute using `[Required(ErrorMessage= "Required")]`.**

POST-REDIRECT-GET

The POST-REDIRECT-GET design pattern is a web development pattern that prevents users from accidently submitting the same form multiple times. Users typically submit a form using the standard browser `POST` mechanism, sending data to the server. This is the normal way by which you might take a payment, for example.

If a server takes the naive approach and responds with a `200 OK` response and some HTML to display, then the user will still be on the same URL. If the user then refreshes their browser, they will be making an *additional* `POST` to the server, potentially making *another* payment! Browsers have some mechanisms to avoid this, such as in the following figure, but the user experience isn't desirable.


Checkout - ValidatingWithDataA
https://localhost:44324/Checkout?a...
Continue
Cancel

Resubmit the form?

The page you're looking for used information that you entered. Returning to this page might trigger a repetition of any action you took there. Do you want to continue?

Refreshing a browser window after a `POST` causes a warning message to be shown to the user.

The POST-REDIRECT-GET pattern says that in response to a successful `POST`, you should return a `REDIRECT` response to a new URL, which will be followed by the browser making a `GET` to the new URL. If the user refreshes their browser now, then they'll be refreshing the final `GET` call to the new URL. No additional `POST` is made, so no additional payments or side effects should occur.

This pattern is easy to achieve in ASP.NET Core MVC applications using the pattern shown in listing 6.7. By returning a `RedirectToPageResult` after a successful `POST`, your application will be safe if the user refreshes the page in their browser.

You might be wondering why validation isn't handled automatically—if validation has occurred, and you have the result, why does the page handler get executed at all? Isn't there a risk that you might forget to check the validation result?

This is true, and in some cases the best thing to do is to make the generation of the validation check and response automatic. In fact, this is exactly the approach we will use for Web APIs when we cover them in chapter 9.

For Razor Pages apps however, you typically still want to generate an HTML response, even when validation failed. This allows the user to see the problem, and potentially correct it. This is much harder to make automatic.

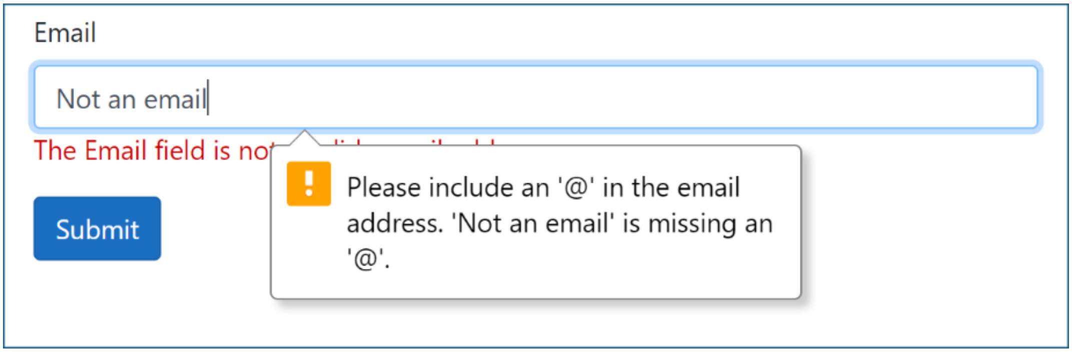
For example, you might find you need to load additional data before you can redisplay the Razor Page—such as loading a list of available currencies. That becomes simpler and more explicit with the `IsValid` pattern. Trying to do that automatically would likely end up with you fighting against edge-cases and workarounds.

Also, by including the `IsValid` check explicitly in your page handlers, it's easier to control what happens when *additional* validation checks fail. For example, if the user tries to update a product, then the `DataAnnotations` validation won't know whether a product with the requested ID exists, only whether the ID has the correct *format*. By moving the validation to the handler method, you can treat data and business rule validation failures in the same way.

I hope I've hammered home how important it is to validate user input in ASP.NET Core, but just in case: VALIDATE! There, we're good. Having said that, *only* performing validation on the server can leave users with a slightly poor experience. How many times have you filled out a form online, submitted it, gone to get a snack, and come back to find out you mistyped something and have to redo it. Wouldn't it be nicer to have that feedback immediately?

6.3.4 Validating on the client for user experience

You can add client-side validation to your application in a couple of different ways. HTML5 has several built-in validation behaviors that many browsers will use. If you display an email address field on a page and use the "email" HMTL input type, then the browser will automatically stop you from submitting an invalid format, as shown in figure 6.8.



Please include an '@' in the email address. 'Not an email' is missing an '@'.

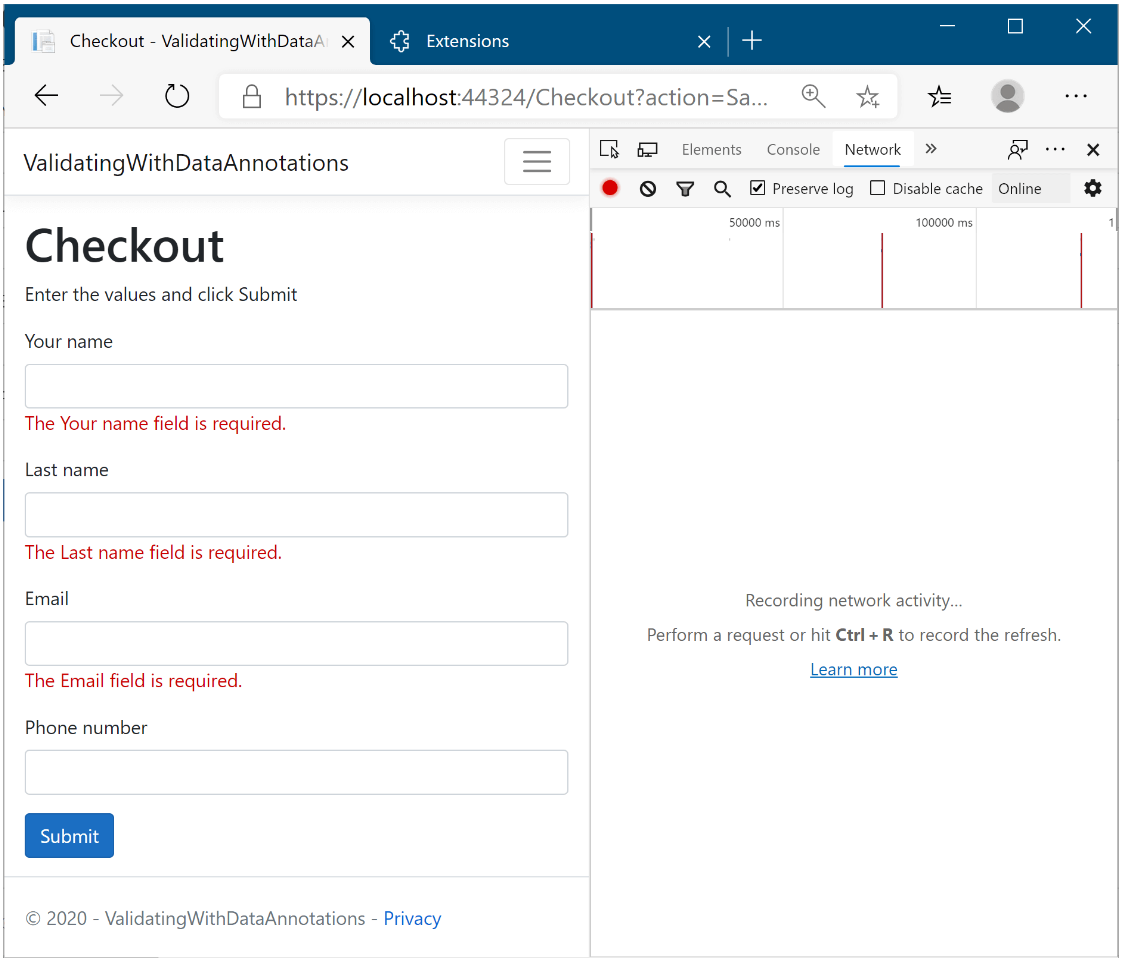
Figure 6.8 By default, modern browsers will automatically validate fields of the email type before a form is submitted.

Your application doesn't control this validation, it's built into modern HTML5 browsers.[26] The alternative approach is to perform client-side validation by running JavaScript on the page and checking the values the user has entered before submitting the form. This is the most common approach used in Razor Pages.

I'll go into detail on how to generate the client-side validation helpers in the next chapter, where you'll see the `DataAnnotations` attributes come to the fore once again. By decorating a view model with these attributes, you provide the necessary metadata to the Razor engine for it to generate the appropriate HTML.

With this approach, the user sees any errors with their form immediately, even before the request is sent to the server, as shown in figure 6.9. This gives a much shorter feedback cycle, providing a much better user experience.

[26] HTML5 constraint validation support varies by browser. For details on the available constraints, see http://mng.bz/daX3 and https://caniuse.com/#feat=constraint-validation.



Checkout - ValidatingWithDataA

Extensions

https://localhost:44324/Checkout?action=Sa...

ValidatingWithDataAnnotations

Checkout

Enter the values and click Submit

Your name

The Your name field is required.

Last name

The Last name field is required.

Email

The Email field is required.

Phone number

Submit

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Recording network activity...

Perform a request or hit **Ctrl + R** to record the refresh.

Learn more

Figure 6.9 With client-side validation, clicking Submit will trigger validation to be shown in the browser before the request is sent to the server. As shown in the right-hand pane, no request is sent.

If you're building an SPA, then the onus is on the client-side framework to validate the data on the client side before posting it to the Web API. The Web API will still validate the data when it arrives at the server, but the client-side framework is responsible for providing the smooth user experience.

When you use Razor Pages to generate your HTML, you get much of this validation for free. It automatically configures client-side validation for most of the built-in attributes without requiring additional work, as you'll see in chapter 7. Unfortunately, if you've used custom `ValidationAttributes`, then these will only run on the server by default; you need to do some additional wiring up of the attribute to make it work on the client side too. Despite this, custom validation attributes can be useful for handling common validation scenarios in your application, as you'll see in chapter 19.

The model binding framework in ASP.NET Core gives you a lot of options on how to organize your Razor Pages: page handler parameters or `PageModel` properties; one binding model or multiple; where should you define your binding model classes? In the next section I give some advice on how *I* like to organize my Razor Pages.

6.4 Organizing your binding models in Razor Pages

In this section I give some general advice on how I like to configure the binding models in my Razor Pages. If you follow the patterns in this section, your Razor Pages will follow a consistent layout, making it easier for others to understand how each Razor Page in your app works.

> **NOTE** This advice is just personal preference, so feel free to adapt it if there are aspects you don't agree with. The important thing is to understand *why* I make each suggestion, and to take that on board. Where appropriate, I deviate from these guidelines too!

Model binding in ASP.NET Core has a lot of equivalent approaches to take, so there is no "correct" way to do it. The following listing shows an example of how I would design a simple Razor Page. This Razor Page displays a form for a product with a given ID and allows you to edit the details using a POST request. It's a much longer sample than we've looked at so far, but I highlight the important points below.

Listing 6.8 Designing an edit product Razor Page

```
public class EditProductModel : PageModel
{
    private readonly ProductService _productService;          #A
    public EditProductModel(ProductService productService)    #A
    {                                                         #A
        _productService = productService;                     #A
    }                                                         #A

    [BindProperty]                                            #B
    public InputModel Input { get; set; }                     #B

    public IActionResult OnGet(int id)                        #C
    {
        var product = _productService.GetProduct(id);         #D

        Input = new InputModel                                #E
        {                                                     #E
            Name = product.ProductName,                       #E
            Price = product.SellPrice,                        #E
        };                                                    #E
        return Page();                                        #E
    }

    public IActionResult OnPost(int id)                       #C
    {
        if (!ModelState.IsValid)                                        #F
        {                                                               #F
            return Page();                                              #F
        }                                                               #F

        _productService.UpdateProduct(id, Input.Name, Input.Price);    #G

        return RedirectToPage("Index");                                 #H
    }


    public class InputModel                                            #I
    {                                                                  #I
        [Required]                                                     #I
        public string Name { get; set; }                               #I
                                                                       #I
        [Range(0, int.MaxValue)]                                       #I
        public decimal Price { get; set; }                             #I
    }                                                                  #I
}
```

#A The ProductService is injected using DI and provides access to the application model
#B A single property is marked with BindProperty
#C The id parameter is model bound from the route template for both OnGet and OnPage handlers
#D Load the product details from the application model
#E Build an instance of the InputModel for editing in the form from the existing product's details
#F If the request was not valid, redisplay the form without saving
#G Update the product in the application model using the ProductService
#H Redirect to a new page using the POST-REDIRECT-GET pattern
#I Define the InputModel as a nested class in the Razor Page

This page shows the `PageModel` for a typical "edit form". These are very common in many line-of-business applications, among others, and is a scenario that Razor Pages works very well for. You'll see how to create the HTML side of forms in chapter 8.

> **NOTE The purpose of this example is only to highlight the model binding approach. The code is overly simplistic from a *logic* point of view. For example, it doesn't check that the product with the provided ID exists, or include any error handling.**

This form shows several patterns related to model binding that I try to adhere to when building Razor Pages:

- *Only bind a single property with* `[BindProperty]`. I favour having a single property decorated with `[BindProperty]` for model binding in general. When more than one value needs to be bound, I create a separate class, `InputModel`, to hold the values, and decorate that single property with `[BindProperty]`. Decorating a single property like this makes it harder to forget to add the attribute and means all of your Razor Pages use the same pattern.
- *Define your binding model as a nested class*. I define the `InputModel` as a nested class inside my Razor Page. The binding model is normally highly specific to that single page,

so doing this keeps everything your working on together. Additionally, I normally use that exact class name, `InputModel` for all my pages. Again, this adds consistency to your Razor Pages.

Don't use `[BindProperties]`. In addition to the `[BindProperty]` attribute, there is a `[BindProperties]` attribute (note the different spelling) that can be applied to the Razor Page `PageModel` directly. This will cause *all* properties in your model to be model bound, which can leave you open to over-posting attacks if you're not careful. I suggest you don't use the `[BindProperties]` attribute and stick to binding a *single* property with `[BindProperty]` instead.

- *Accept route parameters in the page handler*. For simple route parameters, such as the `id` passed into the `OnGet` and `OnPost` handlers in listing 6.8, I add parameters to the page handler method itself. This avoids the clunky `SupportsGet=true` syntax for `GET` requests.
- *Always validate before using data*. I said it before, so I'll say it again. Validate user input!

That concludes this look at model-binding in Razor Pages. You saw how the ASP.NET Core framework uses model binding to simplify the process of extracting values from a request and turning them into normal .NET objects you can quickly work with. The most important aspect of this chapter is the focus on validation—this is a common concern for all web applications, and the use of `DataAnnotations` can make it easy to add validation to your models.

In the next chapter, we continue our journey through Razor Pages by looking at how to create views. In particular, you'll learn how to generate HTML in response to a request using the Razor templating engine.

6.5 Summary

- Razor Pages uses three distinct "models", each responsible for a different aspect of a request. The binding models encapsulates data sent as part of a request. The application model represents the state of the application. The `PageModel` is the backing class for the Razor Page, and exposes the data used by the Razor view to generate a response.
- Model binding extracts values from a request and uses them to create .NET objects the page handler can use when they execute.
- Any properties on the `PageModel` marked with the `[BindProperty]` attribute, and method parameters of the page handlers, will take part in model binding.
- Properties decorated with `[BindProperty]` are not bound for `GET` requests. To bind GET requests, you must use `[BindProperty(SupportsGet = true)]` instead.
- By default, there are three binding sources: POSTed form values, route values, and the query string. The binder will interrogate these in order when trying to bind your binding models.

- When binding values to models, the names of the parameters and properties aren't case sensitive.
- You can bind to simple types or to the properties of complex types.
- To bind complex types, they must have a default constructor and public, settable properties.
- Simple types must be convertible to strings to be bound automatically, for example numbers, dates, and Boolean values.
- Collections and dictionaries can be bound using the `[index]=value` and `[key]=value` syntax, respectively.
- You can customize the binding source for a binding model using `[From*]` attributes applied to the method, such as `[FromHeader]` and `[FromBody]`. These can be used to bind to nondefault binding sources, such as headers or JSON body content.
- In contrast to the previous version of ASP.NET, the `[FromBody]` attribute is required when binding JSON properties (previously it was not required).
- Validation is necessary to check for security threats. Check that data is formatted correctly, confirm that it conforms to expected values and that it meets your business rules.
- ASP.NET Core provides `DataAnnotations` attributes to allow you to declaratively define the expected values.
- Validation occurs automatically after model binding, but you must manually check the result of the validation and act accordingly in your page handler by interrogating the `ModelState` property.
- Client-side validation provides a better user experience than server-side validation alone, but you should always use server-side validation.
- Client-side validation uses JavaScript and attributes applied to your HTML elements to validate form values.

7

Rendering HTML using Razor views

This chapter covers

- **Creating Razor views to display HTML to a user**
- **Using C# and the Razor markup syntax to generate HTML dynamically**
- **Reusing common code with layouts and partial views**

It's easy to get confused between the terms involved in Razor Pages—`PageModel`, page handlers, Razor views—especially as some of the terms describe concrete features, and others describe patterns and concepts. We've touched on all these terms in detail in previous chapters, but it's important to get them straight int your mind:

- Razor Pages—Razor Pages generally refers to the page-based paradigm which combines routing, model binding, and HTML generation using Razor views.
- Razor Page—A single Razor Page represents a single page or "endpoint". It typically consists of two files: a .cshtml file containing the Razor view, and a .cshtml.cs file containing the page's `PageModel`.
- `PageModel`—The `PageModel` for a Razor Page is where most of the action happens. It's where you define the binding models for a page, which extracts data from the incoming request. It's also where you define the page's page handlers.
- Page handler—Each Razor Page typically handles a single *route*, but it can handle multiple HTTP verbs like `GET` and `POST`. Each page handler typically handles a single HTTP verb.
- Razor view—Razor views (also called Razor templates) are used to generate HTML. They are typically used in the final stage of a Razor Page, to generate the HTML response to send back to the user.

In the previous four chapters, I've covered a whole cross-section of Razor Pages, including the MVC design pattern, the Razor Page `PageModel`, page handlers, routing, and binding models. This chapter covers the last part of the MVC pattern—using a view to generate the HTML that's delivered to the user's browser.

In ASP.NET Core, views are normally created using the *Razor* markup syntax (sometimes described as a templating language), which uses a mixture of HTML and C# to generate the final HTML. This chapter covers some of the features of Razor and how to use it to build the view templates for your application. Generally speaking, users will have two sorts of interactions with your app: they read data that your app displays, and they send data or commands back to it. The Razor language contains a number of constructs that make it simple to build both types of applications.

When displaying data, you can use the Razor language to easily combine static HTML with values from your `PageModel`. Razor can use C# as a control mechanism, so adding conditional elements and loops is simple, something you couldn't achieve with HTML alone.

The normal approach to sending data to web applications is with HTML forms. Virtually every dynamic app you build will use forms; some applications will be pretty much nothing *but* forms! ASP.NET Core and the Razor templating language include a number of helpers that make generating HTML forms easy, called *Tag Helpers*.

> **NOTE** You'll get a brief glimpse of Tag Helpers in the next section, but I'll explore them in detail in the next chapter.

In this chapter, we'll be focusing primarily on displaying data and generating HTML using Razor, rather than creating forms. You'll see how to render values from your `PageModel` to the HTML, and how to use C# to control the generated output. Finally, you'll learn how to extract the common elements of your views into sub-views called *layouts* and *partial views*, and how to compose them to create the final HTML page.

7.1 Views: rendering the user interface

In this section, I provide a quick introduction to rendering HTML using Razor views. We'll recap the MVC design pattern used by Razor Pages, and where the view fits in. You'll then see an introduction of how Razor syntax allows you to mix C# and HTML to generate dynamic UIs.

As you know from earlier chapters on the MVC design pattern, it's the job of the Razor Page's page handler to choose what to return to the client. For example, if you're developing a to-do list application, imagine a request to view a particular to-do item, as shown in figure 7.1.

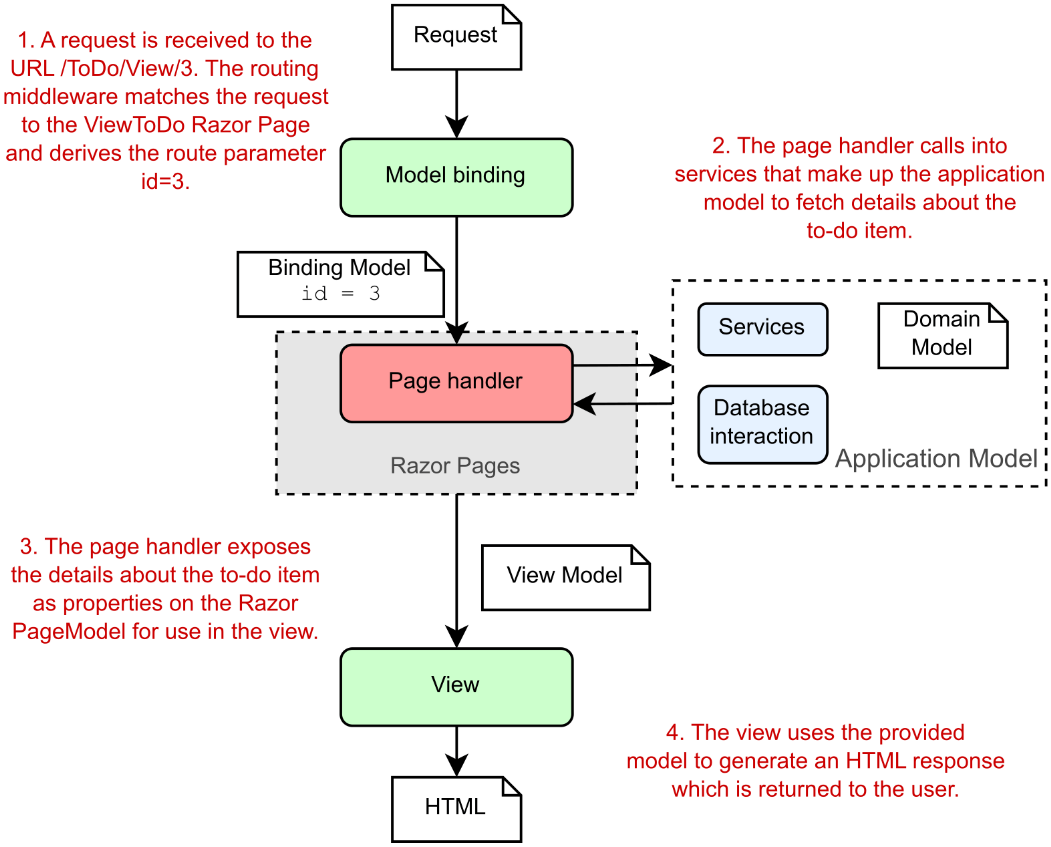

1. A request is received to the URL /ToDo/View/3. The routing middleware matches the request to the ViewToDo Razor Page and derives the route parameter id=3.
Request
Model binding
2. The page handler calls into services that make up the application model to fetch details about the to-do item.
Binding Model
id = 3
Services
Domain Model
Page handler
Database interaction
Razor Pages
Application Model
3. The page handler exposes the details about the to-do item as properties on the Razor PageModel for use in the view.
View Model
View
4. The view uses the provided model to generate an HTML response which is returned to the user.
HTML

Figure 7.1 Handling a request for a to-do list item using ASP.NET Core Razor Pages. The page handler builds the data required by the view and exposes it as properties on the PageModel. The view generates HTML based only on the data provided, it doesn't need to know where that data come from.

A typical request follows the steps shown in figure 7.1:

1. The middleware pipeline receives the request and the routing middleware determines the endpoint to invoke—in this case, the `ViewToDo` Razor Page.
2. The model binder (part of the Razor Pages framework) uses the request to build the binding models for the page, as you saw in the previous chapter. The binding models are set as properties on the Razor Page or are passed to the page handler method as arguments when the handler is executed. The page handler checks that you have passed a valid `id` for the to-do item, making the request valid.
3. Assuming all looks good, the page handler calls out to the various services that make up the application model. This might load the details about the to-do from a database, or from the filesystem, returning them to the handler. As part of this process, either

the application model or the page handler itself generates values to pass to the view and sets them as properties on the Razor Page `PageModel`.

Once the page handler has executed, the `PageModel` should contain all the data required to render a view. In this example, it contains details about the to-do itself, but it might also contain other data: how many to-dos you have left, whether you have any to-dos scheduled for today, your username, and so on, anything that controls how to generate the end UI for the request.

4. The Razor view template uses the `PageModel` to generate the final response and returns it back to the user via the middleware pipeline.

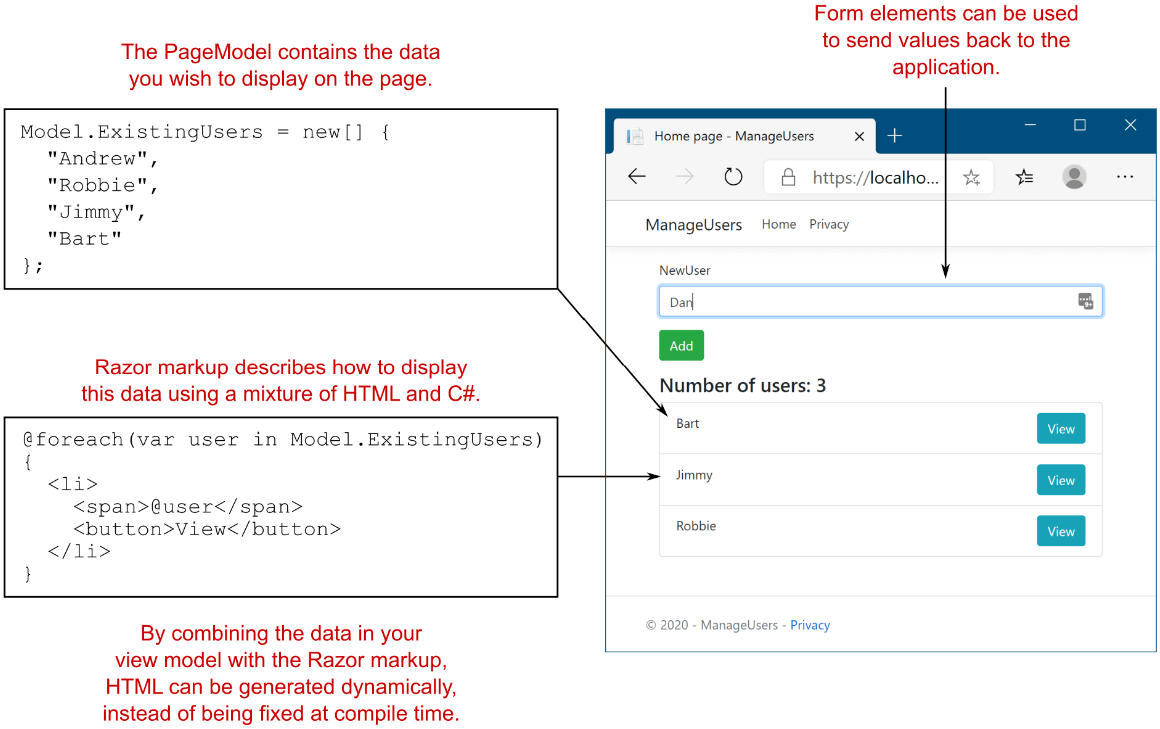
A common thread throughout this discussion of MVC is the separation of concerns MVC brings, and this is no different when it comes to your views. It would be easy enough to directly generate the HTML in your application model or in your controller actions, but instead you delegate that responsibility to a single component, the view.

But even more than that, you'll also separate the *data* required to build the view from the *process* of building it, by using properties on the `PageModel`. These properties should contain all the dynamic data needed by the view to generate the final output.

> **TIP** **Views shouldn't call methods on the `PageModel`—the view should generally only be accessing data that has already been collected and exposed as properties.**

Razor Page handlers indicate that the Razor view should be rendered by returning a `PageResult` (or by returning `void`), as you saw in chapter 4. The Razor Pages infrastructure executes the Razor view associated with a given Razor Page to generate the final response. The use of C# in the Razor template means you can dynamically generate the final HTML sent to the browser. This allows you to, for example, display the name of the current user in the page, hide links the current user doesn't have access to, or render a button for every item in a list.

Imagine your boss asks you to add a page to your application that displays a list of the application's users. You should also be able to view a user from the page, or create a new one, as shown in figure 7.2.



The PageModel contains the data you wish to display on the page.

```
Model.ExistingUsers = new[] {
  "Andrew",
  "Robbie",
  "Jimmy",
  "Bart"
};
```

Razor markup describes how to display this data using a mixture of HTML and C#.

```
@foreach(var user in Model.ExistingUsers)
{
  <li>
    <span>@user</span>
    <button>View</button>
  </li>
}
```

By combining the data in your view model with the Razor markup, HTML can be generated dynamically, instead of being fixed at compile time.

Form elements can be used to send values back to the application.

Figure 7.2 The use of C# in Razor lets you easily generate dynamic HTML that varies at runtime. In this example, using a `foreach` loop inside the Razor view dramatically reduces the duplication in the HTML that you would otherwise have to write.

With Razor templates, generating this sort of dynamic content is simple. For example, the following listing shows the template that could be used to generate the interface in figure 7.2. It combines standard HTML with C# statements, and uses Tag Helpers to generate the form elements.

Listing 7.1 A Razor template to list users and a form for adding a new user

```
@page
@model IndexViewModel
<div class="row">                                           #A
<div class="col-md-6">                                      #A
<form method="post">
    <div class="form-group">
        <label asp-for="NewUser"></label>                   #B
        <input class="form-control" asp-for="NewUser" />    #B
        <span asp-validation-for="NewUser"></span>          #B
    </div>
    <div class="form-group">
        <button type="submit"
          class="btn btn-success">Add</button>
    </div>
</form>
</div>
</div>

<h4>Number of users: @Model.ExistingUsers.Count</h4>  #C
<div class="row">
<div class="col-md-6">
<ul class="list-group">
@foreach (var user in Model.ExistingUsers)             #D
{
<li class="list-group-item d-flex justify-content-between">
    <span>@user</span>
    <a class="btn btn-info"
        asp-page="ViewUser"                            #E
        asp-route-userName="@user">View</a>            #E
</li>
}
</ul>
</div>
</div>
```

#A Normal HTML is sent to the browser unchanged.
#B Tag Helpers attach to HTML elements to create forms.
#C Values can be written from C# objects to the HTML.
#D C# constructs like for loops can be used in Razor.
#E Tag Helpers can also be used outside of forms to help in other HTML generation.

This example demonstrates a variety of Razor features. There's a mixture of HTML that's written unmodified to the response output, and various C# constructs that are used to dynamically generate HTML. In addition, you can see several Tag Helpers. These look like normal HTML attributes that start `asp-`, but they're part of the Razor language. They can customize the HTML element they're attached to, changing how it's rendered. They make building HTML forms much simpler than they would be otherwise. Don't worry if this template is a bit overwhelming at the moment; we'll break it all down as you progress through this chapter and the next.

Razor Pages are compiled when you build your application. Behind the scenes, they become just another C# class in your application. It's also possible to enable *runtime* compilation of your Razor Pages. This allows you modify your Razor Pages while your app is running, without having to explicitly stop and rebuild. This can be handy when developing locally but is best avoided when you deploy to production[27].

> **NOTE** Like most things in ASP.NET Core, it's possible to swap out the Razor templating engine and replace it with your own server-side rendering engine. You can't replace Razor with a client-side framework like

[27] For details on enabling runtime compilation, including enabling conditional pre-compilation for production environments, see the documentation: https://docs.microsoft.com/en-us/aspnet/core/mvc/views/view-compilation.

AngularJS or React. If you want to take this approach, you'd use Web APIs instead. I'll discuss Web APIs in detail in chapter 9.

In the next section we'll look in more detail at how Razor views fit into the Razor Pages framework, and how to pass data from your Razor Page handlers to the Razor view to help build the HTML response.

7.2 Creating Razor views

In this section we look at how Razor views fit into the Razor Pages framework. You'll learn how to pass data from your page handlers to your Razor views, and how you can use that data to generate dynamic HTML.

With ASP.NET Core, whenever you need to display an HTML response to the user, you should use a view to generate it. Although it's possible to directly generate a `string` from your page handlers which will be rendered as HTML in the browser, this approach doesn't adhere to the MVC separation of concerns and will quickly leave you tearing your hair out.

NOTE Some middleware, such as the `WelcomePageMiddleware` you saw in chapter 3, may generate HTML responses without using a view, which can make sense in some situations. But your Razor Page and MVC controllers should always generate HTML using views.

Instead, by relying on Razor views to generate the response, you get access to a wide variety of features, as well as editor tooling to help! This section serves as a gentle introduction to Razor views, the things you can do with them, and the various ways you can pass data to them.

7.2.1 Razor views and code-behind

In this book you've already seen that Razor Pages typically consist of two files:

- The .cshtml file, commonly called the Razor view.
- The .cshtml.cs file, commonly called the "code-behind," which contains the `PageModel`.

The Razor view contains the `@page` directive which *makes it* a Razor Page, as you saw in chapter 4. Without this directive, the Razor Pages framework will not route requests to the page, and the file will be ignored for most purposes.

DEFINITION A *directive* is a statement in a Razor file that changes the way the template is parsed or compiled. Another common directive is the `@using newNamespace` directive, which would make objects in the `newNamespace` namespace available.

The code-behind .cshtml.cs file contains the `PageModel` for an associated Razor Page. It contains the page handlers that respond to requests, and it is where the Razor Page typically interacts with other parts of your application.

Even though the .cshtml and .cshtml.cs files share the same name, for example ToDoItem.cshtml and ToDoItem.cshtml.cs, it’s not the filename that’s linking them together. If it’s not by filename, how does the Razor Pages framework know which `PageModel` is associated with a given Razor Page view file?

At the top of each Razor Page, just after the `@page` directive, is an `@model` directive with a `Type`, indicating which `PageModel` is associated with the Razor view. For example, the following directives indicate that the `ToDoItemModel` is the `PageModel` associated with the Razor Page:

```
@page
@model ToDoItemModel
```

Once a request is routed to a Razor Page, as we covered in chapter 5, the framework looks for the `@model` directive to decide which `PageModel` to use. Based on the `PageModel` selected, it then binds to any properties in the `PageModel` marked with the `[BindProperty]` attribute (as we covered in the chapter 6) and executes the appropriate page handler (based on the request’s HTTP verb).

> **NOTE** Technically, the `PageModel` and `@model` directive are optional. If you don’t specify a `PageModel`, the framework will execute a default page handler, as you saw in chapter 5. It’s also possible to combine the .cshtml and .cshtml.cs files into a single .cshtml file. In practice, neither of these approaches are very common, even for simple pages, but it’s something to be aware of if you run into it.[28]

In addition to the `@page` and `@model` directives, the Razor view file contains the Razor template that is executed to generate the HTML response.

7.2.2 Introducing Razor templates

Razor view templates contain a mixture of HTML and C# code interspersed with one another. The HTML markup lets you easily describe exactly what should be sent to the browser, whereas the C# code can be used to dynamically change what is rendered. For example, the listing below shows an example of Razor rendering a list of strings, representing to-do items.

Listing 7.2 Razor template for rendering a list of strings

```
@page
@{                                                #A
    var tasks = new List<string>                  #A
      { "Buy milk", "Buy eggs", "Buy bread" };    #A
}                                                 #A
<h1>Tasks to complete</h1>                        #B
<ul>
```

[28] These alternative approaches are not generally considered idiomatic, so I don’t discuss them in this book, but you can read more about them here: https://www.learnrazorpages.com/razor-pages.

```
@for(var i=0; i< tasks.Count; i++)                #C
{                                                 #C
  var task = tasks[i];                            #C
  <li>@i - @task</li>                             #C
}                                                 #C
</ul>
```

#A Arbitrary C# can be executed in a template. Variables remain in scope throughout the page.
#B Standard HTML markup will be rendered to the output unchanged.
#C Mixing C# and HTML allows you to dynamically create HTML at runtime.

The pure HTML sections in this template are the angle brackets. The Razor engine copies this HTML directly to the output, unchanged, as though you were writing a normal HTML file.

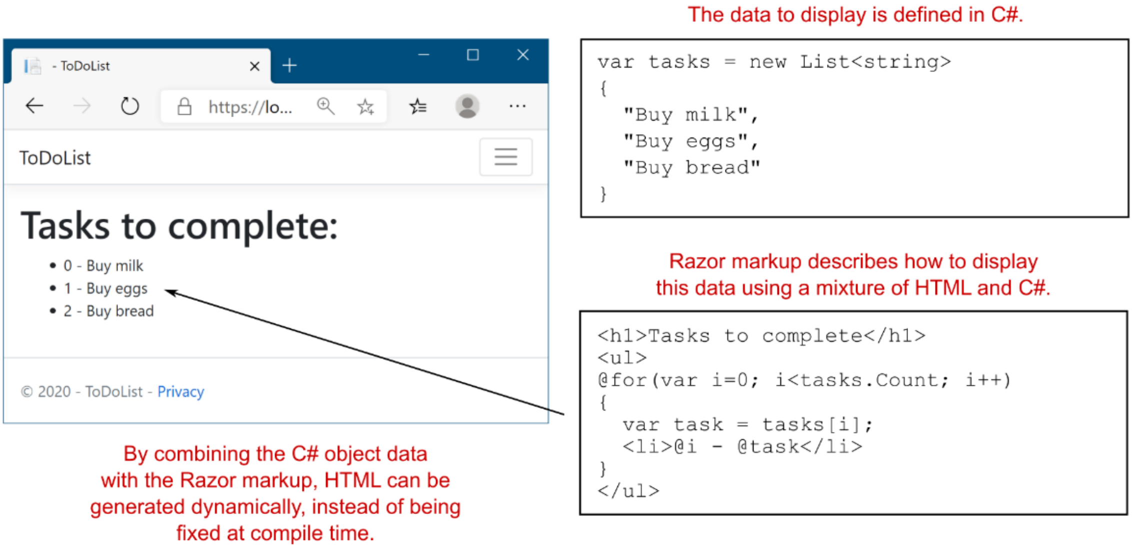
As well as HTML, you can also see a number of C# statements in there. The advantage of being able to, for example, use a `for` loop rather than having to explicitly write out each `<li>` element should be self-evident. I'll dive a little deeper into more of the C# features of Razor in the next section. When rendered, this template would produce the HTML shown here.

Listing 7.3 HTML output produced by rendering a Razor template

```
<h1>Tasks to complete</h1>        #A
<ul>                              #A
  <li>0 - Buy milk</li>           #B
  <li>1 - Buy eggs</li>           #B
  <li>2 - Buy bread</li>          #B
</ul>                             #C
```

#A HTML from the Razor template is written directly to the output.
#B The <li> elements are generated dynamically based on the data.
#C HTML from the Razor template is written directly to the output.

As you can see, the final output of a Razor template after it's been rendered is simple HTML. There's nothing complicated left, just straight HTML markup that can be sent to the browser and rendered. Figure 7.3 shows how a browser would render it.



Tasks to complete:

- 0 - Buy milk
- 1 - Buy eggs
- 2 - Buy bread

The data to display is defined in C#.

```
var tasks = new List<string>
{
  "Buy milk",
  "Buy eggs",
  "Buy bread"
}
```

Razor markup describes how to display this data using a mixture of HTML and C#.

```
<h1>Tasks to complete</h1>
<ul>
@for(var i=0; i<tasks.Count; i++)
{
  var task = tasks[i];
  <li>@i - @task</li>
}
</ul>
```

By combining the C# object data with the Razor markup, HTML can be generated dynamically, instead of being fixed at compile time.

Figure 7.3 Razor templates can be used to generate the HTML dynamically at runtime from C# objects. In this case, a `for` loop is used to create repetitive HTML `<li>` elements.

In this example, I hardcoded the list values for simplicity—there was no dynamic data provided. This is often the case on simple Razor Pages like you might have on your homepage—you need to display an almost static page. For the rest of your application, it will be far more common to have some sort of data you need to display, typically exposed as properties on your `PageModel`.

7.2.3 Passing data to views

In ASP.NET Core, you have several ways of passing data from a page handler in a Razor Page to its view. Which approach is best will depend on the data you're trying to pass through, but in general you should use the mechanisms in the following order:

- `PageModel` *properties*—You should generally expose any data that needs to be displayed as properties on your `PageModel`. Any data which is specific to the associated Razor view should be exposed this way. The `PageModel` object is available in the view when it's rendered, as you'll see shortly.
- `ViewData`—This is a dictionary of objects with `string` keys that can be used to pass arbitrary data from the page handler to the view. In addition, it allows you to pass data to *_layout* files, as you'll see in section 7.4. This is the main reason for using `ViewData` instead of setting properties on the `PageModel`.

- HttpContext—Technically the HttpContext object is available in both the page handler and Razor view, so you *could* use it to transfer data between them. But don't—there's no need for it with the other methods available to you.

Far and away the best approach for passing data from a page handler to a view is to use properties on the PageModel. There's nothing special about the properties themselves; you can store anything there to hold the data you require.

> **NOTE** Many frameworks have the concept of a data context for binding UI components. The PageModel is a similar concept, in that it contains values to display in the UI, but the binding is only one-directional; the PageModel provides values to the UI, and once the UI is built and sent as a response, the PageModel is destroyed.

As I described in section 7.2.1, the @model directive at the top of your Razor view describes which Type of PageModel is associated with a given Razor Page. The PageModel associated with a Razor Page contains one or more page handlers, and exposes data as properties for use in the Razor view.

Listing 7.4 Exposing data as properties on a PageModel

```
public class ToDoItemModel : PageModel                  #A
{
    public List<string> Tasks { get; set; }             #B
    public string Title { get; set; }                   #B

    public void OnGet(int id)
    {
        Title = "Tasks for today",                   #C
        Tasks = new List<string>{                    #C
        {                                            #C
            "Get fuel",                              #C
            "Check oil",                             #C
            "Check tyre pressure"                    #C
        }                                            #C
    }
}
```

#A The PageModel is passed to the Razor view when it executes.
#B The public properties can be accessed from the Razor view.
#C Building the required data: this would normally call out to a service or database to load the data.

You can access the PageModel instance itself from the Razor view using the Model property. For example, to display the Title property of the ToDoItemModel in the Razor view, you'd use `<h1>@Model.Title</h1>`. This would render the string provided in the ToDoItemModel.Title property, producing the `<h1>Tasks for today</h1>` HTML.

> **TIP** Note that the @model directive should be at the top of your view, just after the @page directive, and has a lowercase m. The Model property can be accessed anywhere in the view and has an uppercase M.

In the vast majority of cases, using public properties on your `PageModel` is the way to go; it's the standard mechanism for passing data between the page handler and the view. But in some circumstances, properties on your `PageModel` might not be the best fit. This is often the case when you want to pass data between view layouts (you'll see how this works in section 7.4).

A common example is the title of the page. You need to provide a title for every page in your application, so you *could* create a base class with a `Title` property and make every `PageModel` inherit from it. But that's very cumbersome, so a common approach for this situation is to use the `ViewData` collection to pass data around.

In fact, the standard Razor Page templates use this approach by default by setting values on the `ViewData` dictionary from within the view itself:

```
@{
    ViewData["Title"] = "Home Page";
}
<h2>@ViewData["Title"].</h2>
```

This template sets the value of the `"Title"` key in the `ViewData` dictionary to `"Home Page"` and then fetches the key to render in the template. This set and immediate fetch might seem superfluous, but as the `ViewData` dictionary is shared throughout the request, it makes the title of the page available in layouts, as you'll see later. When rendered, this would produce the following output:

```
<h2>Home Page.</h2>
```

You can also set values in the `ViewData` dictionary from your page handlers in two different ways, as shown in the following listing.

Listing 7.5 Setting ViewData values using an attribute

```
public class IndexModel: PageModel
{
    [ViewData]                                  #A
    public string Title { get; set; }

    public void OnGet()
    {
        Title = "Home Page";                   #B
        ViewData["Subtitle"] = "Welcome";      #C
    }
}
```

#A Properties marked with the [ViewData] attribute are set in the ViewData.
#B The value of ViewData["Title"] will be set to "Home Page".
#C You can set keys in the ViewData dictionary directly.

You can display the values in the template in the same way as before:

```
<h1>@ViewData["Title"]</h3>
<h2>@ViewData["Subtitle"]</h3>
```

TIP **I don't find the `[ViewData]` attribute especially useful, but it's another feature to look out for. Instead, I create a set of global, static constants for any `ViewData` keys, and reference those, instead of typing `"Title"` repeatedly. You'll get IntelliSense for the values, they'll be refactor-safe, and you'll avoid hard-to-spot typos.**

As I mentioned previously, there are other mechanisms besides `PageModel` properties and `ViewData` that you can use to pass data around, but these two are the only ones I use personally, as you can do everything you need with them. As a reminder, always use `PageModel` properties where possible, as you benefit from strong typing and IntelliSense. Only fall back to `ViewData` for values that need to be accessed *outside* of your Razor view.

You've had a small taste of the power available to you in Razor templates, but in the next section, I'd like to dive a little deeper into some of the available C# capabilities.

7.3 Creating dynamic web pages with Razor

You might be glad to know that pretty much anything you can do in C# is possible in Razor syntax. Under the covers, the cshtml files are compiled into normal C# code (with `string` for the raw HTML sections), so whatever weird and wonderful behavior you need can be created!

Having said that, just because you *can* do something doesn't mean you *should*. You'll find it much easier to work with, and maintain, your files if you keep them as simple as possible. This is true of pretty much all programming, but I find to be especially so with Razor templates.

This section covers some of the more common C# constructs you can use. If you find you need to achieve something a bit more exotic, refer to the Razor syntax documentation at https://docs.microsoft.com/en-us/aspnet/core/mvc/views/razor.

7.3.1 Using C# in Razor templates

One of the most common requirements when working with Razor templates is to render a value you've calculated in C# to the HTML. For example, you might want to print the current year to use with a copyright statement in your HTML, to give

```
<p>Copyright 2020 ©</p>
```

or you might want to print the result of a calculation, for example

```
<p>The sum of 1 and 2 is <i>3</i><p>
```

You can do this in two ways, depending on the exact C# code you need to execute. If the code is a single statement, then you can use the `@` symbol to indicate you want to write the result to the HTML output, as shown in figure 7.4. You've already seen this used to write out values from the `PageModel` or from `ViewData`.

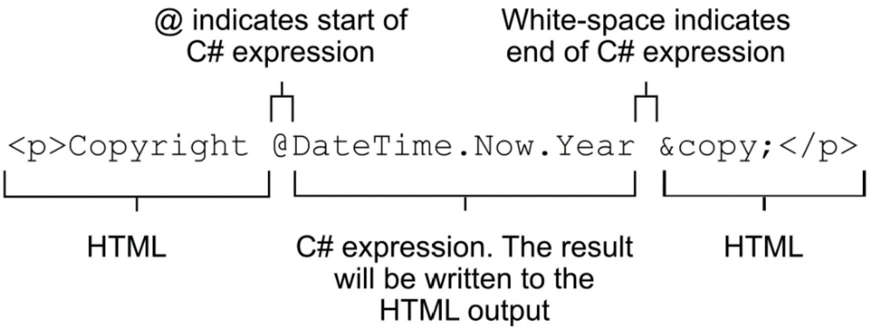

@ indicates start of C# expression
White-space indicates end of C# expression
<p>Copyright @DateTime.Now.Year &copy;</p>
HTML
C# expression. The result will be written to the HTML output
HTML

Figure 7.4 Writing the result of a C# expression to HTML. The `@` symbol indicates where the C# code begins and the expression ends at the end of the statement, in this case at the space.

If the C# you want to execute is something that *needs* a space, then you need to use parentheses to demarcate the C#, as shown in figure 7.5.

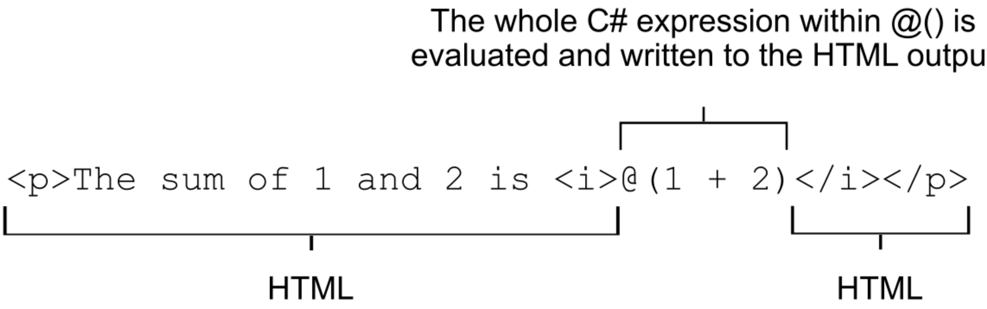

The whole C# expression within @() is evaluated and written to the HTML output
<p>The sum of 1 and 2 is <i>@(1 + 2)</i></p>
HTML
HTML

Figure 7.5 When a C# expression contains whitespace, you must wrap it in parentheses using `@()` so the Razor engine knows where the C# stops and HTML begins.

These two approaches, in which C# is evaluated and written directly to the HTML output, are called *Razor expressions*. Sometimes you want to execute some C#, but you don't need to output the values. We used this technique when we were setting values in `ViewData`:

```
@{
    ViewData["Title"] = "Home Page";
}
```

This example demonstrates a *Razor code block*, which is normal C# code, identified by the `@{}` structure. Nothing is written to the HTML output here; it's all compiled as though you'd written it in any other normal C# file.

TIP When you execute code within code blocks, it must be valid C#, so you need to add semicolons. Conversely, when you're writing values directly to the response using Razor expressions, you don't need them. If your output HTML breaks unexpectedly, keep an eye out for missing or rogue extra semicolons!

Razor expressions are one of the most common ways of writing data from your `PageModel` to the HTML output. You'll see the other approach, using Tag Helpers, in the next chapter. Razor's capabilities extend far further than this, however, as you'll see in the next section where you'll learn how to include traditional C# structures in your templates.

7.3.2 Adding loops and conditionals to Razor templates

One of the biggest advantages of using Razor templates over static HTML is the ability to dynamically generate the output. Being able to write values from your `PageModel` to the HTML using Razor expressions is a key part of that, but another common use is loops and conditionals. With these, you could hide sections of the UI, or produce HTML for every item in a list, for example.

Loops and conditionals include constructs such as `if` and `for` loops. Using them in Razor templates is almost identical to C#, but you need to prefix their usage with the `@` symbol. In case you're not getting the hang of Razor yet, when in doubt, throw in another `@`!

One of the big advantages of Razor in the context of ASP.NET Core is that it uses languages you're already familiar with: C# and HTML. There's no need to learn a whole new set of primitives for some other templating language: it's the same `if`, `foreach`, and `while` constructs you already know. And when you don't need them, you're writing raw HTML, so you can see exactly what the user will be getting in their browser.

In listing 7.6, I've applied a number of these different techniques in the template for displaying a to-do item. The `PageModel` has a `bool IsComplete` property, as well as a `List<string>` property called `Tasks`, which contains any outstanding tasks.

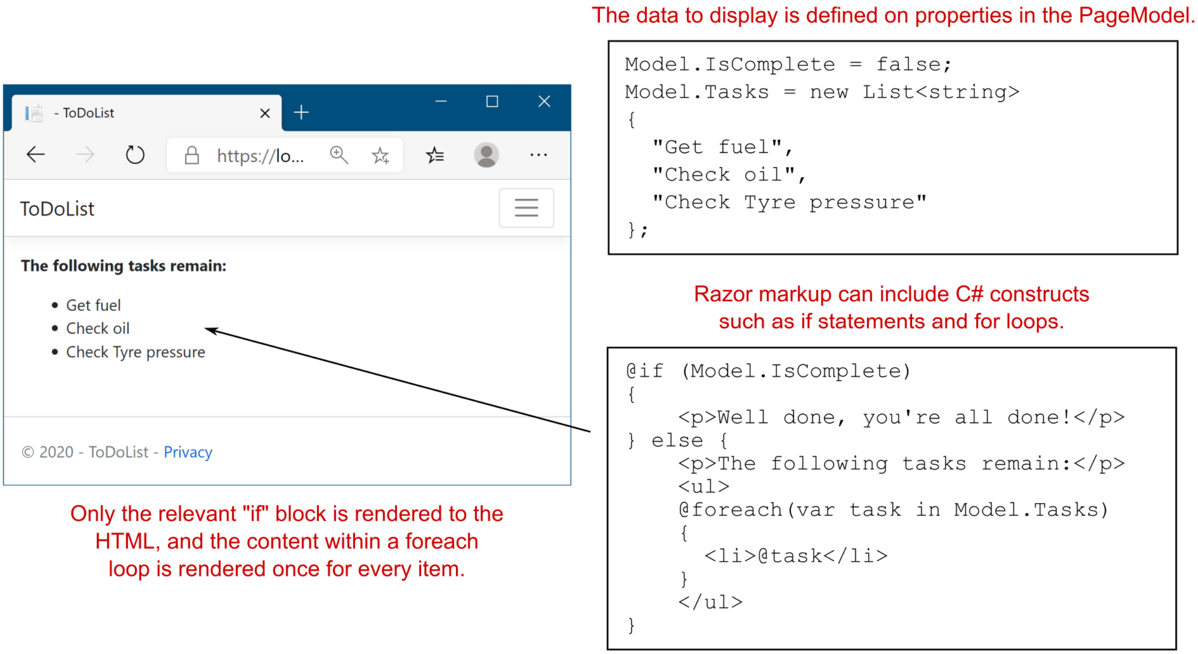
Listing 7.6 Razor template for rendering a `ToDoItemViewModel`

```
@page
@model ToDoItemModel                                          #A
<div>
    @if (Model.IsComplete)
    {                                                         #B
        <strong>Well done, you're all done!</strong>          #B
    }                                                         #B
    else
    {
        <strong>The following tasks remain:</strong>
        <ul>
            @foreach (var task in Model.Tasks)               #C
            {
                <li>@task</li>                               #D
            }
        </ul>
    }
</div>
```

#A The @model directive indicates the type of PageModel in Model.
#B The if control structure checks the value of the PageModel's IsComplete property at runtime.
#C The foreach structure will generate the <li> elements once for each task in Model.Tasks.
#D A razor expression is used to write the task to the HTML output.

This code definitely lives up to the promise of mixing C# and HTML! There are traditional C# control structures, like `if` and `foreach`, that you'd expect in any normal program, interspersed with the HTML markup that you want to send to the browser. As you can see, the `@` symbol is used to indicate when you're starting a control statement, but you generally let the Razor template infer when you're switching back and forth between HTML and C#.

The template shows how to generate dynamic HTML at runtime, depending on the exact data provided. If the model has outstanding `Tasks`, then the HTML will generate a list item for each task, producing output something like that shown in figure 7.6.



The data to display is defined on properties in the PageModel.

```
Model.IsComplete = false;
Model.Tasks = new List<string>
{
  "Get fuel",
  "Check oil",
  "Check Tyre pressure"
};
```

ToDoList

The following tasks remain:

- Get fuel
- Check oil
- Check Tyre pressure

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Razor markup can include C# constructs such as if statements and for loops.

```
@if (Model.IsComplete)
{
    <p>Well done, you're all done!</p>
} else {
    <p>The following tasks remain:</p>
    <ul>
    @foreach(var task in Model.Tasks)
    {
      <li>@task</li>
    }
    </ul>
}
```

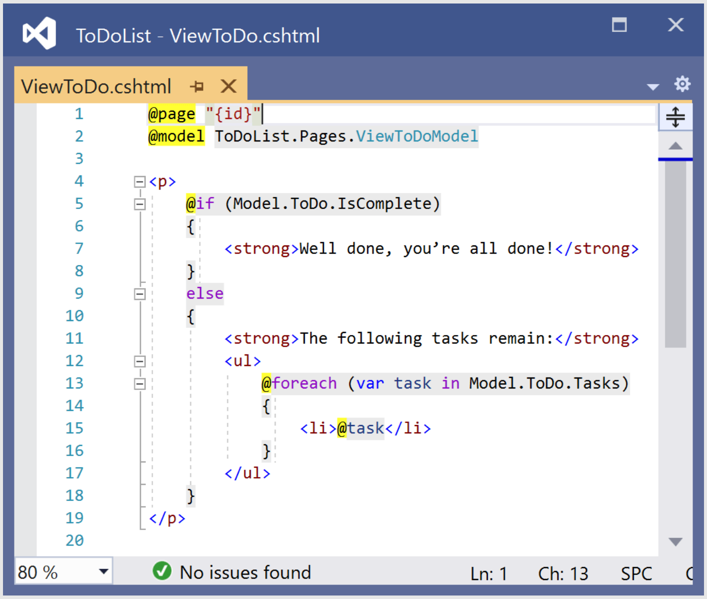
Only the relevant "if" block is rendered to the HTML, and the content within a foreach loop is rendered once for every item.

Figure 7.6 The Razor template generates a `<li>` item for each remaining task, depending on the data passed to the view at runtime. You can use an `if` block to render completely different HTML depending on the values in your model.

IntelliSense and tooling support

The mixture of C# and HTML might seem hard to read in the book, and that's a reasonable complaint. It's also another valid argument for trying to keep your Razor templates as simple as possible.

Luckily, if you’re using an editor like Visual Studio or Visual Studio Code, then the tooling can help somewhat. As you can see in this figure, the C# portions of the code are shaded to help distinguish them from the surrounding HTML.



```
@page "{id}"
@model ToDoList.Pages.ViewToDoModel

<p>
    @if (Model.ToDo.IsComplete)
    {
        <strong>Well done, you’re all done!</strong>
    }
    else
    {
        <strong>The following tasks remain:</strong>
        <ul>
            @foreach (var task in Model.ToDo.Tasks)
            {
                <li>@task</li>
            }
        </ul>
    }
</p>

```

Visual Studio shades the C# regions of code and highlights `@` symbols where C# transitions to HTML. This makes the Razor templates easier to read.

Although the ability to use loops and conditionals is powerful—they’re one of the advantages of Razor over static HTML—they also add to the complexity of your view. Try to limit the amount of logic in your views to make them as easy to understand and maintain as possible.

A common trope of the ASP.NET Core team is that they try to ensure you “fall into the pit of success” when building an application. This refers to the idea that, by default, the *easiest* way to do something should be the *correct* way of doing it. This is a great philosophy, as it means you shouldn’t get burned by, for example, security problems if you follow the standard approaches. Occasionally, however, you may need to step beyond the safety rails; a common use case is when you need to render some HTML contained in a C# object to the output, as you’ll see in the next section.

7.3.3 Rendering HTML with Raw

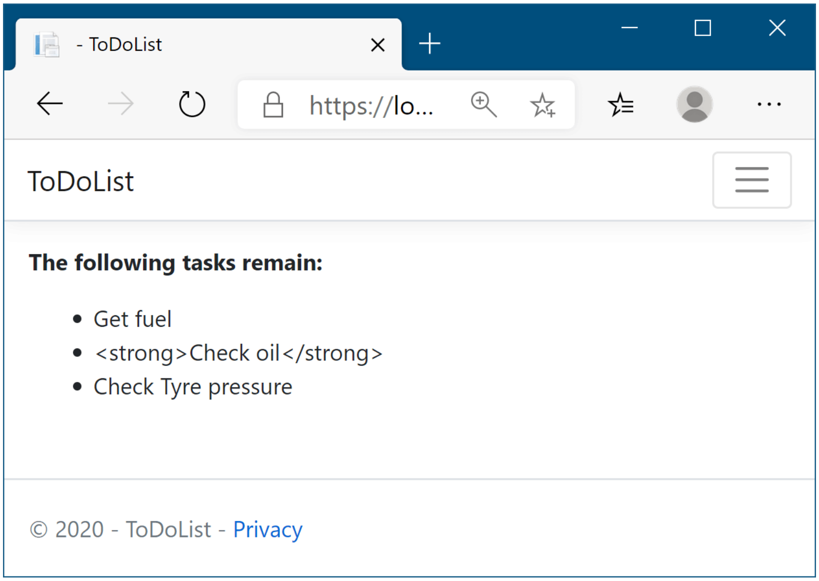
In the previous example, we rendered the list of tasks to HTML by writing the `string task` using the `@task` Razor expression. But what if the `task` variable contains HTML you want to display, so instead of `"Check oil"` it contains `"<strong>Check oil</strong>"`? If you use a Razor expression to output this as you did previously, then you might hope to get this:

```
<li><strong>Check oil</strong></li>
```

But that’s not the case. The HTML generated comes out like this:

```
<li>&lt;strong&gt;Check oil&lt;/strong&gt;</li>
```

Hmm, looks odd, right? What’s happened here? Why did the template not write your variable to the HTML, like it has in previous examples? If you look at how a browser displays this HTML, like in figure 7.7, then hopefully it makes more sense.



The following tasks remain:

- Get fuel
- <strong>Check oil</strong>
- Check Tyre pressure

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Figure 7.7 The second item, <strong>Check oil<strong> has been HTML-encoded, so the <strong> elements are visible to the user as part of the task. This avoids any security issues, as users can’t inject malicious scripts into your HTML.

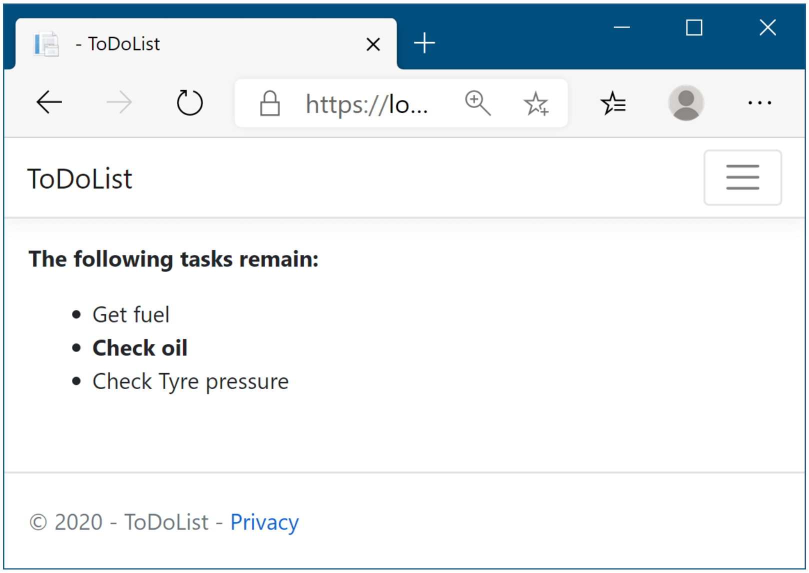
Razor templates encode C# expressions before they’re written to the output stream. This is primarily for security reasons; writing out arbitrary strings to your HTML could allow users to inject malicious data and JavaScript into your website. Consequently, the C# variables you print in your Razor template get written as HTML-encoded values.

In some cases, you might need to directly write out HTML contained in a `string` to the response. If you find yourself in this situation, first, stop. Do you *really* need to do this? If the values you’re writing have been entered by a user, or were created based on values provided by users, then there’s a serious risk of creating a security hole in your website.

If you *really* need to write the variable out to the HTML stream, then you can do so using the `Html` property on the view page and calling the `Raw` method:

```
<li>@Html.Raw(task)</li>
```

With this approach, the string in `task` will be directly written to the output stream, producing the HTML you originally wanted, `<li><strong>Check oil</strong></li>`, which renders as shown in figure 7.8.



The following tasks remain:

- Get fuel
- **Check oil**
- Check Tyre pressure

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Figure 7.8 The second item, "`<strong>Check oil<strong>`" has been output using `Html.Raw()`, so it hasn't been HTML encoded. The `<strong>` elements result in the second item being shown in bold instead. Using `Html.Raw()` in this way should be avoided where possible, as it is a security risk.

WARNING **Using `Html.Raw` on user input creates a security risk that users could use to inject malicious code into your website. Avoid using `Html.Raw` if possible!**

The C# constructs shown in this section can be useful, but they can make your templates harder to read. It's generally easier to understand the intention of Razor templates that are predominantly HTML markup rather than C#.

In the previous version of ASP.NET, these constructs, and in particular the `Html` helper property, were the standard way to generate dynamic markup. You can still use this approach in ASP.NET Core by using the various `HtmlHelper`[29] methods on the `Html` property, but these have largely been superseded by a cleaner technique: Tag Helpers.

NOTE **I'll discuss Tag Helpers, and how to use them to build HTML forms, in the next chapter.**

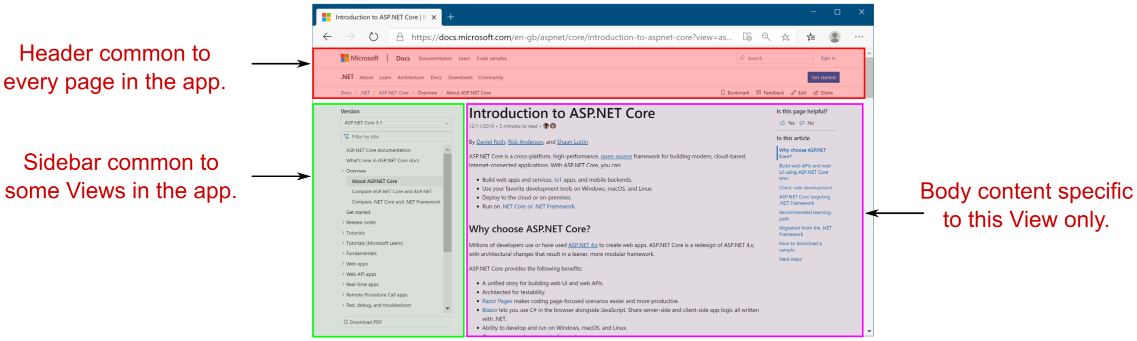
[29] **HTML Helpers are almost obsolete, though they're still available if you prefer to use them.**

Tag Helpers are a useful feature that's new to Razor in ASP.NET Core, but a number of other features have been carried through from the previous version of ASP.NET. In the next section of this chapter, you'll see how you can create nested Razor templates and use partial views to reduce the amount of duplication in your views.

7.4 Layouts, partial views, and _ViewStart

In this section you'll learn about layouts and partial views, which allow you to extract common code to reduce duplication. These files make it easier to make changes to your HTML that affect multiple pages at once. You'll also learn how to run common code for every Razor Page using _ViewStart and _ViewImports, and how to include optional sections in your pages.

Every HTML document has a certain number of elements that are required: `<html>`, `<head>`, and `<body>`. As well, there are often common sections that are repeated on every page of your application, such as the header and footer, as shown in figure 7.9. Each page on your application will also probably reference the same CSS and JavaScript files.


Header common to every page in the app.
Sidebar common to some Views in the app.
Body content specific to this View only.
Introduction to ASP.NET Core | M
https://docs.microsoft.com/en-gb/aspnet/core/introduction-to-aspnet-core?view=as...
Microsoft
Docs
Documentation
Learn
Code samples
Search
Sign in
.NET
About
Learn
Architecture
Docs
Downloads
Community
Get started
Docs / .NET / ASP.NET Core / Overview / About ASP.NET Core
Bookmark
Feedback
Edit
Share
Version
ASP.NET Core 3.1
Filter by title
ASP.NET Core documentation
What's new in ASP.NET Core docs
Overview
About ASP.NET Core
Compare ASP.NET Core and ASP.NET
Compare .NET Core and .NET Framework
Get started
Release notes
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Web apps
Web API apps
Real-time apps
Remote Procedure Call apps
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Is this page helpful?
Yes
No
In this article
Why choose ASP.NET Core?
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Client-side development
ASP.NET Core targeting .NET Framework
Recommended learning path
Migration from the .NET Framework
How to download a sample
Next steps

Introduction to ASP.NET Core

12/11/2019 • 5 minutes to read •

By Daniel Roth, Rick Anderson, and Shaun Luttin

ASP.NET Core is a cross-platform, high-performance, open-source framework for building modern, cloud-based, Internet-connected applications. With ASP.NET Core, you can:

- Build web apps and services, IoT apps, and mobile backends.
- Use your favorite development tools on Windows, macOS, and Linux.
- Deploy to the cloud or on-premises.
- Run on .NET Core or .NET Framework.

Why choose ASP.NET Core?

Millions of developers use or have used ASP.NET 4.x to create web apps. ASP.NET Core is a redesign of ASP.NET 4.x, with architectural changes that result in a leaner, more modular framework.

ASP.NET Core provides the following benefits:

- A unified story for building web UI and web APIs.
- Architected for testability.
- Razor Pages makes coding page-focused scenarios easier and more productive.
- Blazor lets you use C# in the browser alongside JavaScript. Share server-side and client-side app logic all written with .NET.
- Ability to develop and run on Windows, macOS, and Linux.

Figure 7.9 A typical web application has a block-based layout, where some blocks are common to every page of your application. The header block will likely be identical across your whole application, but the sidebar may only be identical for the pages in one section. The body content will differ for every page in your application.

All these different elements add up to a maintenance nightmare. If you had to manually include these in every view, then making any changes would be a laborious, error-prone process or manually editing every page. Instead, Razor lets you extract these common elements into *layouts*.

> **DEFINITION** A *layout* in Razor is a template that includes common code. It can't be rendered directly, but it can be rendered in conjunction with normal Razor views.

By extracting your common markup into layouts, you can reduce the duplication in your app. This makes changes easier, makes your views easier to manage and maintain, and is generally good practice!

7.4.1 Using layouts for shared markup

Layout files are, for the most part, normal Razor templates that contain markup common to more than one page. An ASP.NET Core app can have multiple layouts, and layouts can reference other layouts. A common use for this is to have different layouts for different sections of your application. For example, an e-commerce website might use a three-column view for most pages, but a single-column layout when you come to the checkout pages, as shown in figure 7.10.

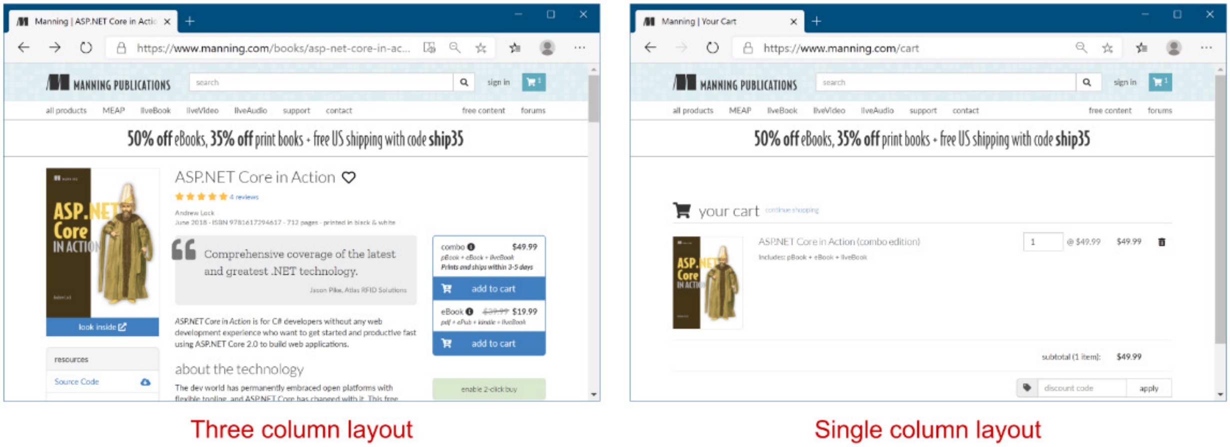

Manning | ASP.NET Core in Actio
https://www.manning.com/books/asp-net-core-in-ac...
MANNING PUBLICATIONS
50% off eBooks, 35% off print books + free US shipping with code ship35
ASP.NET Core in Action
add to cart
Three column layout
Manning | Your Cart
https://www.manning.com/cart
your cart
ASP.NET Core in Action (combo edition)
subtotal (1 item): $49.99
Single column layout

Figure 7.10 The https://manning.com website uses different layouts for different parts of the web application. The product pages use a three-column layout, but the cart page uses a single-column layout.

You'll often use layouts across many different Razor Pages, so they're typically placed in the Pages/Shared folder. You can name them anything you like, but there's a common convention to use _Layout.cshtml as the filename for the base layout in your application. This is the default name used by the Razor Page templates in Visual Studio and the .NET CLI.

> **TIP** A common convention is to prefix your layout files with an underscore (_) to distinguish them from standard Razor templates in your Pages folder.

A layout file looks similar to a normal Razor template, with one exception: every layout must call the `@RenderBody()` function. This tells the templating engine where to insert the content from the child views. A simple layout is shown in the following listing. Typically, your application will reference all your CSS and JavaScript files in the layout, as well as include all the common elements such as headers and footers, but this example includes pretty much the bare minimum HTML.

Listing 7.7 A basic Layout.cshtml file calling `RenderBody`

```
<!DOCTYPE html>
<html>
<head>
    <meta charset="utf-8" />
    <title>@ViewData["Title"]</title>                  #A
    <link rel="stylesheet" href="~/css/site.css" />    #B
</head>
<body>
    @RenderBody()                                      #C
</body>
</html>
```

#A ViewData is the standard mechanism for passing data to a layout from a view.
#B Elements common to every page, such as your CSS, are typically found in the layout.
#C Tells the templating engine where to insert the child view's content

As you can see, the layout file includes the required elements, such as `<html>` and `<head>`, as well as elements you need on every page, such as `<title>` and `<link>`. This example also shows the benefit of storing the page title in `ViewData`; the layout can render it in the `<title>` element so that it shows in the browser's tab, as shown in figure 7.11.

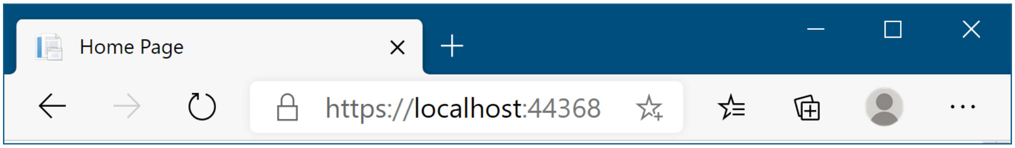


Figure 7.11 The contents of the `<title>` element is used to name the tab in the user's browser, in this case Home Page.

Views can specify a layout file to use by setting the `Layout` property inside a Razor code block.

Listing 7.8 Setting the `Layout` property from a view

```
@{
    Layout = "_Layout";                   #A
    ViewData["Title"] = "Home Page";      #B
}
<h1>@ViewData["Title"]</h1>               #C
<p>This is the home page</p>              #C
```

#A Set the layout for the page to _Layout.cshtml.
#B ViewData is a convenient way of passing data from a Razor view to the layout.
#C The content in the Razor view to render inside the layout

Any contents in the view will be rendered inside the layout, where the call to `@RenderBody()` occurs. Combining the two previous listings will result in the following HTML being generated and sent to the user.

Listing 7.9 Rendered output from combining a view with its layout

```
<!DOCTYPE html>
<html>
<head>
    <meta charset="utf-8" />
    <title>Home Page</title>                           #A
    <link rel="stylesheet" href="/css/site.css" />
</head>
<body>
    <h1>Home Page</h1>                                  #B
    <p>This is the home page</p>                           #B
</body>
<html>
```

#A ViewData set in the view is used to render the layout.
#B The RenderBody call renders the contents of the view.

Judicious use of layouts can be extremely useful in reducing the duplication on a page. By default, layouts only provide a single location where you can render content from the view, at the call to `@RenderBody`. In cases where this is too restrictive, you can render content using *sections*.

7.4.2 Overriding parent layouts using sections

A common requirement when you start using multiple layouts in your application is to be able to render content from child views in more than one place in your layout. Consider the case of a layout that uses two columns. The view needs a mechanism for saying "render *this* content in the *left* column" and "render this *other* content in the *right* column". This is achieved using *sections*.

> **NOTE** Remember, all of the features outlined in this chapter are specific to Razor, which is a server-side rendering engine. If you're using a client-side SPA framework to build your application, you'll likely handle these requirements in other ways, either within the client code or by making multiple requests to a Web API endpoint.

Sections provide a way of organizing where view elements should be placed within a layout. They're defined in the view using an `@section` definition, as shown in the following listing, which defines the HTML content for a sidebar separate from the main content, in a section called `Sidebar`. The `@section` can be placed anywhere in the file, top or bottom, wherever is convenient.

Listing 7.10 Defining a section in a view template

```
@{
    Layout = "_TwoColumn";
}
@section Sidebar {                            #A
    <p>This is the sidebar content</p>        #A
}                                             #A
```

```
<p>This is the main content </p>             #B
```

#A All content inside the braces is part of the Sidebar section, not the main body content.
#B Any content not inside an @section will be rendered by the @RenderBody call.

The section is rendered in the parent layout with a call to `@RenderSection()`. This renders the content contained in the child section into the layout. Sections can be either required or optional. If they're required, then a view *must* declare the given `@section`; if they're optional then they can be omitted, and the layout will skip it. Skipped sections won't appear in the rendered HTML. This listing shows a layout that has a required section called `Sidebar`, and an optional section called `Scripts`.

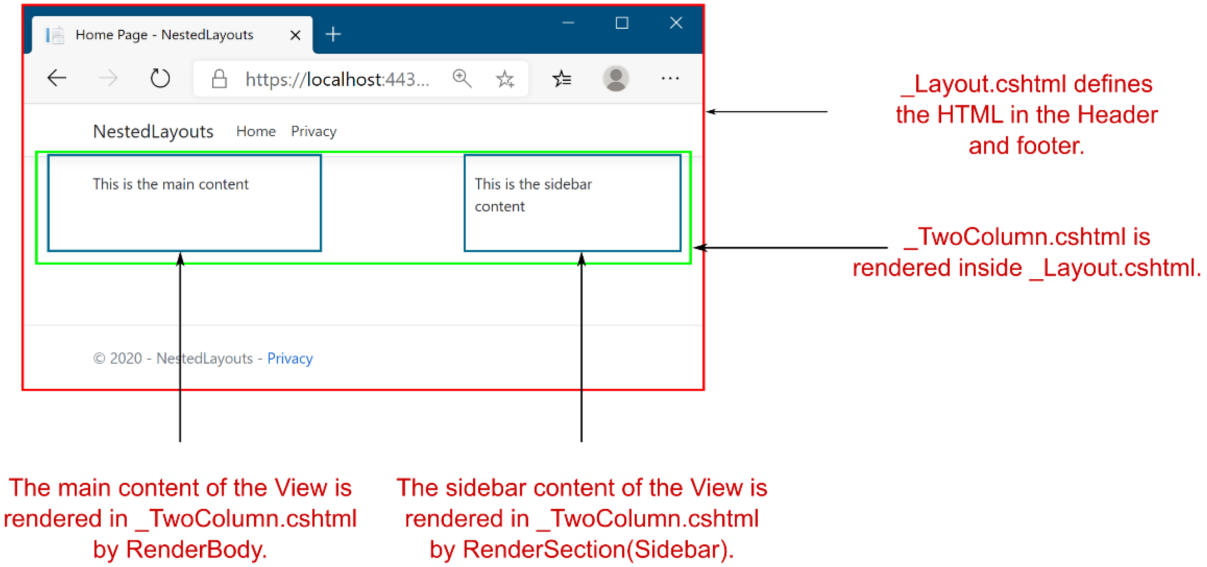
Listing 7.11 Rendering a section in a layout file, _TwoColumn.cshtml

```
@{
    Layout = "_Layout";                            #A
}
<div class="main-content">
    @RenderBody()                                  #B
</div>
<div class="side-bar">
    @RenderSection("Sidebar", required: true)      #C
</div>
@RenderSection("Scripts", required: false)         #D
```

#A This layout is nested inside a layout itself.
#B Renders all the content from a view that isn't part of a section
#C Renders the Sidebar section; if the Sidebar section isn't defined in the view, throws an error
#D Renders the Scripts section; if the Scripts section isn't defined in the view, ignore it.

> **TIP** It's common to have an optional section called `Scripts` in your layout pages. This can be used to render additional JavaScript that's required by some views, but that isn't needed on every view. A common example is the jQuery Unobtrusive Validation scripts for client-side validation. If a view requires the scripts, it adds the appropriate `@section Scripts` to the Razor markup.

You may notice that the previous listing defines a `Layout` property, even though it's a layout itself, not a view. This is perfectly acceptable, and lets you create nested hierarchies of layouts, as shown in figure 7.12.


Home Page - NestedLayouts
https://localhost:443...
NestedLayouts
Home
Privacy
This is the main content
This is the sidebar content
© 2020 - NestedLayouts - Privacy

_Layout.cshtml defines the HTML in the Header and footer.

_TwoColumn.cshtml is rendered inside _Layout.cshtml.

The main content of the View is rendered in _TwoColumn.cshtml by RenderBody.

The sidebar content of the View is rendered in _TwoColumn.cshtml by RenderSection(Sidebar).

Figure 7.12 Multiple layouts can be nested to create complex hierarchies. This allows you to keep the elements common to all views in your base layout and extract layout common to multiple views into sub-layouts.

> **TIP** **Most websites these days need to be “responsive”, so they work on a wide variety of devices. You generally *shouldn’t* use layouts for this. Don’t serve different layouts for a single page based on the device making the request. Instead, serve the same HTML to all devices, and use CSS on the client-side to adapt the display of your web page as required.**

Layout files and sections provide a lot of flexibility to build sophisticated UIs, but one of their most important uses is in reducing the duplication of code in your application. They’re perfect for avoiding duplication of content that you’d need to write for every view. But what about those times when you find you want to reuse part of a view somewhere else? For those cases, you have partial views.

7.4.3 Using partial views to encapsulate markup

Partial views are exactly what they sound like—they’re part of a view. They provide a means of breaking up a larger view into smaller, reusable chunks. This can be useful for both reducing the complexity in a large view by splitting it into multiple partial views, or for allowing you to reuse part of a view inside another.

Most web frameworks that use server-side rendering have this capability—Ruby on Rails has partial views, Django has inclusion tags, and Zend has partials. All of these work in the same way, extracting common code into small, reusable templates. Even client-side templating engines such as Mustache and Handlebars used by client-side frameworks like Angular and Ember have similar “partial view” concepts.

Consider a to-do list application again. You might find you have a Razor Page called ViewToDo.cshtml that displays a single to-do with a given `id`. Later on, you create a new Razor Page, RecentToDos.cshtml, that displays the five most recent to-do items. Instead of copying and pasting the code from one page to the other, you could create a partial view, called _ToDo.cshtml.

Listing 7.12 Partial view _ToDo.cshtml for displaying a `ToDoItemViewModel`

```
@model ToDoItemViewModel                    #A
<h2>@Model.Title</h2>                       #B
<ul>                                        #B
    @foreach (var task in Model.Tasks)      #B
    {                                       #B
        <li>@task</li>                      #B
    }                                       #B
</ul>                                       #B
```

#A Partial views can bind to data in the Model property, like a normal Razor Page uses a PageModel.
#B The content of the partial view, which previously existed in the ViewToDo.cshtml file

Partial views are a bit like Razor Pages without the `PageModel` and handlers. Partial views are purely about rendering small sections of HTML, rather than handling requests, model binding and validation, and calling the application model. They are great for encapsulating small usable bits of HTML that you need to generate on multiple Razor Pages.

Both the ViewToDo.cshtml and RecentToDos.cshtml Razor Pages can render the _ToDo .cshtml partial view, which handles generating the HTML for a single class. Partial views are rendered using the `<partial />` Tag Helper, providing the name of the partial view to render, and the data (the model) to render. For example, the RecentToDos.cshtml view could achieve this as shown in the following listing.

Listing 7.13 Rendering a partial view from a Razor Page

```
@page                                                #A
@model RecentToDoListModel                           #B

@foreach(var todo in Model.RecentItems)              #C
{
    <partial name="_ToDo" model="todo" />            #D
}
```

#A This is a Razor Page, so it uses the @page directive. Partial views do not use @page.
#B The PageModel contains the list of recent items to render
#C Loop through the recent items. todo is a ToDoItemViewModel, as required by the partial view.
#D Use the partial tag helper to render the _ToDo partial view, passing in the model to render.

When you render a partial view without providing an absolute path or file extension, for example _ToDo in listing 7.13, the framework tries to locate the view by searching the Pages folder, starting from the Razor Page that invoked it. For example, if your Razor Page is located at Pages/Agenda/ToDos/RecentToDos.chstml, the framework would look in the following places for a file called _ToDo.chstml:

- Pages/Agenda/ToDos/ (the current Razor Page's folder)
- Pages/Agenda/
- Pages/
- Pages/Shared/
- Views/Shared/

The first location that contains a file called _ToDo.cshtml will be selected. If you include the cshtml file extension when you reference the partial view, the framework will *only* look in the current Razor Page's folder. Also, if you provide an absolute path to the partial, such as /Pages/Agenda/ToDo.cshtml, then that's the only place the framework will look.[30]

NOTE Like layouts, partial views are typically named with a leading underscore.

The Razor code contained in a partial view is almost identical to a standard view. The main difference is the fact that partial views are only called from other views. The other difference is that partial views don't run _ViewStart.cshtml when they execute, which you'll see shortly.

Child actions in ASP.NET Core

In the previous version of ASP.NET MVC, there was the concept of a *child action*. This was an action method that could be invoked *from inside a view*. This was the main mechanism for rendering discrete sections of a complex layout that had nothing to do with the main action method. For example, a child action method might render the shopping cart on an e-commerce site.

This approach meant you didn't have to pollute every page's view model with the view model items required to render the shopping cart, but it fundamentally broke the MVC design pattern, by referencing controllers from a view.

In ASP.NET Core, child actions are no more. *View components* have replaced them. These are conceptually quite similar in that they allow both the execution of arbitrary code and the rendering of HTML, but they don't directly invoke controller actions. You can think of them as a more powerful partial view that you should use anywhere a partial view needs to contain significant code or business logic. You'll see how to build a small view component in chapter 19.

Partial views aren't the only way to reduce duplication in your view templates. Razor also allows you to pull common elements such as namespace declarations and layout configuration into centralized files. In the next section, you'll see how to wield these files to clean up your templates.

[30] As with most of Razor Pages, the search locations are conventions that you can customize if you wish. If you find the need, you can customize the paths as shown here https://www.learnrazorpages.com/razor-pages/partial-pages#naming-and-locating-partial-pages.

7.4.4 Running code on every view with _ViewStart and _ViewImports

Due to the nature of views, you'll inevitably find yourself writing certain things repeatedly. If all of your views use the same layout, then adding the following code to the top of every page feels a little redundant:

```
@{
    Layout = "_Layout";
}
```

Similarly, if you find you need to reference objects from a different namespace in your Razor views, then having to add `@using WebApplication1.Models` to the top of every page can get to be a chore. Thankfully, ASP.NET Core includes two mechanisms for handling these common tasks: `_ViewImports.cshtml` and `_ViewStart.cshtml`.

IMPORTING COMMON DIRECTIVES WITH _VIEWIMPORTS

The _ViewImports.cshtml file contains directives that will be inserted at the top of every view. This includes things like the `@using` and `@model` statements that you've already seen—basically any Razor directive. To avoid adding a using statement to every view, you can include it in here instead.

Listing 7.13 A typical _ViewImports.cshtml file importing additional namespaces

```
@using WebApplication1                                     #A
@using WebApplication1.Pages                               #A
@using WebApplication1.Models                                #B
@addTagHelper *, Microsoft.AspNetCore.Mvc.TagHelpers       #C
```

#A The default namespace of your application and the Pages folder
#B Add this directive to avoid placing it in every view
#C Makes Tag Helpers available in your views, added by default

The _ViewImports.cshtml file can be placed in any folder, and it will apply to all views and sub-folders in that folder. Typically, it's placed in the root Pages folder so that it applies to every Razor Page and partial view in your app.

It's important to note that you should *only* put Razor directives in _ViewImports.cshtml—you can't put any old C# in there. As you can see in the previous listing, this is limited to things like `@using` or the `@addTagHelper` directive that you'll learn about in the next chapter. If you want to run some arbitrary C# at the start of every view in your application, for example to set the `Layout` property, then you should use the _ViewStart.cshtml file instead.

RUNNING CODE FOR EVERY VIEW WITH _VIEWSTART

You can easily run common code at the start of every Razor Page by adding a _ViewStart.cshtml file to the Pages folder in your application. This file can contain any Razor code, but it's typically used to set the `Layout` for all the pages in your application, as shown in the following listing. You can then omit the `Layout` statement from all pages that use the default layout. If a view needs to use a nondefault layout then you can override it by setting the value in the Razor page itself.

Listing 7.14 A typical _ViewStart.cshtml file setting the default layout

```
@{
    Layout = "_Layout";
}
```

Any code in the _ViewStart.cshtml file runs before the view executes. Note that _ViewStart.cshtml only runs for Razor Page views—it doesn't run for layouts or partials views. Also, note that the names for these special Razor files are enforced rather than conventions you can change.

> **WARNING** You must use the names _ViewStart.cshtml and _ViewImports .cshtml for the Razor engine to locate and execute them correctly. To apply them to all your app's pages, add them to the root of the Pages folder, not to the Shared subfolder.

You can specify additional _ViewStart.cshtml or _ViewImports.cshtml files to run for a subset of your views by including them in a subfolder in Pages. The files in the subfolders will run after the files in the root Pages folder.

Partial views, layouts, and AJAX

This chapter describes using Razor to render full HTML pages server-side, which are then sent to the user's browser in traditional web apps. A common alternative approach when building web apps is to use a JavaScript client-side framework to build a Single Page Application (SPA), which renders the HTML client-side in the browser.

One of the technologies SPAs typically use is AJAX (Asynchronous JavaScript and XML), in which the browser sends requests to your ASP.NET Core app without reloading a whole new page. It's also possible to use AJAX requests with apps that use server-side rendering. To do so, you'd use JavaScript to request an update for part of a page.

If you want to use AJAX with an app that uses Razor, you should consider making extensive use of partial views. You can then expose these via additional Razor Page handlers, as shown in this article https://www.learnrazorpages.com/razor-pages/ajax/partial-update. Using AJAX can reduce the overall amount of data that needs to be sent back and forth between the browser and your app, and it can make your app feel smoother and more responsive, as it requires fewer full-page loads. But using AJAX with Razor can add complexity, especially for larger apps. If you foresee yourself making extensive use of AJAX to build a highly dynamic web app, you might want to consider using Web API controllers with a client-side framework (see chapter 9), or consider Blazor instead.

In this chapter I've focused on using Razor views with the Razor Page framework, as that's the approach I suggest if you're creating a server-side rendered ASP.NET Core application. However, as I described in chapter 4, you may want to use MVC controllers in some cases. In the final section of this chapter we look at how you can render Razor views from your MVC controller actions, and how the framework locates the correct Razor view to render.

7.5 Selecting a view from an MVC controller

This section covers:

- How MVC controllers use `ViewResult`s to render Razor views
- How to create a new Razor view
- How the framework locates a Razor view to render

If you follow my advice from chapter 4, then you should be using Razor Pages for your server-side rendered applications instead of the MVC controllers that were common in versions 1.x and 2.0. One of the big advantages Razor Pages gives is the close coupling of a Razor view to the associated page handlers, instead of having to navigate between multiple folders in your solution.

If for some reason you *do* need to use MVC controllers instead of Razor Pages, then it's important to understand how you choose which view to render once an action method has executed. Figure 7.13 shows a zoomed-in view of this process, right after the action has invoked the application model and received some data back.

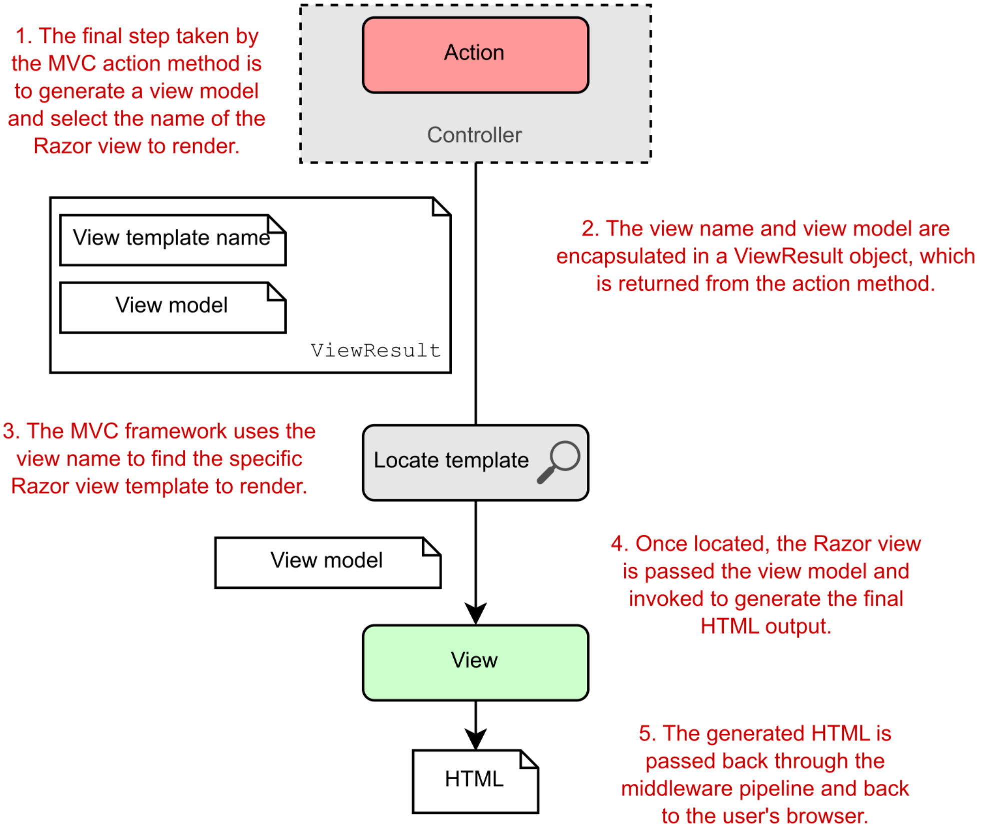

1. The final step taken by the MVC action method is to generate a view model and select the name of the Razor view to render.
Action
Controller
View template name
View model
ViewResult
2. The view name and view model are encapsulated in a ViewResult object, which is returned from the action method.
3. The MVC framework uses the view name to find the specific Razor view template to render.
Locate template
View model
4. Once located, the Razor view is passed the view model and invoked to generate the final HTML output.
View
HTML
5. The generated HTML is passed back through the middleware pipeline and back to the user's browser.

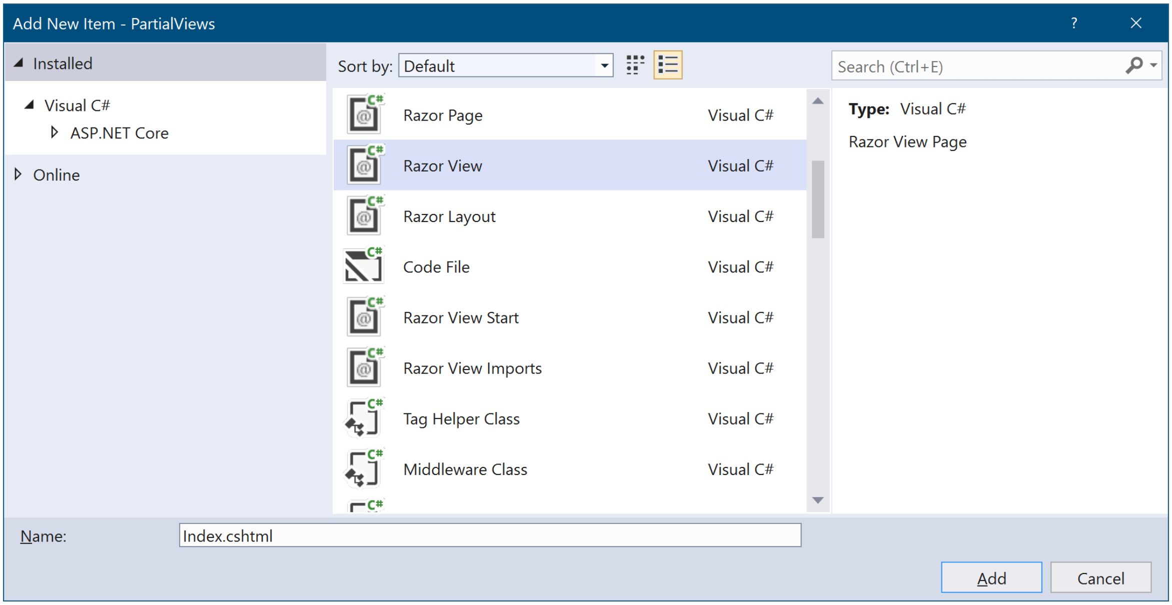
Figure 7.13 The process of generating HTML from an MVC controller using a ViewResult. This is very similar to the process for a Razor Page. The main difference is that for Razor Pages, the view is an integral part of the Razor Page; for MVC controllers, the view must be located at runtime.

Some of this figure should be familiar—it’s the lower half of figure 4.7 from chapter 4 (with a couple of additions) and is the MVC equivalent of figure 7.1. It shows that the MVC controller action method uses a `ViewResult` object to indicate that a Razor view should be rendered. This `ViewResult` contains the name of the Razor view template to render and a view model, an arbitrary POCO class containing the data to render.

> **NOTE** I discussed `ViewResult`s in chapter 4. They are the MVC equivalent of Razor Page’s `PageResult`. The main difference is that a `ViewResult` includes a view name to render and a model to pass to the view template, while a `PageResult` always renders the Razor Page’s associated view and passes the `PageModel` to the view template.

After returning a ViewResult from an action method, the control flow passes back to the MVC framework, which uses a series of heuristics to locate the view, based on the template name provided. Once a Razor view template has been located, the Razor engine passes the view model from the ViewResult to the view and executes the template to generate the final HTML. This final step, rendering the HTML, is essentially the same process as for Razor Pages.

You saw how to create controllers in chapter 4, and in this section, you'll see how to create views and ViewResult objects and how to specify the template to render. You can add a new view template to your application in Visual Studio by right-clicking in an MVC application in Solution Explorer and choosing Add > New Item, and selecting Razor View from the dialog, as shown in figure 7.14. If you aren't using Visual Studio, create a blank new file in the Views folder with the file extension .cshtml.



Sort by: Default

Type: Visual C#

Razor View Page

Name: Index.cshtml

Figure 7.14 The Add New Item dialog. Choosing Razor View will add a new Razor view template file to your application.

With your view template created, you now need to invoke it. In most cases, you won't create a ViewResult directly in your action methods. Instead, you'll use one of the View helper methods on the Controller base class. These helper methods simplify passing in a view model and selecting a view template, but there's nothing magic about them—all they do is create ViewResult objects.

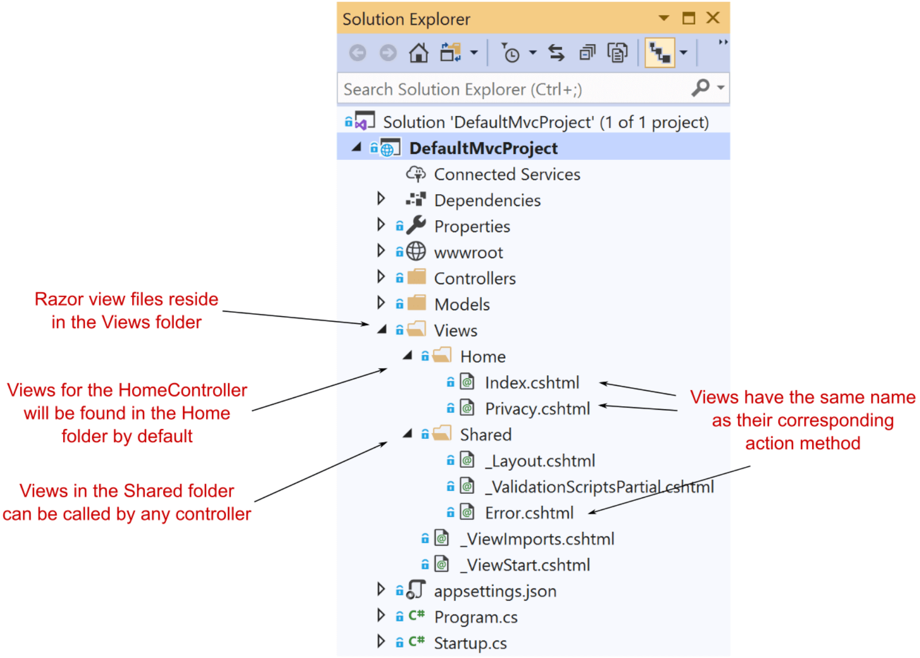
In the simplest case, you can call the View method without any arguments, as shown in the listing below. This helper method returns a ViewResult that will use conventions to find the view template to render, and will not supply a view model when executing the view.

Listing 7.15 Returning `ViewResult` from an action method using default conventions

```
public class HomeController : Controller         #A
{
    public IActionResult Index()
    {
        return View();                            #B
    }
}
```

#A Inheriting from the Controller base class makes the View helper methods available.
#B The View helper method returns a ViewResult.

In this example, the `View` helper method returns a `ViewResult` without specifying the name of a template to run. Instead, the name of the template to use is based on the name of the controller and the name of the action method. Given that the controller is called `HomeController` and the method is called `Index`, by default the Razor template engine looks for a template at the Views/Home/Index.cshtml location, as shown in figure 7.15.



Solution Explorer
Search Solution Explorer (Ctrl+;)
Solution 'DefaultMvcProject' (1 of 1 project)
DefaultMvcProject
Connected Services
Dependencies
Properties
wwwroot
Controllers
Models
Views
Home
Index.cshtml
Privacy.cshtml
Shared
_Layout.cshtml
_ValidationScriptsPartial.cshtml
Error.cshtml
_ViewImports.cshtml
_ViewStart.cshtml
appsettings.json
Program.cs
Startup.cs
Razor view files reside in the Views folder
Views for the HomeController will be found in the Home folder by default
Views in the Shared folder can be called by any controller
Views have the same name as their corresponding action method

Figure 7.15 View files are located at runtime based on naming conventions. Razor view files reside in a folder based on the name of the associated MVC controller and are named with the name of the action method that requested it. Views in the Shared folder can be used by any controller.

This is another case of using conventions in MVC to reduce the amount of boilerplate you have to write. As always, the conventions are optional. You can also explicitly pass the name of the template to run as a `string` to the `View` method. For example, if the `Index` method instead returned `View("ListView")`, then the templating engine would look for a template called ListView.cshtml instead. You can even specify the complete path to the view file, relative to your application's root folder, such as `View("Views/global.cshtml")`, which would look for the template at the Views/global.chtml location.

> **NOTE** When specifying the absolute path to a view, you must include both the top-level Views folder and the cshtml file extension in the path. This is similar to the rules for locating partial view templates.

The process of locating an MVC Razor view is very similar to the process of locating a partial view to render, as you saw in section 7.4. The framework searches in multiple locations to find the requested view. The difference is that for Razor Pages the search process only happens for *partial* view rendering, as the main Razor view to render is already known—it's the Razor Page's view template.

Figure 7.16 shows the complete process used by the MVC framework to locate the correct View template to execute when a `ViewResult` is returned from an MVC controller. It's possible for more than one template to be eligible, for example if an Index.chstml file exists in both the Home and Shared folders. Similar to the rules for locating partial views, the engine will use the first template it finds.

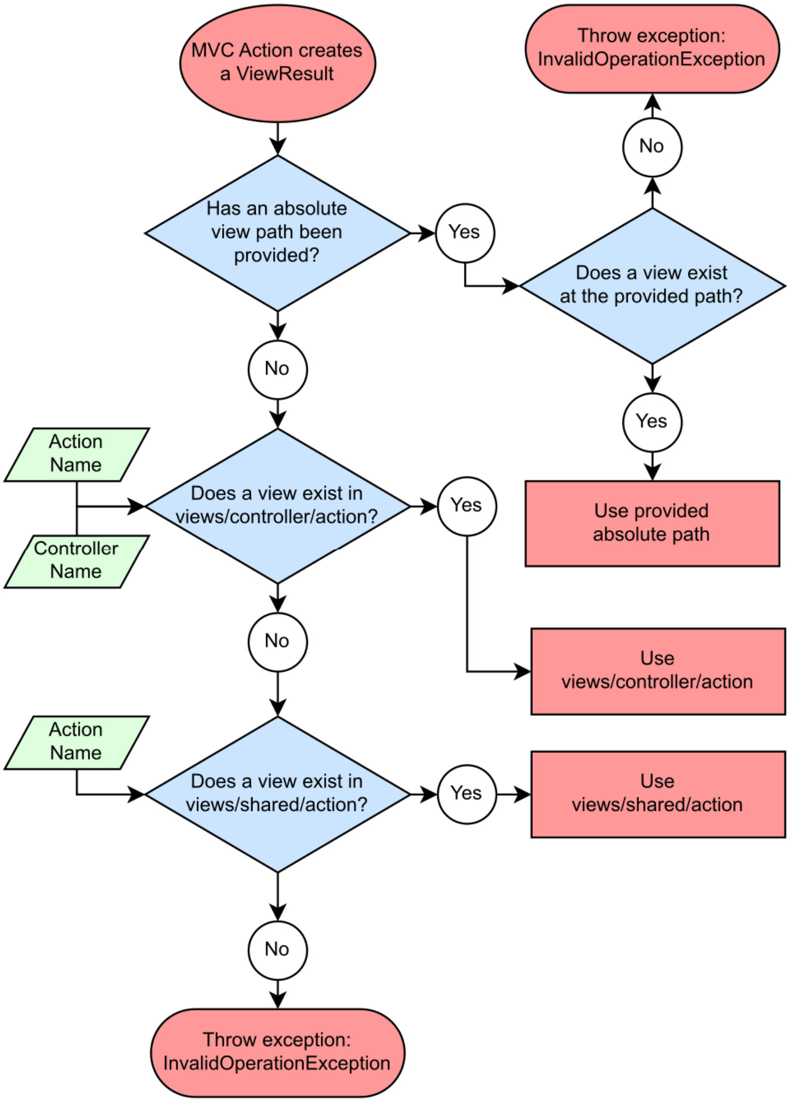

MVC Action creates a ViewResult
Has an absolute view path been provided?
Yes
No
Does a view exist at the provided path?
No
Throw exception: InvalidOperationException
Yes
Use provided absolute path
Action Name
Controller Name
Does a view exist in views/controller/action?
Yes
Use views/controller/action
No
Action Name
Does a view exist in views/shared/action?
Yes
Use views/shared/action
No
Throw exception: InvalidOperationException

Figure 7.16 A flow chart describing how the Razor templating engine locates the correct view template to execute. Avoiding the complexity of this diagram is one of the reasons I recommend using Razor Pages wherever possible!

> **TIP** You can modify all these conventions, including the algorithm shown in figure 7.16, during initial configuration. In fact, you can replace the whole Razor templating engine if required, but that's beyond the scope of this book.

You may find it tempting to explicitly provide the name of the view file you want to render in your controller; if so, I'd encourage you to fight that urge. You'll have a much simpler time if you embrace the conventions as they are and go with the flow. That extends to anyone else who looks at your code; if you stick to the standard conventions, then there'll be a comforting familiarity when they look at your app. That can only be a good thing!

As well as providing a view template name, you can also pass an object to act as the view model for the Razor view. This object should match the type specified in the view's `@model` directive, and is accessed in exactly the same way as for Razor Pages; using the `Model` property. The listing below shows two examples of passing a view model to a view.

Listing 7.15 Returning `ViewResult` from an action method using default conventions

```
public class ToDoController : Controller
{
    public IActionResult Index()
    {
        var listViewModel = new ToDoListMdel();      #A
        return View(listViewModel);                  #B
    }

    public IActionResult View(int id)
    {
        var viewModel = new ViewToDoModel();
        return View("ViewToDo", viewModel);          #C
    }

}
```

#A Creating an instance of the view model to pass to the Razor view.
#B The view model is passed as an argument to View
#C You can provide the view template name at the same time as the view model.

Once the Razor view template has been located, the view is rendered using the Razor syntax you've seen throughout this chapter. You can use all the features you've already seen—layouts, partial views, _ViewImports, and _ViewStart for example. From the point of the view of the Razor view, there's no difference between a Razor Pages view and an MVC Razor view.

That concludes our first look at rendering HTML using the Razor templating engine. In the next chapter, you'll learn about Tag Helpers and how to use them to build HTML forms, a staple of modern web applications. Tag Helpers are one of the biggest improvements to Razor in ASP.NET Core over the previous version, so getting to grips with them will make editing your views an overall more pleasant experience!

7.6 Summary

- In the MVC design pattern, views are responsible for generating the UI for your application.
- Razor is a templating language that allows you to generate dynamic HTML using a mixture of HTML and C#.

- HTML forms are the standard approach for sending data from the browser to the server. You can use Tag Helpers to easily generate these forms.
- Razor Pages can pass strongly-typed data to a Razor view by setting public properties on the `PageModel`. To access the properties on the view model, the view should declare the model type using the `@model` directive.
- Page handlers can pass key-value pairs to the view using the `ViewData` dictionary.
- Razor expressions render C# values to the HTML output using `@` or `@()`. You don’t need to include a semicolon after the statement when using Razor expressions.
- Razor code blocks, defined using `@{}`, execute C# without outputting HTML. The C# in Razor code blocks must be complete statements, so it must include semicolons.
- Loops and conditionals can be used to easily generate dynamic HTML in templates, but it’s a good idea to limit the number of `if` statements in particular, to keep your views easy to read.
- If you need to render a `string` as raw HTML you can use `Html.Raw`, but do so sparingly—rendering raw user input can create a security vulnerability in your application.
- Tag Helpers allow you to bind your data model to HTML elements, making it easier to generate dynamic HTML while staying editor friendly.
- You can place HTML common to multiple views in a layout. The layout will render any content from the child view at the location `@RenderBody` is called.
- Encapsulate commonly used snippets of Razor code in a partial view. A partial view can be rendered using the `<partial />` tag.
- _ViewImports.cshtml can be used to include common directives, such as `@using` statements, in every view.
- _ViewStart.cshtml is called before the execution of each Razor Page and can be used to execute code common to all Razor Pages, such as setting a default layout page. It doesn’t execute for layouts or partial views.
- _ViewImports.cshtml and _ViewStart.cshtml are hierarchical—files in the root folder execute first, followed by files in controller-specific view folders.
- Controllers can invoke a Razor view by returning a `ViewResult`. This may contain the name of the view to render and optionally a view model object to use when rendering the view. If the view name is not provided, a view is chosen using conventions.
- By convention, MVC Razor views are named the same as the action method that invokes them. They reside either in a folder with the same name as the action method’s controller or in the Shared folder.

8

Building forms with Tag Helpers

This chapter covers

- **Building forms easily with Tag Helpers**
- **Generating URLs with the Anchor Tag Helper**
- **Using Tag Helpers to add functionality to Razor**

In chapter 7, you learned about Razor templates and how to use them to generate the views for your application. By mixing HTML and C#, you can create dynamic applications that can display different data based on the request, the logged-in user, or any other data you can access.

Displaying dynamic data is an important aspect of many web applications, but it's typically only one half of the story. As well as displaying data to the user, you often need the user to be able to submit data *back* to your application. You can use data to customize the view, or to update the application model by saving it to a database, for example. For traditional web applications, this data is usually submitted using an HTML form.

In chapter 6, you learned about model binding, which is how you *accept* the data sent by a user in a request and convert it into C# objects that you can use in your Razor Pages. You also learned about validation, and how important it is to validate the data sent in a request. You used `DataAnnotations` to define the rules associated with your models, as well as other associated metadata like the display name for a property.

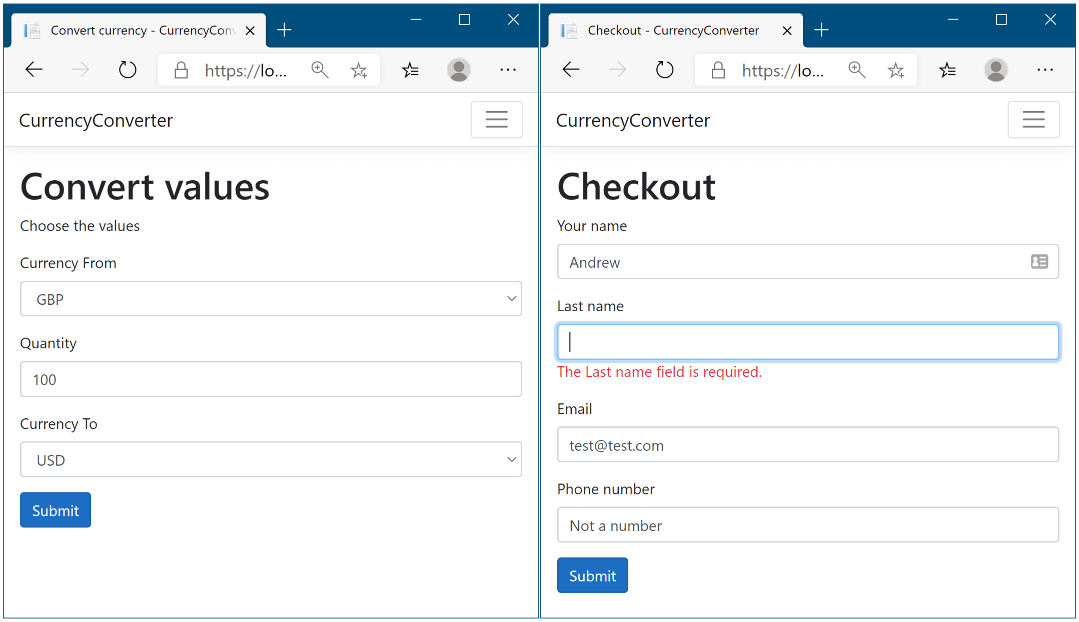
The final aspect we haven't yet looked at is how to *build* the HTML forms that users use to send this data in a request. Forms are one of the key ways users will interact with your application in the browser, so it's important they're both correctly defined for your application and also user friendly. ASP.NET Core provides a feature to achieve this, called *Tag Helpers*.

Tag Helpers are new to ASP.NET Core. They're additions to Razor syntax that you can use to customize the HTML generated in your templates. Tag Helpers can be added to an otherwise standard HTML element, such as an `<input>`, to customize its attributes based on your C# model, saving you from having to write boilerplate code. Tag Helpers can also be standalone elements and can be used to generate completely customized HTML.

> **NOTE** **Remember, Razor, and therefore Tag Helpers, are for server-side HTML rendering. You can't use Tag Helpers directly in frontend frameworks like Angular or React.**

If you've used the previous version of ASP.NET, then Tag Helpers may sound reminiscent of HTML Helpers, which could also be used to generate HTML based on your C# classes. Tag Helpers are the logical successor to HTML Helpers, as they provide a more streamlined syntax than the previous, C#-focused helpers. HTML Helpers are still available in ASP.NET Core, so if you're converting some old templates to ASP.NET Core you can still use them in your templates, but I won't be covering them in this book.

In this chapter, you'll primarily learn how to use Tag Helpers when building forms. They simplify the process of generating correct element names and IDs so that model binding can occur seamlessly when the form is sent back to your application. To put them into context, you're going to carry on building the currency converter application that you've seen in previous chapters. You'll add the ability to submit currency exchange requests to it, validate the data, and redisplay errors on the form using Tag Helpers to do the leg work for you, as shown in figure 8.1.



Convert values

Choose the values

Currency From: GBP

Quantity: 100

Currency To: USD

Submit

Checkout

Your name: Andrew

Last name:

The Last name field is required.

Email: test@test.com

Phone number: Not a number

Submit

Figure 8.1 The currency converter application forms, built using Tag Helpers. The labels, dropdowns, input elements, and validation messages are all generated using Tag Helpers.

As you develop the application, you'll meet the most common Tag Helpers you'll encounter when working with forms. You'll also see how you can use Tag Helpers to simplify other common tasks, such as generating links, conditionally displaying data in your application, and ensuring users see the latest version of an image file when they refresh their browser.

To start, I'll talk a little about why you need Tag Helpers when Razor can already generate any HTML you like by combining C# and HTML in a file.

8.1 Catering to editors with Tag Helpers

One of the common complaints about the mixture of C# and HTML in Razor templates is that you can't easily use standard HTML editing tools with them; all the `@` and `{}` symbols in the C# code tend to confuse the editors. Reading the templates can be similarly difficult for people; switching paradigms between C# and HTML can be a bit jarring sometimes.

This arguably wasn't such a problem when Visual Studio was the only supported way to build ASP.NET websites, as it could obviously understand the templates without any issues, and helpfully colorize the editor. But with ASP.NET Core going cross-platform, the desire to play nicely with other editors reared its head again.

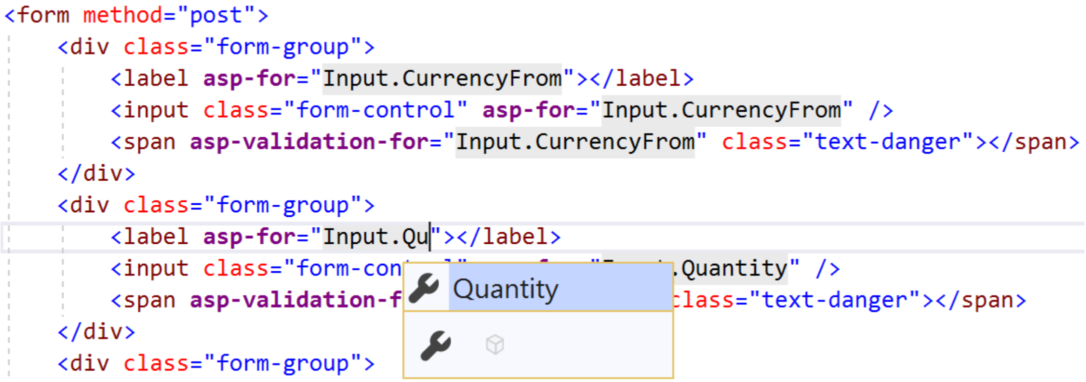
This was one of the big motivations for Tag Helpers. They integrate seamlessly into the standard HTML syntax by adding what look to be attributes, typically starting with `asp-*`. They're most often used to generate HTML forms, as shown in the following listing. This listing shows a view from the first iteration of the currency converter application, in which you choose the currencies and quantity to convert.

Listing 8.1 User registration form using Tag Helpers

```
@page                                                               #A
@model ConvertModel                                                 #A
<form method="post">
    <div class="form-group">
        <label asp-for="CurrencyFrom"></label>                      #B
        <input class="form-control" asp-for="CurrencyFrom" />       #C
        <span asp-validation-for="CurrencyFrom"></span>             #D
    </div>
    <div class="form-group">
        <label asp-for="Quantity"></label>                          #B
        <input class="form-control" asp-for="Quantity" />           #C
        <span asp-validation-for="Quantity"></span>                 #D
    </div>
    <div class="form-group">
        <label asp-for="CurrencyTo"></label>                        #B
        <input class="form-control" asp-for="CurrencyTo" />         #C
        <span asp-validation-for="CurrencyTo"></span>               #D
    </div>
    <button type="submit" class="btn btn-primary">Submit</button>
</form>
```

#A This is the view for the Razor Page Convert.cshtml. The Model type is ConvertModel.
#B asp-for on Labels generates the caption for labels based on the view model.
#C asp-for on Inputs generate the correct type, value, name, and validation attributes for the model.
#D Validation messages are written to a span using Tag Helpers.

At first glance, you might not even spot the Tag Helpers, they blend in so well with the HTML! This makes it easy to edit the files with any standard HTML text editor. But don't be concerned that you've sacrificed readability in Visual Studio—as you can see in figure 8.2, elements with Tag Helpers are clearly distinguishable from the standard HTML `<div>` element and the standard HTML `class` attribute on the `<input>` element. The C# properties of the view model being referenced (`CurrencyFrom`, in this case) are also still shaded, as with other C# code in Razor files. And of course, you get IntelliSense, as you'd expect.[31]



```
<form method="post">
    <div class="form-group">
        <label asp-for="Input.CurrencyFrom"></label>
        <input class="form-control" asp-for="Input.CurrencyFrom" />
        <span asp-validation-for="Input.CurrencyFrom" class="text-danger"></span>
    </div>
    <div class="form-group">
        <label asp-for="Input.Qu"></label>
        <input class="form-con                    .Quantity" />
        <span asp-validation-f                    class="text-danger"></span>
    </div>
    <div class="form-group">
```

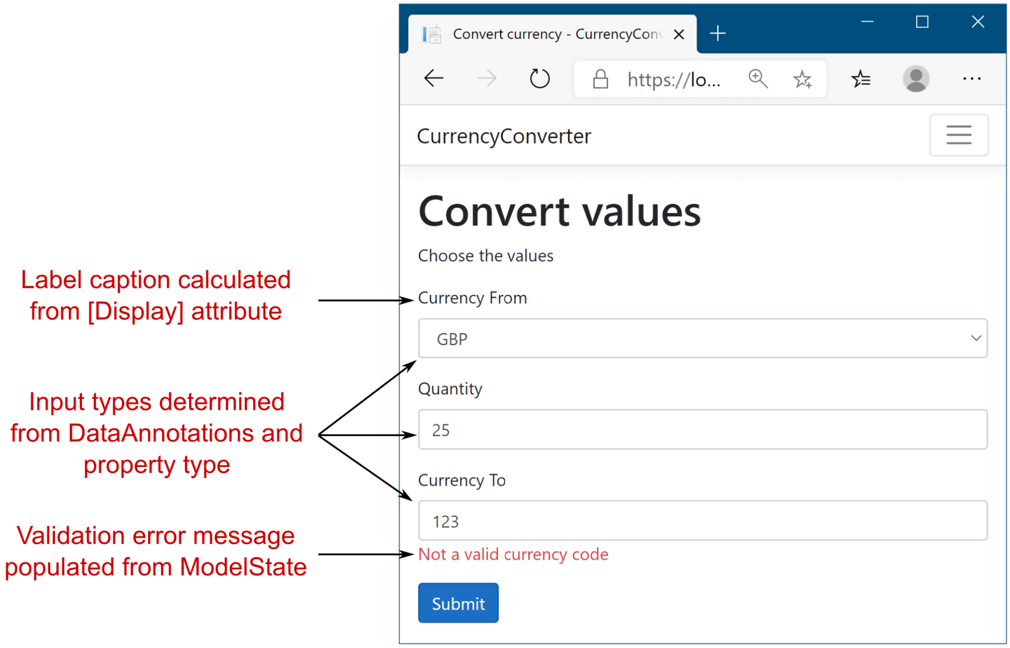
Figure 8.2 In Visual Studio, Tag Helpers are distinguishable from normal elements by being bold and a different color, C# is shaded, and IntelliSense is available.

Tag Helpers are extra attributes on standard HTML elements (or new elements entirely) that work by modifying the HTML element they're attached to. They let you easily integrate your server-side values, such as those exposed on your `PageModel`, with the generated HTML.

Notice that listing 8.1 didn't specify the captions to display in the labels. Instead, you declaratively used `asp-for="CurrencyFrom"` to say, "for this `<label>`, use the `CurrencyFrom` property to work out what caption to use." Similarly, for the `<input>` elements, Tag Helpers are used to

- Automatically populate the value from the `PageModel` property
- Choose the correct `id` and `name`, so that when the form is `POST`ed back to the Razor Page, the property will be model bound correctly.
- Choose the correct input type to display (for example, a `number` input for the `Quantity` property)
- Display any validation errors, as shown in figure 8.3[32]

[31] Other editors like Visual Studio Code, JetBrains Rider, and Visual Studio for Mac also include syntax highlighting and IntelliSense support.
[32] To learn more about the internals of Tag Helpers, read the documentation at http://mng.bz/Idb0.



Convert values

Choose the values

Currency From

GBP

Quantity

25

Currency To

123

Not a valid currency code

Label caption calculated from [Display] attribute

Input types determined from DataAnnotations and property type

Validation error message populated from ModelState

Figure 8.3 Tag Helpers hook into the metadata provided by `DataAnnotation`s, as well as the property types themselves. The Validation Tag Helper can even populate error messages based on the `ModelState`, as you saw in the last chapter on validation.

Tag Helpers can perform a variety of functions by modifying the HTML elements they're applied to. This chapter introduces a number of the common Tag Helpers and how to use them, but it's not an exhaustive list. I don't cover all of the helpers that come out of the box in ASP.NET Core (there are more coming with every release!), and you can easily create your own, as you'll see in chapter 19. Alternatively, you could use those published by others on NuGet or GitHub[33]. As with all of ASP.NET Core, Microsoft is developing Tag Helpers in the open on GitHub, so you can always take a look at the source code to see how they're implemented.

WebForms flashbacks

For those who used ASP.NET back in the day of WebForms, before the advent of the MVC pattern for web development, Tag Helpers may be triggering bad memories. Although the `asp-` prefix is somewhat reminiscent of ASP.NET Web Server control definitions, never fear—the two are different beasts.

[33] A good example is Damian Edwards' (of the ASP.NET Core team) Tag Helper pack https://github.com/DamianEdwards/TagHelperPack.

Web Server controls were directly added to a page's backing C# class, and had a broad scope that could modify seemingly unrelated parts of the page. Coupled with that, they had a complex lifecycle that was hard to understand and debug when things weren't working. The perils of trying to work with that level of complexity haven't been forgotten, and Tag Helpers aren't the same.

Tag Helpers don't have a lifecycle—they participate in the rendering of the element to which they're attached, and that's it. They can modify the HTML element they're attached to, but they can't modify anything else on your page, making them conceptually much simpler. An additional capability they bring is the ability to have multiple Tag Helpers acting on a single element—something Web Server controls couldn't easily achieve.

Overall, if you're writing Razor templates, you'll have a much more enjoyable experience if you embrace Tag Helpers as integral to its syntax. They bring a lot of benefits without obvious downsides, and your cross-platform-editor friends will thank you!

8.2 Creating forms using Tag Helpers

In this section you'll learn how to use some of the most useful Tag Helpers: Tag helpers that work with forms. You'll learn how to use them to generate HTML markup based on properties of your `PageModel`, creating the correct `id` and `name` attributes and setting the `value` of the element to the model property's value (among other things). This capability significantly reduces the amount of markup you need to write manually.

Imagine you're building the checkout page for the currency converter application, and you need to capture the user's details on the checkout page. In chapter 6, you built a `UserBindingModel` model (shown in listing 8.2), added `DataAnnotation` attributes for validation, and saw how to model bind it in a `POST` to a Razor Page. In this chapter, you'll see how to create the view for it, by exposing the `UserBindingModel` as a property on your `PageModel`.

> **WARNING** With Razor Pages, you often expose the same object in your view that you use for model binding. When you do this, you must be careful to not include sensitive values (that shouldn't be edited) in the binding model, to avoid mass-assignment attacks on your app.[34]

Listing 8.2 `UserBindingModel` for creating a user on a checkout page

```
public class UserBindingModel
{
    [Required]
    [StringLength(100, ErrorMessage = "Maximum length is {1}")]
    [Display(Name = "Your name")]
    public string FirstName { get; set; }

    [Required]
    [StringLength(100, ErrorMessage = "Maximum length is {1}")]
```

[34] You can read more about over posting attacks at https://andrewlock.net/preventing-mass-assignment-or-over-posting-with-razor-pages-in-asp-net-core/.

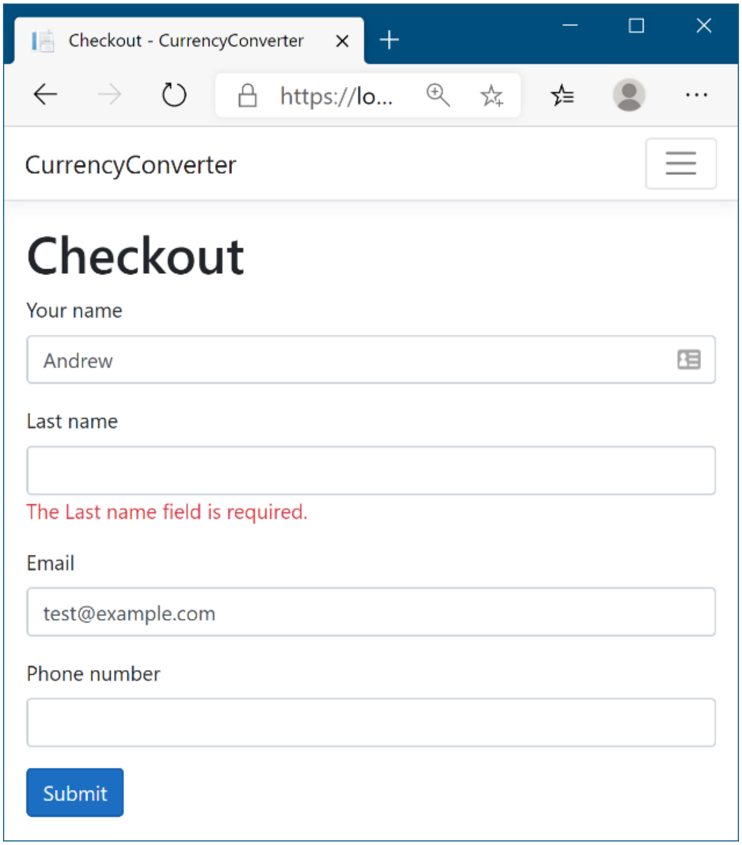
```
    [Display(Name = "Last name")]
    public string LastName { get; set; }

    [Required]
    [EmailAddress]
    public string Email { get; set; }

    [Phone(ErrorMessage = "Not a valid phone number.")]
    [Display(Name = "Phone number")]
    public string PhoneNumber { get; set; }
}
```

The `UserBindingModel` is decorated with a number of `DataAnnotations` attributes. In chapter 6, you saw that these attributes are used during model validation when the model is bound to a request, before the page handler is executed. These attributes are *also* used by the Razor templating language to provide the metadata required to generate the correct HTML when you use Tag Helpers.

You can use the pattern I described in chapter 6, exposing a `UserBindindModel` as an `Input` property of your `PageModel` to use the model for both model binding and in your Razor view:

```
public class CheckoutModel: PageModel
{
    [BindProperty]
    public UserBindingModel Input { get; set; }
}
```

With the help of the `UserBindingModel` property, Tag Helpers, and a little HTML, you can create a Razor view that lets the user enter their details, as shown in figure 8.4.



Checkout

Your name

Andrew

Last name

The Last name field is required.

Email

test@example.com

Phone number

Figure 8.4 The checkout page for an application. The HTML is generated based on a `UserBindingModel`, using Tag Helpers to render the required element values, input types, and validation messages.

The Razor template to generate this page is shown in listing 8.3. This code uses a variety of tag helpers, including

- A Form Tag Helper on the `<form>` element
- Label Tag Helpers on the `<label>`
- Input Tag Helpers on the `<input>`
- Validation Message Tag Helpers on `<span>` validation elements for each property in the `UserBindingModel`

Listing 8.3 Razor template for binding to `UserBindingModel` on the checkout page

```
@page
@model CheckoutModel                                              #A
@{
    ViewData["Title"] = "Checkout";
}
<h1>@ViewData["Title"]</h1>
<form asp-page="Checkout">                                         #B
    <div class="form-group">
        <label asp-for="Input.FirstName"></label>                  #C
        <input class="form-control" asp-for="Input.FirstName" />
        <span asp-validation-for="Input.FirstName"></span>
    </div>
    <div class="form-group">
        <label asp-for="Input.LastName"></label>
        <input class="form-control" asp-for="Input.LastName" />
        <span asp-validation-for="Input.LastName"></span>
    </div>
    <div class="form-group">
        <label asp-for="Input.Email"></label>
        <input class="form-control" asp-for="Input.Email" />           #D
        <span asp-validation-for="Input.Email"></span>
    </div>
    <div class="form-group">
        <label asp-for="Input.PhoneNumber"></label>
        <input class="form-control" asp-for="Input.PhoneNumber" />
        <span asp-validation-for="Input.PhoneNumber"></span>           #E
    </div>
    <button type="submit" class="btn btn-primary">Submit</button>
</form>
```

#A The CheckoutModel is the PageModel, which exposes a UserBindingModel on the Input property
#B Form Tag Helpers use routing to determine the URL the form will be posted to.
#C The Label Tag Helper uses DataAnnotations on a property to determine the caption to display.
#D The Input Tag Helper uses DataAnnotations to determine the type of input to generate.
#E The Validation Tag Helper displays error messages associated with the given property.

You can see the HTML markup that this template produces in listing 8.4. This Razor markup and the resulting HTML produces the results you saw in figure 8.4. You can see that each of the HTML elements with a Tag Helper has been customized in the output: the `<form>` element has an `action` attribute, the `<input>` elements have an `id` and `name` based on the name of the referenced property, and both the `<input>` and `<span>` have `data-*` elements for validation.

Listing 8.4 HTML generated by the Razor template on the checkout page

```
<form action="/Checkout" method="post">
  <div class="form-group">
    <label for="Input_FirstName">Your name</label>
    <input class="form-control" type="text"
      data-val="true" data-val-length="Maximum length is 100"
      id="Input_FirstName" data-val-length-max="100"
      data-val-required="The Your name field is required."
      maxlength="100" name="Input.FirstName" value="" />
    <span data-valmsg-for="Input.FirstName"
      class="field-validation-valid" data-valmsg-replace="true"></span>
  </div>
  <div class="form-group">
    <label for="Input_LastName">Your name</label>
    <input class="form-control" type="text"
      data-val="true" data-val-length="Maximum length is 100"
      id="Input_LastName" data-val-length-max="100"
      data-val-required="The Your name field is required."
      maxlength="100" name="Input.LastName" value="" />
    <span data-valmsg-for="Input.LastName"
      class="field-validation-valid" data-valmsg-replace="true"></span>
  </div>
  <div class="form-group">
    <label for="Input_Email">Email</label>
    <input class="form-control" type="email" data-val="true"
      data-val-email="The Email field is not a valid e-mail address."
      data-val-required="The Email field is required."
      id="Input_Email" name="Input.Email" value="" />
    <span class="text-danger field-validation-valid"
      data-valmsg-for="Input.Email" data-valmsg-replace="true"></span>
    </div>
  <div class="form-group">
    <label for="Input_PhoneNumber">Phone number</label>
    <input class="form-control" type="tel" data-val="true"
      data-val-phone="Not a valid phone number." id="Input_PhoneNumber"
      name="Input.PhoneNumber" value="" />
    <span data-valmsg-for="Input.PhoneNumber"
      class="text-danger field-validation-valid"
      data-valmsg-replace="true"></span>
  </div>
  <button type="submit" class="btn btn-primary">Submit</button>
  <input name="__RequestVerificationToken" type="hidden"
    value="CfDJ8PkYhAINFx1JmYUVIDWbpPyy_TRUNCATED" />
</form>
```

Wow, that's a lot of markup! If you're new to working with HTML, this might all seem a little overwhelming, but the important thing to notice is that *you didn't have to write most of it*! The Tag Helpers took care of most of the plumbing for you. That's basically Tag Helpers in a nutshell; they simplify the fiddly mechanics of building HTML forms, leaving you to concentrate on the overall design of your application instead of writing boilerplate markup.

> **NOTE** **If you're using Razor to build your views, Tag Helpers will make your life easier, but they're entirely optional. You're free to write raw HTML without them, or to use the legacy HTML Helpers.**

Tag Helpers simplify and abstract the process of HTML generation, but they generally try to do so without getting in your way. If you need the final generated HTML to have a particular attribute, then you can add it to your markup. You can see that in the previous listings where `class` attributes are defined on `<input>` elements, such as `<input class="form-control" asp-for="Input.FirstName" />`, they pass untouched through from Razor to the HTML output.

> **TIP** **This is different from the way HTML Helpers worked in the previous version of ASP.NET; HTML helpers often require jumping through hoops to set attributes in the generated markup.**

Even better than this, you can also set attributes that are normally generated by a Tag Helper, like the `type` attribute on an `<input>` element. For example, if the `FavoriteColor` property on your `PageModel` was a `string`, then by default, Tag Helpers would generate an `<input>` element with `type="text"`. Updating your markup to use the HTML5 `color` picker type is trivial; set the `type` explicitly in your Razor view:

```
<input type="color" asp-for="FavoriteColor" />
```

> **TIP** **HTML5 adds a huge number of features, including lots of form elements that you may not have come across before, such as `range` inputs and `color` pickers. We're not going to cover them in this book, but you can read about them on the Mozilla Developer Network website at http://mng.bz/qOc1.**

In this section, you'll build the currency calculator Razor templates from scratch, adding Tag Helpers as you find you need them. You'll probably find you use most of the common form Tag Helpers in every application you build, even if it's on a simple login page.

8.2.1 The Form Tag Helper

The first thing you need to start building your HTML form is, unsurprisingly, the `<form>` element. In the previous example, the `<form>` element was augmented with a Tag Helper attribute: `asp-page`:

```
<form asp-page="Checkout">
```

This results in the addition of `action` and `method` attributes to the final HTML, indicating the URL that the form should be sent to when submitted and the HTTP verb to use:

```
<form action="/Checkout" method="post">
```

Setting the `asp-page` attribute allows you to specify a different Razor Page in your application that the form will be posted to when it's submitted. If you omit the `asp-page` attribute, the form will post back to the same URL address it was served from. This is *very* common with Razor Pages. You normally handle the result of a form post in the same Razor Page that is used to display it.

> **WARNING** **If you omit the `asp-page` attribute you must manually add the `method="post"` attribute. It's important to add this attribute, so the form is sent using the `POST` verb, instead of the default `GET` verb. Using `GET` for forms can be a security risk.**

The `asp-page` attribute is added by a `FormTagHelper`. This Tag Helper uses the value provide to generate a URL for the `action` attribute using the URL generation features of routing that I described at the end of chapter 5.

> **NOTE** **Tag Helpers can make multiple attributes available on an element. Think of them like properties on a Tag Helper configuration object. Adding a single `asp-` attribute activates the Tag Helper on the element. Adding additional attributes lets you override further default values of its implementation.**

The Form Tag Helper makes several other attributes available on the `<form>` element that you can use to customize the generated URL. Hopefully you'll remember from chapter 5 that you can set route values when generating URLs. For example, if you have a Razor Page called Product.cshtml which uses the directive

```
@page "{id}"
```

Then the full route template for the page would be `"Product/{id}"`. To correctly generate the URL for this page, you must provide the `{id}` route value. How can you set that value using the Form Tag Helper?

The Form Tag Helper defines an `asp-route-*` wildcard attribute that you can use to set arbitrary route parameters. Set the `*` in the attribute to the route parameter name. For example, to set the `id` route parameter, you'd set the `asp-route-id` value (shown with a fixed value of `5` in the example below, but more commonly would be dynamic):

```
<form asp-page="Product" asp-route-id="5">
```

Based on the route template of the Product.cshtml Razor Page, this would generate the following markup:

```
<form action="/Product/5" method="post">
```

You can add as many `asp-route-*` attributes as necessary to your `<form>` to generate the correct `action` URL. You can also set the Razor Page handler to use using the `asp-page-handler` attribute. This ensures the form `POST` will be handled by the handler you specify.

> **NOTE** **The Form Tag Helper has many additional attributes, such as `asp-action` and `asp-controller`, that you generally won't need to use with Razor Pages. Those are only useful if you're using MVC controllers with views. In particular, look out for the `asp-route` attribute—this is *not* the same as the `asp-route-*` attribute. The former is used to specify a *named* route (not used with Razor Pages), and the latter is used to specify the route *values* to use during URL generation.**

Just as for all other Razor constructs, you can use C# values from your `PageModel` (or C# in general) in Tag Helpers. For example, if the `ProductId` property of your `PageModel` contains the value required for the `{id}` route value, you could use

```
<form asp-page="Product" asp-route-id="@Model.ProductId">
```

The main job of the Form Tag Helper is to generate the `action` attribute, but it performs one additional, important function: generating a hidden `<input>` field needed to prevent *cross-site request forgery* (CSRF) attacks.

> **DEFINITION** ***Cross-site request forgery* (CSRF) attacks are a website exploit that can be used to execute actions on your website by an unrelated malicious website. You'll learn about them in detail in chapter 18.**

You can see the generated hidden `<input>` at the bottom of the `<form>` in listing 8.4; it's named `__RequestVerificationToken` and contains a seemingly random string of characters. This field won't protect you on its own, but I'll describe in chapter 18 how it's used to protect your website. The Form Tag Helper generates it by default, so generally speaking you won't need to worry about it, but if you need to disable it, you can do so by adding `asp-antiforgery="false"` to your `<form>` element.

The Form Tag Helper is obviously useful for generating the `action` URL, but it's time to move on to more interesting elements, those that you can see in your browser!

8.2.2 The Label Tag Helper

Every `<input>` field in your currency converter application needs to have an associated label so the user knows what the `<input>` is for. You could easily create those yourself, manually typing the name of the field and setting the `for` attribute as appropriate, but luckily there's a Tag Helper to do that for you.

The Label Tag Helper is used to generate the caption (the visible text) and the `for` attribute for a `<label>` element, based on the properties in the `PageModel`. It's used by providing the name of the property in the `asp-for` attribute:

```
<label asp-for="FirstName"></label>
```

The Label Tag Helper uses the `[Display] DataAnnotations` attribute that you saw in chapter 6 to determine the appropriate value to display. If the property you're generating a label for doesn't have a `[Display]` attribute, the Label Tag Helper will use the name of the property instead. So, for the model

```
public class UserModel
{
    [Display(Name = "Your name")]
    public string FirstName { get; set; }
    public string Email { get; set; }
}
```

in which the `FirstName` property has a `[Display]` attribute, but the `Email` property doesn't; the following Razor

```
<label asp-for="FirstName"></label>
<label asp-for="Email"></label>
```

would generate the HTML

```
<label for="FirstName">Your Name</label>
<label for="Email">Email</label>
```

The caption text inside the `<label>` element uses the value set in the `[Display]` attribute, or the property name in the case of the `Email` property. Also note that the `for` attribute has been generated with the name of the property. This is a key bonus of using Tag Helpers—it hooks in with the element IDs generated by other Tag Helpers, as you'll see shortly.

NOTE The `for` attribute is important for accessibility. It specifies the ID of the element to which the label refers. This is important for users that are using a screen reader, for example, as they can tell what property a form field relates to.

As well as properties on the `PageModel`, you can also reference sub-properties on child objects. For example, as I described in chapter 6, it's common to create a nested class in a Razor Page, expose that as a property, and decorate it with the `[BindProperty]` attribute:

```
public class CheckoutModel: PageModel
{
    [BindProperty]
    public UserBindingModel Input { get; set; }
}
```

You can reference the `FirstName` property of the `UserBindingModel` by "dotting" into the property as you would in any other C# code. Listing 8.3 shows more examples of this.

```
<label asp-for="Input.FirstName"></label>
<label asp-for="Input.Email"></label>
```

As is typical with Tag Helpers, the Label Tag Helper won't override values that you set yourself. If, for example, you don't want to use the caption generated by the helper, you could insert your own manually. The following code

```
<label asp-for="Email">Please enter your Email</label>
```

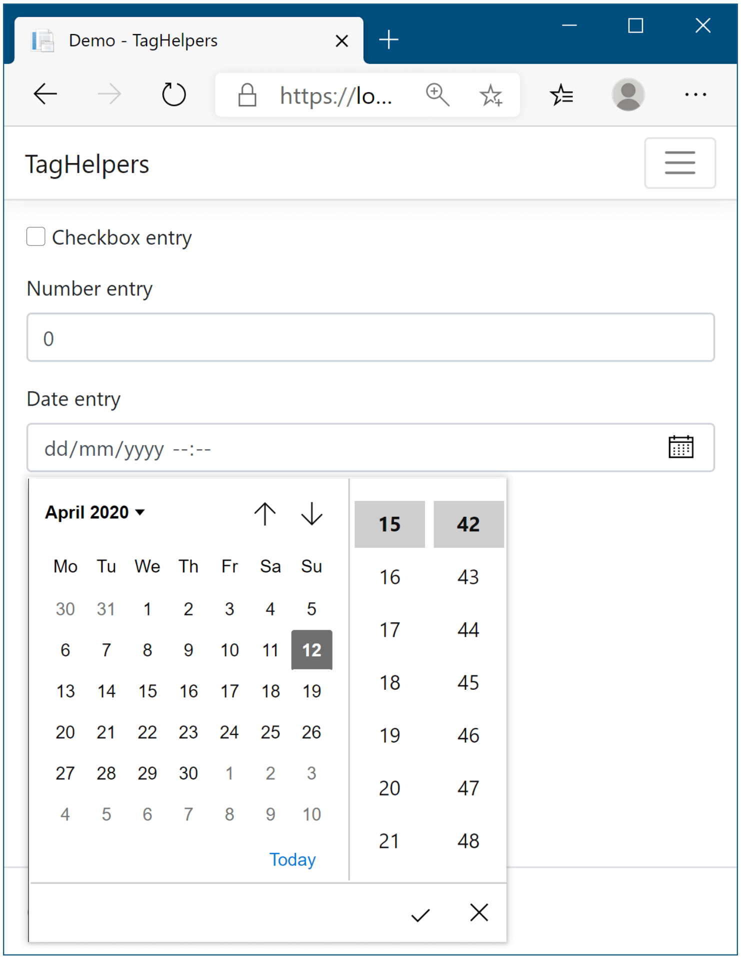
would generate the HTML

```
<label for="Email">Please enter your Email</label>
```

As ever, you'll generally have an easier time with maintenance if you stick to the standard conventions and don't override values like this, but the option is there. Right, next up is a biggie: the Input and Textarea Tag Helpers.

8.2.3 The Input and Textarea Tag Helpers

Now you're getting into the meat of your form—the `<input>` elements that handle user input. Given that there's such a wide array of possible input types, there's a variety of different ways they can be displayed in the browser. For example, Boolean values are typically represented by a `checkbox` type `<input>` element, whereas integer values would use a `number` type `<input>` element, and a date would use the `date` type, shown in figure 8.5.



□ Checkbox entry

Number entry

0

Date entry

dd/mm/yyyy --:--

Figure 8.5 Various input element types. The exact way in which each type is displayed varies by browser.

To handle this diversity, the Input Tag Helper is one of the most powerful Tag Helpers. It uses information based on both the type of the property (`bool`, `string`, `int`, and so on) and any `DataAnnotations` attributes applied to it (`[EmailAddress]` and `[Phone]`, among others) to determine the type of the `input` element to generate. The `DataAnnotations` are also used to add `data-val-*` client-side validation attributes to the generated HTML.

Consider the `Email` property from listing 8.2 that was decorated with the `[Email-Address]` attribute. Adding an `<input>` is as simple as using the `asp-for` attribute:

```
<input asp-for="Input.Email" />
```

The property is a string, so ordinarily, the Input Tag Helper would generate an <input> with type="text". But the addition of the [EmailAddress] attribute provides additional metadata about the property. Consequently, the Tag Helper generates an HTML5 <input> with type="email":

```
<input type="email" id="Input_Email" name="Input.Email"
    value="test@example.com" data-val="true"
    data-val-email="The Email Address field is not a valid e-mail address."
    data-val-required="The Email Address field is required."
    />
```

You can take a whole host of things away from this example. First, the id and name attributes of the HTML element have been generated from the name of the property. The value of the id attribute matches the value generated by the Label Tag Helper in its for attribute, Input_Email. The value of the name attribute preserves the "dot" notation, Input.Email, so that model binding works correctly when the field is POSTed to the Razor Page.

Also, the initial value of the field has been set to the value currently stored in the property ("test@example.com", in this case). The type of the element has also been set to the HTML5 email type, instead of using the default text type.

Perhaps the most striking addition is the swath of data-val-* attributes. These can be used by client-side JavaScript libraries such as jQuery to provide client-side validation of your DataAnnotations constraints. Client-side validation provides instant feedback to users when the values they enter are invalid, providing a smoother user experience than can be achieved with server-side validation alone, as I described in chapter 6.

Client-side validation

In order to enable client-side validation in your application, you need to add some jQuery libraries to your HTML pages. In particular, you need to include the jQuery, jQuery-validation, and jQuery-validation-unobtrusive JavaScript libraries. You can do this in a number of ways, but the simplest is to include the script files at the bottom of your view using

```
<script src="~/lib/jquery-validation/dist/jquery.validate.min.js"></script>
<script src="~/lib/jquery-validation-
unobtrusive/jquery.validate.unobtrusive.min.js"></script>
```

The default templates include these scripts for you, in a handy partial template that you can add to your page in a Scripts section. If you're using the default layout and need to add client-side validation to your view, add the following section somewhere on your view:

```
@section Scripts{
    @Html.Partial("_ValidationScriptsPartial")
}
```

This partial view references files in your wwwroot folder. The default _layout template includes jQuery itself, as that's required by the front-end component library Bootstrap.[35]

The Input Tag Helper tries to pick the most appropriate template for a given property based on `DataAnnotation` attributes or the type of the property. Whether this generates the exact `<input>` type you need may depend, to an extent, on your application. As always, you can override the generated `type` by adding your own `type` attribute to the Razor. Table 8.1 shows how some of the common data types are mapped to `<input>` types, and how the data types themselves can be specified.

Table 8.1 Common data types, how to specify them, and the input element type they map to

Data type	How it's specified	Input element type
`byte, int, short, long, uint`	**Property type**	`number`
`decimal, double, float`	**Property type**	`text`
`string`	**Property type,** `[DataType(DataType.Text)]` **attribute**	`text`
`HiddenInput`	`[HiddenInput]` **attribute**	`hidden`
`Password`	`[Password]` **attribute**	`password`
`Phone`	`[Phone]` **attribute**	`tel`
`EmailAddress`	`[EmailAddress]` **attribute**	`email`
`Url`	`[Url]` **attribute**	`url`
`Date`	`DateTime` **property type,** `[DataType(DataType.Date)]` **attribute**	`date`

The Input Tag Helper has one additional attribute that can be used to customize the way data is displayed: `asp-format`. HTML forms are entirely string-based, so when the `value` of an `<input>` is set, the Input Tag Helper must take the value stored in the property and convert it to a `string`. Under the covers, this performs a `string.Format()` on the property's value, passing in the format string.

[35] You can also load these files from a Content Delivery Network. If you wish to take this approach, you should consider scenarios where the CDN is unavailable or compromised, as I discuss in this post: https://andrewlock.net/using-jquery-and-bootstrap-from-a-cdn-with-fallback-scripts-in-asp-net-core-3/.

The Input Tag Helper uses a default format string for each different data type, but with the `asp-format` attribute, you can set the specific format string to use. For example, you could ensure a `decimal` property, `Dec`, is formatted to three decimal places with the following code:

```
<input asp-for="Dec" asp-format="{0:0.000}" />
```

If the `Dec` property had a value of 1.2, this would generate HTML similar to

```
<input type="text" id="Dec" name="Dec" value="1.200">
```

> **NOTE You may be surprised that `decimal` and `double` types are rendered as `text` fields and not as `number` fields. This is due to several technical reasons, predominantly related to the way some cultures render numbers with commas and spaces. Rendering as text avoids errors that would only appear in certain browser-culture combinations.**

In addition to the Input Tag Helper, ASP.NET Core provides the Textarea Tag Helper. This works in a similar way, using the `asp-for` attribute, but is attached to a `<textarea>` element instead:

```
<textarea asp-for="BigtextValue"></textarea>
```

This generates HTML similar to the following. Note that the property value is rendered inside the Tag, and `data-val-*` validation elements are attached as usual:

```
<textarea data-val="true" id="BigtextValue" name="BigtextValue"
    data-val-length="Maximum length 200." data-val-length-max="200"
    data-val-required="The Multiline field is required." >This is some text,
I'm going to display it
in a text area</textarea>
```

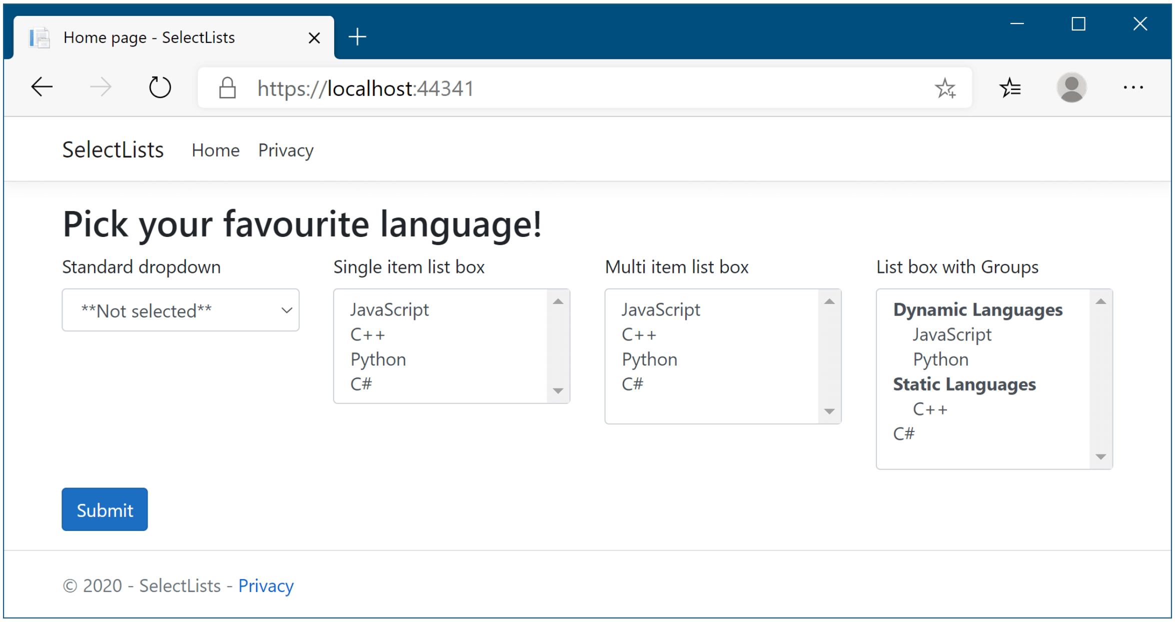
Hopefully, this section has hammered home how much typing Tag Helpers can cut down on, especially when using them in conjunction with `DataAnnotations` for generating validation attributes. But this is more than reducing the number of keystrokes required; Tag Helpers ensure that the markup generated is *correct*, and has the correct `name`, `id`, and format to automatically bind your binding models when they're sent to the server.

With `<form>`, `<label>`, and `<input>` under your belt, you're able to build most of your currency converter forms. Before we look at displaying validation messages, there's one more element to look at: the `<select>`, or drop-down, input.

8.2.4 The Select Tag Helper

As well as `<input>` fields, a common element you'll see on web forms is the `<select>` element, or dropdowns and list boxes. Your currency converter application, for example, could use a `<select>` element to let you pick which currency to convert from a list.

By default, this element shows a list of items and lets you select one, but there are several variations, as shown in figure 8.6. As well as the normal drop-down box, you could show a list box, add multiselection, or display your list items in groups.



Pick your favourite language!

Standard dropdown

Not selected

Single item list box

JavaScript
C++
Python
C#

Multi item list box

JavaScript
C++
Python
C#

List box with Groups

Dynamic Languages
JavaScript
Python
Static Languages
C++
C#

Submit

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Figure 8.6 Some of the many ways to display `<select>` elements using the Select Tag Helper.

To use `<select>` elements in your Razor code, you'll need to include two properties in your `PageModel`: one property for the list of options to display and one to hold the value (or values) selected. For example, listing 8.5 shows the properties on the `PageModel` used to create the three left-most select lists you saw in figure 8.6. Displaying groups requires a slightly different setup, as you'll see shortly.

Listing 8.5 View model for displaying select element dropdowns and list boxes

```
public class SelectListsModel: PageModel
{
    [BindProperty]                                                #A
    public class InputModel Input { get; set; }                   #A

    public IEnumerable<SelectListItem> Items { get; set; }        #B
        = new List<SelectListItem>                                #B
    {                                                             #B
        new SelectListItem{Value= "csharp", Text="C#"},           #B
        new SelectListItem{Value= "python", Text= "Python"},      #B
        new SelectListItem{Value= "cpp", Text="C++"},             #B
        new SelectListItem{Value= "java", Text="Java"},           #B
        new SelectListItem{Value= "js", Text="JavaScript"},       #B
        new SelectListItem{Value= "ruby", Text="Ruby"},           #B
    };                                                            #B


    public class InputModel
    {
        public string SelectedValue1 { get; set; }              #C
        public string SelectedValue2 { get; set; }              #C
        public IEnumerable<string> MultiValues { get; set; }    #D
    }
}
```

#A The InputModel for binding the user's selections to the select boxes
#B The list of items to display in the select boxes
#C These properties will hold the values selected by the single-selection select boxes.
#D To create a multiselect list box, use an IEnumerable<>.

This listing demonstrates a number of aspects of working with `<select>` lists:

- `SelectedValue1`/`SelectedValue2`—Used to hold the values selected by the user. They're model-bound to the value selected from the drop-down/listbox and used to pre-select the correct item when rendering the form.
- `MultiValues`—Used to hold the selected values for a multiselect list. It's an `IEnumerable`, so it can hold more than one selection per `<select>` element.
- `Items`—Provides the list of options to display in the `<select>` elements. Note that the element type must be `SelectListItem`, which exposes the `Value` and `Text` properties, to work with the Select Tag Helper. This isn't part of the `InputModel`, as we don't want to model-bind these items to the request—they would normally be loaded directly from the application-model or hard-coded.

NOTE The Select Tag Helper only works with `SelectListItem` elements. That means you'll normally have to convert from an application-specific list set of items (for example, a `List<string>` or `List<MyClass>`) to the UI-centric `List<SelectListItem>`.

The Select Tag Helper exposes the `asp-for` and `asp-items` attributes that you can add to `<select>` elements. As for the Input Tag Helper, the `asp-for` attribute specifies the property in your `PageModel` to bind to. The `asp-items` attribute is provided for the `IEnumerable<SelectListItem>` to display the available `<option>` elements.

TIP It's common to want to display a list of `enum` options in a `<select>` list. This is so common that ASP.NET Core ships with a helper for generating a `SelectListItem` for any `enum`. If you have an `enum` of the `TEnum` type, you can generate the available options in your View using `asp-items="Html.GetEnumSelectList<TEnum>()"`.

The following listing shows how to display a drop-down list, a single-selection list box, and a multiselection list box. It uses the `PageModel` from the previous listing, binding each `<select>` list to a different property, but reusing the same `Items` list for all of them.

Listing 8.6 Razor template to display a select element in three different ways

```
@page
@model SelectListsModel
```

```
<select asp-for="Input.SelectedValue1"                  #A
    asp-items="Model.Items"></select>                   #A
<select asp-for="Input.SelectedValue2"                  #B
    asp-items="Model.Items" size="4"></select>          #B
<select asp-for="Input.MultiValues"                     #C
    asp-items="Model.Items"></select>                   #C
```

#A Creates a standard drop-down select list by binding to a standard property in asp-for
#B Creates a single-select list box of height 4 by providing the standard HTML size attribute
#C Creates a multiselect list box by binding to an IEnumerable property in asp-for

Hopefully, you can see that the Razor for generating a drop-down `<select>` list is almost identical to the Razor for generating a multiselect `<select>` list. The Select Tag Helper takes care of adding the `multiple` HTML attribute to the generated output if the property it's binding to is an `IEnumerable`.

> **WARNING The `asp-for` attribute *must not* include the `Model.` prefix. The `asp-items` attribute, on the other hand, *must* include it if referencing a property on the `PageModel`. The `asp-items` attribute can also reference other C# items, such as objects stored in `ViewData`, but using a `PageModel` property is the best approach.**

You've seen how to bind three different types of select list so far, but the one I haven't yet covered from figure 8.6 is how to display groups in your list boxes using `<optgroup>` elements. Luckily, nothing needs to change in your Razor code, you just have to update how you define your `SelectListItem`s.

The `SelectListItem` object defines a `Group` property that specifies the `SelectListGroup` the item belongs to. The following listing shows how you could create two groups and assign each list item to either a "dynamic" or "static" group, using a `PageModel` similar to that shown in listing 8.5. The final list item, `C#`, isn't assigned to a group, so it will be displayed as normal, without an `<optgroup>`.

Listing 8.7 Adding `Groups` to `SelectListItems` to create `optgroup` elements

```
public class SelectListsModel: PageModel
{
    [BindProperty]
    public IEnumerable<string> SelectedValues { get; set; }
    public IEnumerable<SelectListItem> Items { get; set; }

    public SelectListsModel()                                       #A
    {
        var dynamic = new SelectListGroup { Name = "Dynamic" };     #B
        var stat = new SelectListGroup { Name = "Static" };         #B
        Items = new List<SelectListItem>
        {
            new SelectListItem {
                Value= "js",
                Text="Javascript",
                Group = dynamic                                     #C
            },
            new SelectListItem {
                Value= "cpp",
                Text="C++",
                Group = stat                                          #C
            },
            new SelectListItem {
                Value= "python",
                Text="Python",
                Group = dynamic                                      #C
            },
            new SelectListItem {                                     #D
                Value= "csharp",                                     #D
                Text="C#",                                           #D
            }
        };
    }
}
```

#A Initializes the list items in the constructor
#B Creates single instance of each group to pass to SelectListItems
#C Sets the appropriate group for each SelectListItem
#D If a SelectListItem doesn't have a Group, it won't be added to an <optgroup>.

With this in place, the Select Tag Helper will generate `<optgroup>` elements as necessary when rendering the Razor to HTML. The Razor template:

```
@page
@model SelectListsModel
<select asp-for="SelectedValues" asp-items="Model.Items"></select>
```

would be rendered to HTML as:

```
<select id="SelectedValues" name="SelectedValues" multiple="multiple">
    <optgroup label="Dynamic">
        <option value="js">JavaScript</option>
        <option value="python">Python</option>
    </optgroup>
    <optgroup label="Static Languages">
        <option value="cpp">C++</option>
    </optgroup>
    <option value="csharp">C#</option>
</select>
```

Another common requirement when working with `<select>` elements is to include an option in the list that indicates "no value selected," as shown in figure 8.7. Without this extra option, the default `<select>` dropdown will always have a value, and will default to the first item in the list.

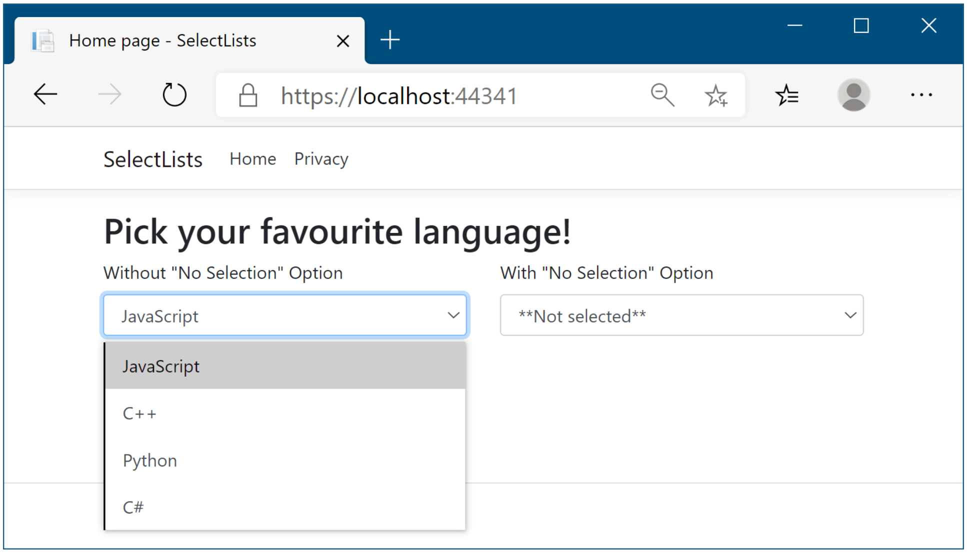


Figure 8.7 Without a “no selection” option, the `<select>` element will always have a value. This may not be the behavior you desire if you don’t want an `<option>` to be selected by default.

You can achieve this in one of two ways: you could either add the “not selected” option to the available `SelectListItem`s, or you could manually add the option to the Razor, for example by using

```
<select asp-for="SelectedValue" asp-items="Model.Items">
    <option Value = "">**Not selected**</option>
</select>
```

This will add an extra `<option>` at the top of your `<select>` element, with a blank `Value` attribute, allowing you to provide a “no selection” option for the user.

> **TIP** **Adding a “no selection” option to a `<select>` element is so common; you might want to create a partial view to encapsulate this logic.**

With the Input Tag Helper and Select Tag Helper under your belt, you should be able to create most of the forms that you’ll need. You have all the pieces you need to create the currency converter application now, with one exception.

Remember, whenever you accept input from a user, you should always validate the data. The Validation Tag Helpers provide a way to display model validation errors to the user on your form, without having to write a lot of boilerplate markup.

8.2.5 The Validation Message and Validation Summary Tag Helpers

In section 8.2.3 you saw that the Input Tag Helper generates the necessary `data-val-*` validation attributes on form input elements themselves. But you also need somewhere to display the validation messages. This can be achieved for each property in your view model using the Validation Message Tag Helper applied to a `<span>` by using the `asp-validation-for` attribute:

```
<span asp-validation-for="Email"></span>
```

When an error occurs during client-side validation, the appropriate error message for the referenced property will be displayed in the `<span>`, as shown in figure 8.8. This `<span>` element will also be used to show appropriate validation messages if server-side validation fails, and the form is being redisplayed.

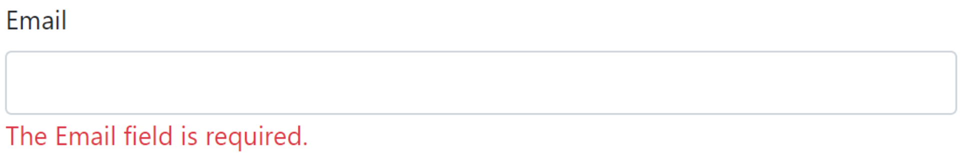


Figure 8.8 Validation messages can be shown in an associated `<span>` by using the Validation Message Tag Helper.

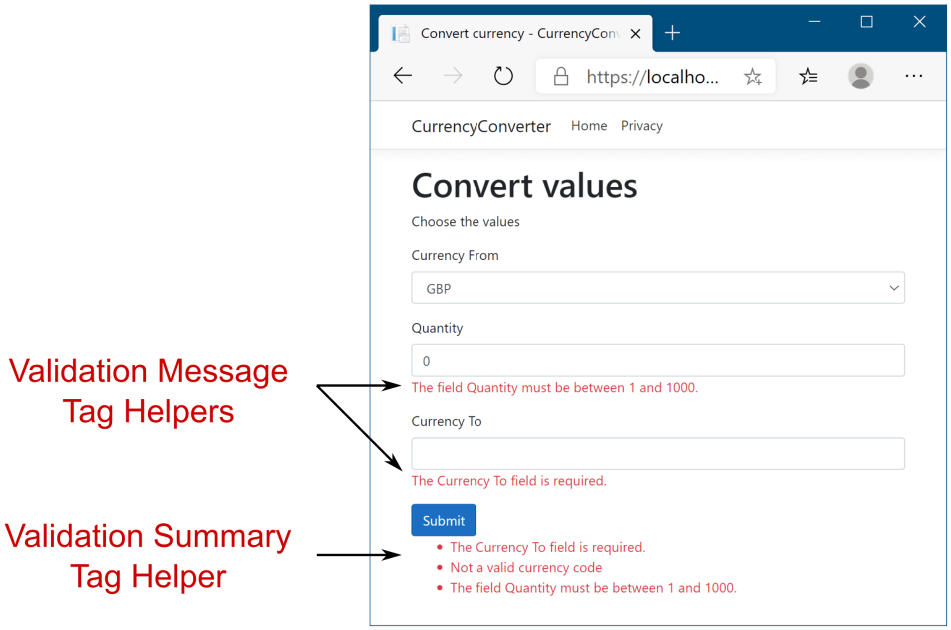
Any errors associated with the `Email` property stored in `ModelState` will be rendered in the element body, and the element will have appropriate attributes to hook into jQuery validation:

```
<span class="field-validation-valid" data-valmsg-for="Email"
  data-valmsg-replace="true">The Email Address field is required.</span>
```

The validation error shown in the element will be replaced when the user updates the `Email` `<input>` field and client-side validation is performed.

> **NOTE** For further details on `ModelState` and server-side model validation, see chapter 6.

As well as displaying validation messages for individual properties, you can also display a summary of all the validation messages in a `<div>` by using the Validation Summary Tag Helper, shown in figure 8.9. This renders a `<ul>` containing a list of the `ModelState` errors.



CurrencyConverter Home Privacy

Convert values

Choose the values

Currency From

GBP

Quantity

0

The field Quantity must be between 1 and 1000.

Currency To

The Currency To field is required.

Submit

- The Currency To field is required.
- Not a valid currency code
- The field Quantity must be between 1 and 1000.

Figure 8.9 Form showing validation errors. The Validation Message Tag Helper is applied to `<span>`, close to the associated input. The Validation Summary Tag Helper is applied to a `<div>`, normally at the top or bottom of the form.

The Validation Summary Tag Helper is applied to a `<div>` using the `asp-validation-summary` attribute and providing a `ValidationSummary` enum value, such as

```
<div asp-validation-summary="All"></div>
```

The `ValidationSummary enum` controls which values are displayed, and has three possible values:

- `None`—Don't display a summary. (I don't know why you'd use this.)
- `ModelOnly`—Only display errors that are *not* associated with a property.
- `All`—Display errors either associated with a property or with the model.

The Validation Summary Tag Helper is particularly useful if you have errors associated with your page that aren't specific to a single property. These can be added to the model state by using a blank key, as shown in listing 8.8. In this example, the property validation passed, but we provide additional model-level validation to check that we aren't trying to convert a currency to itself.

Listing 8.8 Adding model-level validation errors to the `ModelState`

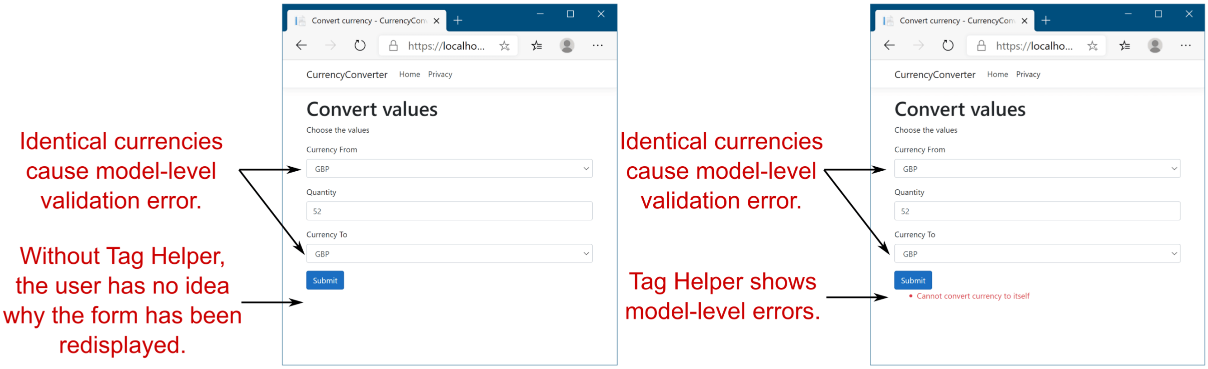
```
public class ConvertModel : PageModel
```

```
{
    [BindProperty]
    public InputModel Input { get; set; }

    [HttpPost]
    public IActionResult OnPost()
    {
        if(Input.CurrencyFrom == Input.CurrencyTo)         #A
        {
            ModelState.AddModelError(                      #B
                string.Empty,                              #B
                "Cannot convert currency to itself");      #B
        }
        if (!ModelState.IsValid)                           #C
        {                                                  #C
            return Page();                                 #C
        }                                                  #C

        //store the valid values somewhere etc
        return RedirectToPage("Checkout");
    }
}
```

#A Can't convert currency to itself
#B Adds model-level error, not tied to a specific property, by using empty key
#C If there are any property-level or model-level errors, display them.

Without the Validation Summary Tag Helper, the model-level error would still be added if the user used the same currency twice, and the form would be redisplayed. Unfortunately, there would have been no visual cue to the user indicating why the form did not submit—obviously that's a problem! By adding the Validation Summary Tag Helper, the model-level errors are shown to the user so they can correct the problem, as shown in figure 8.10.

> **NOTE** For simplicity, I added the validation check to the page handler. A better approach might be to create a custom validation attribute to achieve this instead. That way, your handler stays lean and sticks to the single responsibility principle. You'll see how to achieve this in chapter 19.



Convert values

Choose the values

Currency From
GBP

Quantity
52

Currency To
GBP

Convert values

Choose the values

Currency From
GBP

Quantity
52

Currency To
GBP

• Cannot convert currency to itself

Identical currencies cause model-level validation error.

Without Tag Helper, the user has no idea why the form has been redisplayed.

Identical currencies cause model-level validation error.

Tag Helper shows model-level errors.

Figure 8.10 Model-level errors are only displayed by the Validation Summary Tag Helper. Without one, users won't have any indication that there were errors on the form, and so won't be able to correct them.

This section has covered most of the common Tag Helpers available for working with forms, including all the pieces you need to build the currency converter forms. They should give you everything you need to get started building forms in your own applications. But forms aren't the only area in which Tag Helpers are useful; they're generally applicable any time you need to mix server-side logic with HTML generation.

One such example is generating links to other pages in your application using routing-based URL generation. Given that routing is designed to be fluid as you refactor your application, keeping track of the exact URLs the links should point to would be a bit of a maintenance nightmare if you had to do it "by hand." As you might expect, there's a Tag Helper for that: the Anchor Tag Helper.

8.3 Generating links with the Anchor Tag Helper

At the end of chapter 5, I showed how you could generate URLs for links to other pages in your application from inside your page handlers by using `ActionResult`s. Views are the other common place where you need to link to other pages in your application, normally by way of an `<a>` element with an `href` attribute pointing to the appropriate URL.

In this section I show how to use the Anchor Tag Helper to generate the URL for a given Razor Page using routing. Conceptually, this is almost identical to the way the Form Tag Helper generates the `action` URL, as you saw in section 8.2.1. For the most part, using the Anchor Tag Helper is identical too; you provide `asp-page` and `asp-page-handler` attributes, along with `asp-route-*` attributes as necessary. The default Razor Page templates use the Anchor Tag Helper to generate the links shown in the navigation bar using the code in the listing below.

Listing 8.9 Using the Anchor Tag Helper to generate URLs in _Layout.cshtml

```
<ul class="navbar-nav flex-grow-1">
```

```
    <li class="nav-item">
        <a class="nav-link text-dark"
            asp-area="" asp-page="/Index">Home</a>
    </li>
    <li class="nav-item">
        <a class="nav-link text-dark"
            asp-area="" asp-page="/Privacy">Privacy</a>
    </li>
</ul>
```

As you can see, each `<a>` element has an `asp-page` attribute. This Tag Helper uses the routing system to generate an appropriate URL for the `<a>`, resulting in the following markup:

```
<ul class="nav navbar-nav">
    <li class="nav-item">
        <a class="nav-link text-dark" href="/">Home</a>
    </li>
    <li class="nav-item">
        <a class="nav-link text-dark" href="/Privacy">Privacy</a>
    </li>t
</ul>
```

The URLs use default values where possible, so the `Index` Razor Page generates the simple `"/"` URL instead of `"/Index"`.

If you need more control over the URL generated, the Anchor Tag Helper exposes several additional properties you can set, which will be used during URL generation. The most commonly used with Razor Pages are:

- `asp-page`—Sets the Razor Page to execute.
- `asp-page-handler`—Sets the Razor Page handler to execute.
- `asp-area`—Sets the area route parameter to use. Areas can be used to provide an additional layer of organization to your application.[36]
- `asp-host`—If set, the link will point to the provided host and will generate an absolute URL instead of a relative URL.
- `asp-protocol`—Sets whether to generate an http or https link. If set, it will generate an absolute URL instead of a relative URL.
- `asp-route-*`—Sets the route parameters to use during generation. Can be added multiple times for different route parameters.

By using the Anchor Tag Helper and its attributes, you generate your URLs using the routing system, as described in chapter 5. This reduces the duplication in your code by removing the hardcoded URLs you'd otherwise need to embed in all your views.

[36] I won't cover areas in detail this book. They're an optional aspect of MVC that are often only used on large projects. You can read about them here: http://mng.bz/3X64.

If you find yourself writing repetitive code in your markup, chances are someone has written a Tag Helper to help with it. The Append Version Tag Helper in the following section is a great example of using Tag Helpers to reduce the amount of fiddly code required.

8.4 Cache-busting with the Append Version Tag Helper

A common problem with web development, both when developing and when an application goes into production, is ensuring that browsers are all using the latest files. For performance reasons, browsers often cache files locally and reuse them for subsequent requests, rather than calling your application every time a file is requested.

Normally, this is great—most of the static assets in your site rarely change, so caching them significantly reduces the burden on your server. Think of an image of your company logo—how often does that change? If every page shows your logo, then caching the image in the browser makes a lot of sense.

But what happens if it *does* change? You want to make sure users get the updated assets as soon as they're available. A more critical requirement might be if the JavaScript files associated with your site change. If users end up using cached versions of your JavaScript then they might see strange errors, or your application might appear broken to them.

This conundrum is a common one in web development, and one of the most common ways for handling it is to use a *cache-busting query string*.

> **DEFINITION** A cache-busting query string adds a query parameter to a URL, such as `?v=1`. Browsers will cache the response and use it for subsequent requests to the URL. When the resource changes, the query string is also changed, for example to `?v=2`. Browsers will see this as a request for a new resource and will make a fresh request.

The biggest problem with this approach is that it requires you to update a URL every time an image, CSS, or JavaScript file changes. This is a manual step that requires updating every place the resource is referenced, so it's inevitable that mistakes are made. Tag Helpers to the rescue! When you add a `<script>`, `<img>`, or `<link>` element to your application, you can use Tag Helpers to automatically generate a cache-busting query string:

```
<script src="~/js/site.js" asp-append-version="true"></script>
```

The `asp-append-version` attribute will load the file being referenced and generate a unique hash based on its contents. This is then appended as a unique query string to the resource URL:

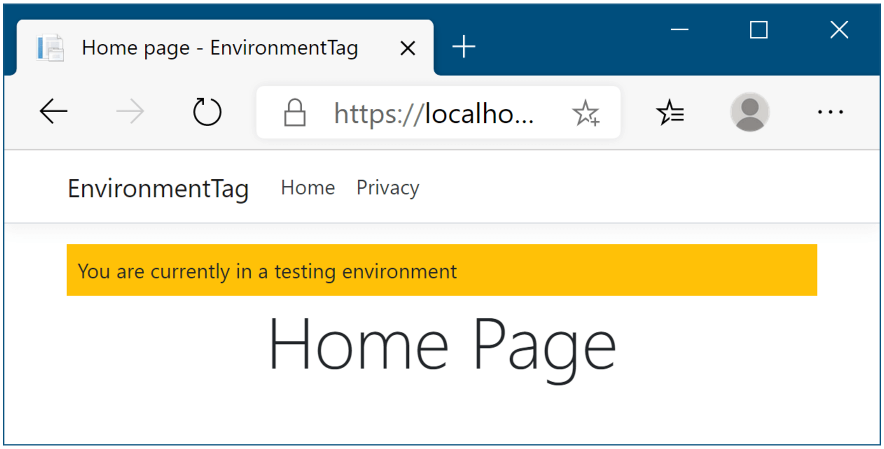
```
<script src="/js/site.js?v=EWaMeWsJBYWmL2g_KkgXZQ5nPe"></script>
```

As this value is a hash of the file contents, it will remain unchanged as long as the file isn't modified, so the file will be cached in users' browsers. But if the file is modified, then the hash of the contents will change and so will the query string. This ensures browsers are always served the most up-to-date files for your application without your having to worry about manually updating every URL whenever you change a file.

So far in this chapter you've seen how to use Tag Helpers for forms, link generation, and cache busting. You can also use Tag Helpers to conditionally render different markup depending on the current environment. This uses a technique you haven't seen yet, where the Tag Helper is declared as a completely separate element.

8.5 Using conditional markup with the Environment Tag Helper

In many cases, you want to render different HTML in your Razor templates depending if your website is running in a development or production environment. For example, in development, you typically want your JavaScript and CSS assets to be verbose and easy to read, but in production you'd process these files to make them as small as possible. Another example might be the desire to apply a banner to the application when it's running in a testing environment, which is removed when you move to production, shown in figure 8.11.



You are currently in a testing environment

Home Page

Figure 8.11 The warning banner will be shown whenever you're running in a testing environment, to make it easy to distinguish from production.

NOTE You'll learn about configuring your application for multiple environments in chapter 11.

You've already seen how to use C# to add `if` statements to your markup, so it would be perfectly possible to use this technique to add an extra `div` to your markup when the current environment has a given value. If we assume that the `env` variable contains the current environment, then you could use something like

```
@if(env == "Testing" || env == "Staging")
{
    <div class="warning">You are currently on a testing environment</div>
}
```

There’s nothing wrong with this, but a better approach would be to use the Tag Helper paradigm to keep your markup clean and easy to read. Luckily, ASP.NET Core comes with the `EnvironmentTagHelper`, which can be used to achieve the same result in a slightly clearer way:

```
<environment include="Testing,Staging">
    <div class="warning">You are currently on a testing environment</div>
</environment>
```

This Tag Helper is a little different from the others you’ve seen before. Instead of augmenting an existing HTML element using an `asp-` attribute, *the whole element* is the Tag Helper. This Tag Helper is completely responsible for generating the markup, and it uses an attribute to configure it.

Functionally, this Tag Helper is identical to the C# markup (although for now I’ve glossed over how the `env` variable could be found), but it’s more declarative in its function than the C# alternative. You’re obviously free to use either approach, but personally I like the HTML-like nature of Tag Helpers.

We’ve reached the end of this chapter on Tag Helpers, and with it, our first look at building traditional web applications that display HTML to users. In the last part of the book, we’ll revisit Razor templates, and you’ll learn how to build custom components like custom Tag Helpers and View Components. For now, you have everything you need to build complex Razor layouts—the custom components can help tidy up your code down the line.

Part 1 of this book has been a whistle-stop tour of how to build Razor Page applications with ASP.NET Core. You now have the basic building blocks to start making simple ASP.NET Core applications. In the second part of this book, I’ll show you some of the additional features you’ll need to understand to build complete applications. But before we get to that, I’ll take a chapter to discuss building Web APIs.

I’ve mentioned the Web API approach previously, in which your application serves data using the MVC framework, but instead of returning user-friendly HTML, it returns machine-friendly JSON. In the next chapter, you’ll see why and how to build a Web API, take a look at an alternative routing system designed for APIs, and learn how to generate JSON responses to requests.

8.6 Summary

- With Tag Helpers, you can bind your data model to HTML elements, making it easier to generate dynamic HTML while remaining editor friendly.
- As with Razor in general, Tag Helpers are for server-side rendering of HTML only. You can’t use them directly in frontend frameworks, such as Angular or React.
- Tag Helpers can be standalone elements or can attach to existing HTML using attributes. This lets you both customise HTML elements and add entirely new elements.
- Tag Helpers can customize the elements they’re attached to, add additional attributes, and customize how they’re rendered to HTML. This can greatly reduce the amount of markup you need to write.

- Tag Helpers can expose multiple attributes on a single element. This makes it easier to configure the Tag Helper, as you can set multiple, separate, values.
- You can add the `asp-page` and `asp-page-handler` attributes to the `<form>` element to set the `action` URL using the URL generation feature of Razor Pages.
- You specify route values to use during routing with the Form Tag Helper using `asp-route-*` attributes. These values are used to build the final URL or are passed as query data.
- The Form Tag Helper also generates a hidden field that you can use to prevent CSRF attacks. This is added automatically and is an important security measure.
- You can attach the Label Tag Helper to a `<label>` using `asp-for`. It generates an appropriate `for` attribute and caption based on the `[Display] Data-Annotations` attribute and the `PageModel` property name.
- The Input Tag Helper sets the `type` attribute of an `<input>` element to the appropriate value based on a bound property's `Type` and any `DataAnnotations` applied to it. It also generates the `data-val-*` attributes required for client-side validation. This significantly reduces the amount of HTML code you need to write.
- To enable client-side validation, you must add the necessary JavaScript files to your view for jQuery validation and unobtrusive validation.
- The Select Tag Helper can generate drop-down `<select>` elements as well as list boxes, using the `asp-for` and `asp-items` attributes. To generate a multiselect `<select>` element, bind the element to an `IEnumerable` property on the view model. You can use these approaches to generate several different styles of select box.
- The items supplied in `asp-for` must be an `IEnumerable<SelectListItem>`. If you try to bind another type, you'll get a compile time error in your Razor view.
- You can generate an `IEnumerable<SelectListItem>` for an `enum TEnum` using the `Html.GetEnumSelectList<TEnum>()` helper method. This saves you having to write the mapping code yourself.
- The Select Tag Helper will generate `<optgroup>` elements if the items supplied in `asp-for` have an associated `SelectListGroup` on the `Group` property. Groups are can be used to separate items in select lists.
- Any extra additional `<option>` elements added to the Razor markup will be passed through to the final HTML. You can use these additional elements to easily add a "no selection" option to the `<select>` element.
- The Validation Message Tag Helper is used to render the client- and server-side validation error messages for a given property. This gives important feedback to your users when elements have errors. Use the `asp-validation-for` attribute to attach the Validation Message Tag Helper to a `<span>`.
- The Validation Summary Tag Helper is used to display validation errors for the model, as well as for individual properties. You can use model-level properties to display additional validation that doesn't apply to just one property. Use the asp`-validation-summary` attribute to attach the Validation Summary Tag Helper to a `<div>`.

- You can generate `<a>` URLs using the Anchor Tag Helper. This Helper uses routing to generate the `href` URL using `asp-page`, `asp-page-handler`, and `asp-route-*` attributes, giving you the full power of routing.
- You can add the `asp-append-version` attribute to `<link>`, `<script>`, and `<img>` elements to provide cache-busting capabilities based on the file's contents. This ensures users cache files for performance reasons, yet still always get the latest version of files.
- You can use the Environment Tag Helper to conditionally render different HTML based on the app's current execution environment. You can use this to render completely different HTML in different environments if you wish.

9

Creating a Web API for mobile and client applications using MVC

This chapter covers

- **Creating a Web API controller to return JSON to clients**
- **Using attribute routing to customize your URLs**
- **Generating a response using content negotiation**
- **Applying common conventions with the `[ApiController]` attribute**

In the previous five chapters, you've worked through each layer of a server-side rendered ASP.NET Core application, using Razor Pages to render HTML to the browser. In this chapter, you'll see a different take on an ASP.NET Core application. Instead of using Razor Pages, we'll explore Web APIs, which serve as the backend for client-side SPAs and mobile apps.

You can apply much of what you've already learned to Web APIs; they use the same MVC design pattern, and the concepts of routing, model binding, and validation all carry through. The differentiation from traditional web applications is primarily in the *view* part of MVC. Instead of returning HTML, they return data as JSON or XML, which client applications use to control their behavior or update the UI.

In this chapter, you'll learn how to define controllers and actions and see how similar they are to the Razor Pages and controllers you already know. You'll learn how to create an API model to return data and HTTP status codes in response to a request, in a way that client apps can understand.

After exploring how the MVC design pattern applies to Web APIs, you'll see how a related topic works with Web APIs: routing. We'll look at how *attribute routing* reuses many of the same concepts from chapter 5 but applies them to your action methods rather than to Razor Pages.

One of the big features added in ASP.NET Core 2.1 was the `[ApiController]` attribute. This attribute applies several common conventions used in Web APIs, which reduces the amount of code you must write yourself. In section 9.5 you'll learn how automatic bad responses for invalid requests, model binding parameter inference, and `ProblemDetails` objects can make building APIs easier and more consistent.

You'll also learn how to format the API models returned by your action methods using content negotiation, to ensure you generate a response that the calling client can understand. As part of this, you'll learn how to add support for additional format types, such as XML, so that you can generate XML responses if the client requests it.

One of the great aspects of ASP.NET Core is the variety of applications you can create with it. The ability to easily build a generalized HTTP Web API presents the possibility of using ASP.NET Core in a greater range of situations than can be achieved with traditional web apps alone. But should *you* build a Web API and why? In the first section of this chapter, I'll go over some of the reasons why you might or might not want to create a Web API.

9.1 What is a Web API and when should you use one?

Traditional web applications handle requests by returning HTML to the user, which is displayed in a web browser. You can easily build applications of this nature using Razor Pages to generate HTML with Razor templates, as you've seen in recent chapters. This approach is common and well understood, but the modern application developer also has a number of other possibilities to consider, as shown in figure 9.1.

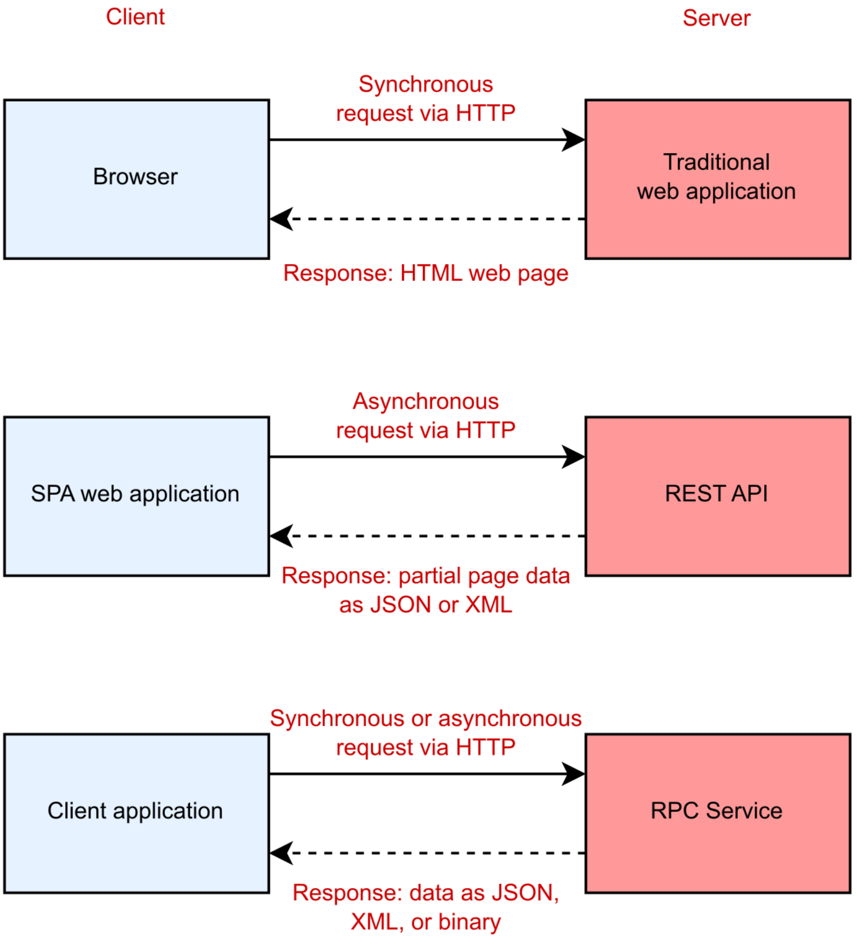

Client
Server
Synchronous request via HTTP
Browser
Traditional web application
Response: HTML web page
Asynchronous request via HTTP
SPA web application
REST API
Response: partial page data as JSON or XML
Synchronous or asynchronous request via HTTP
Client application
RPC Service
Response: data as JSON, XML, or binary

Figure 9.1 Modern developers have to consider a number of different consumers of their applications. As well as traditional users with web browsers, these could be SPAs, mobile applications, or other apps.

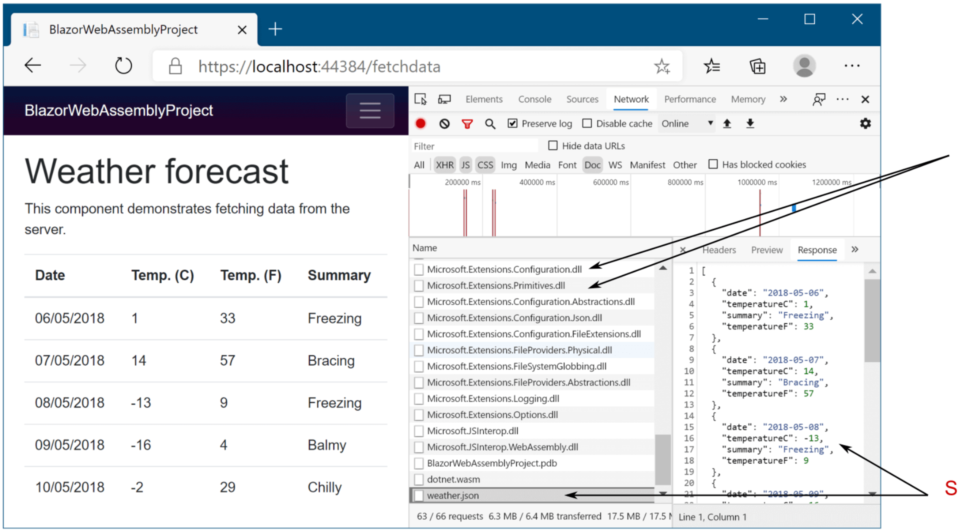
Client-side single-page applications (SPAs) have become popular in recent years with the development of frameworks such as Angular, React, and Vue. These frameworks typically use JavaScript that runs in a user's web browser to generate the HTML they see and interact with. The server sends this initial JavaScript to the browser when the user first reaches the app. The user's browser loads the JavaScript and initializes the SPA, before loading any application data from the server.

> **NOTE** Blazor WebAssembly is an exciting new SPA framework. Blazor lets you write an SPA that runs in the browser just like other SPAs, but it uses C# and Razor templates instead of JavaScript by using the new web

standard, WebAssembly. I don't cover Blazor in this book, so to find out more, I recommend *Blazor in Action*, by Chris Sainty (Manning, 2021).

Once the SPA is loaded in the browser, communication with a server still occurs over HTTP, but instead of sending HTML directly to the browser in response to requests, the server-side application sends data (normally in a format such as JSON) to the client-side application. The SPA then parses the data and generates the appropriate HTML to show to a user, as shown in figure 9.2. The server-side application endpoint that the client communicates with is sometimes called a *Web API*.

DEFINITION A *Web API* exposes a number of URLs that can be used to access or change data on a server. It's typically accessed using HTTP.



BlazorWebAssemblyProject

https://localhost:44384/fetchdata

BlazorWebAssemblyProject

Weather forecast

This component demonstrates fetching data from the server.

Date	Temp. (C)	Temp. (F)	Summary
06/05/2018	1	33	Freezing
07/05/2018	14	57	Bracing
08/05/2018	-13	9	Freezing
09/05/2018	-16	4	Balmy
10/05/2018	-2	29	Chilly

Name
Microsoft.Extensions.Configuration.dll
Microsoft.Extensions.Primitives.dll
Microsoft.Extensions.Configuration.Abstractions.dll
Microsoft.Extensions.Configuration.Json.dll
Microsoft.Extensions.Configuration.FileExtensions.dll
Microsoft.Extensions.FileProviders.Physical.dll
Microsoft.Extensions.FileSystemGlobbing.dll
Microsoft.Extensions.FileProviders.Abstractions.dll
Microsoft.Extensions.Logging.dll
Microsoft.Extensions.Options.dll
Microsoft.JSInterop.dll
Microsoft.JSInterop.WebAssembly.dll
BlazorWebAssemblyProject.pdb
dotnet.wasm
weather.json

```
[
  {
    "date": "2018-05-06",
    "temperatureC": 1,
    "summary": "Freezing",
    "temperatureF": 33
  },
  {
    "date": "2018-05-07",
    "temperatureC": 14,
    "summary": "Bracing",
    "temperatureF": 57
  },
  {
    "date": "2018-05-08",
    "temperatureC": -13,
    "summary": "Freezing",
    "temperatureF": 9
  },
  {
    "date": "2018-05-09",
```

63 / 66 requests 6.3 MB / 6.4 MB transferred 17.5 MB / 17.5 M

Line 1, Column 1

Initial requests fetch client-side Blazor application.

Subsequent requests fetch data in JSON format.

Figure 9.2 A sample client-side SPA using Blazor WebAssembly. The initial requests load the SPA files into the browser, and subsequent requests fetch data from a Web API, formatted as JSON.

These days, mobile applications are common and are, from the server application's point of view, similar to client-side SPAs. A mobile application will typically communicate with a server application using an HTTP Web API, receiving data in a common format, such as JSON, just like an SPA. It then modifies the application's UI depending on the data it receives.

One final use case for a Web API is where your application is designed to be partially or solely consumed by other back-end services. Imagine you've built a web application to send emails. By creating a Web API, you can allow other application developers to use your email service by sending you an email address and a message. Virtually all languages and platforms have access to an HTTP library they could use to access your service from code.

This is all there is to a Web API. It exposes a number of endpoints (URLs) that client applications can send requests to and retrieve data from. These are used to power the behavior of the client apps, as well as to provide all the data the client apps need to display the correct interface to a user.

Whether you need or want to create a Web API for your ASP.NET Core application depends on the type of application you want to build. If you're familiar with client-side frameworks, will need to develop a mobile application, or already have an SPA build-pipeline configured, then you'll most likely want to add Web APIs for them to be able to access your application.

One of the selling points of using a Web API is that it can serve as a generalized backend for all of your client applications. For example, you could start by building a client-side application that uses a Web API. Later, you could add a mobile app that uses the same Web API, with little or no modification required to your ASP.NET Core code.

If you're new to web development, have no need to call your application from outside a web browser, or don't want/need the effort involved in configuring a client-side application, then you probably won't need Web APIs initially. You can stick to generating your UI using Razor Pages and will no doubt be highly productive!

> **NOTE** Although there has definitely been a shift toward client-side frameworks, server-side rendering using Razor is still relevant. Which approach you choose will depend largely on your preference for building HTML applications in the traditional manner versus using JavaScript on the client.

Having said that, adding Web APIs to your application isn't something you have to worry about ahead of time. Adding them later is simple, so you can always ignore them initially and add them in as the need arises. In many cases, this will be the best approach.

SPAs with ASP.NET Core

The cross-platform and lightweight design of ASP.NET Core means it lends itself well to acting as a backend for your SPA framework of choice. Given the focus of this book and the broad scope of SPAs in general, I won't be looking at Angular, React, or other SPAs here. Instead, I suggest checking out the resources appropriate to your chosen SPA. Books are available from Manning for all the common client-side JavaScript frameworks:

- React in Action by Mark Tielens Thomas (Manning, 2018) https://livebook.manning.com/book/react-in-action/.
- Angular in Action by Jeremy Wilken (Manning, 2018) https://livebook.manning.com/book/angular-in-action/.
- Vue.js in Action by Erik Hanchett with Benjamin Listwon (Manning, 2018) https://livebook.manning.com/book/vue-js-in-action/.

To learn about Blazor WebAssembly, see the documentation at https://dotnet.microsoft.com/apps/aspnet/web-apps/blazor.

Once you've established that you need a Web API for your application, creating one is easy, as it's built in to ASP.NET Core. In the next section, you'll see how to create a Web API project and your first API controller.

9.2 Creating your first Web API project

In this section you'll learn how to create an ASP.NET Core Web API project and create your first Web API controllers. You'll see how to use controller action methods to handle HTTP requests, and how to use `ActionResult`s to generate a response.

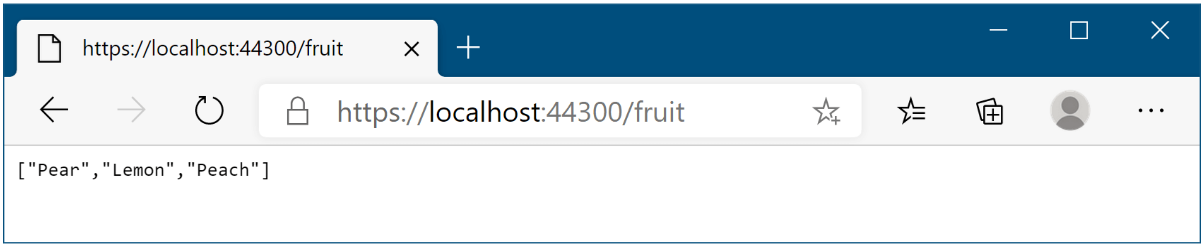
Some people think of the MVC design pattern as only applying to applications that directly render their UI, like the Razor views you've seen in previous chapters. In ASP.NET Core, the MVC pattern applies equally well when building a Web API; but the *view* part of MVC involves generating a *machine*-friendly response rather than a *user*-friendly response.

As a parallel to this, you create Web API controllers in ASP.NET Core in the very same way you create traditional MVC controllers. The only thing that differentiates them from a code perspective is the type of data they return—MVC controllers typically return a `ViewResult`; Web API controllers generally return raw .NET objects from the action methods, or an `IActionResult` such as `StatusCodeResult`, as you saw in chapter 4.

> **NOTE** This is different from the previous version of ASP.NET, where the MVC and Web API stacks were completely independent. ASP.NET Core unifies the two stacks into a single approach (and adds Razor Pages to the mix) which makes using any option in a project painless!

To give you an initial taste of what you're working with, figure 9.3 shows the result of calling a Web API endpoint from your browser. Instead of a friendly HTML UI, you receive data that can be easily consumed in code. In this example, the Web API returns a list of `string` fruit names as JSON when you request the URL `/fruit`.

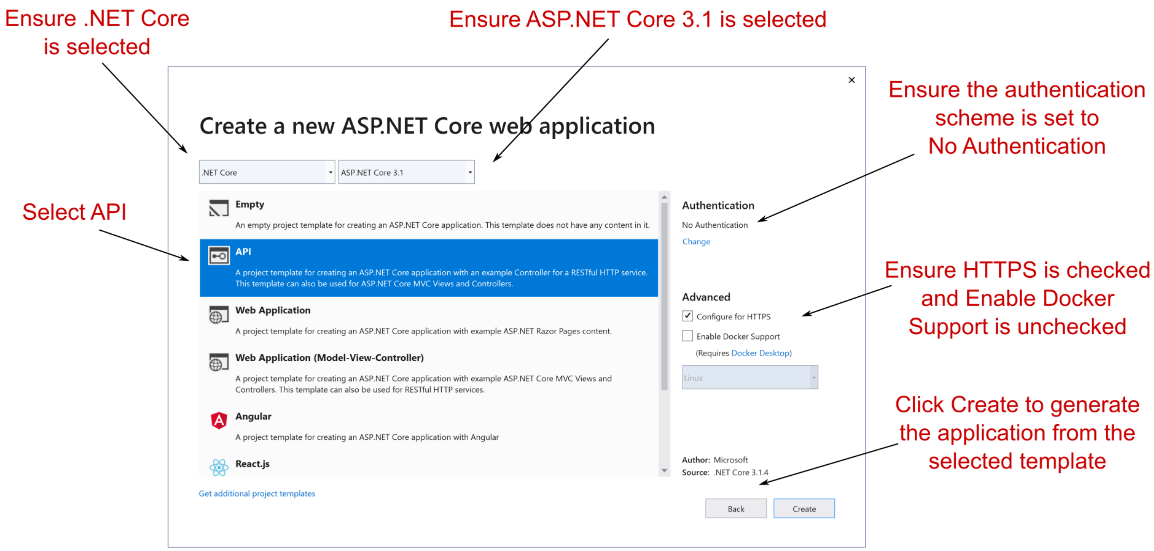
> **TIP** Web APIs are normally accessed from code by SPAs or mobile apps, but by accessing the URL in your web browser directly, you can view the data the API is returning.



```
["Pear","Lemon","Peach"]
```

Figure 9.3 Testing a Web API by accessing the URL in the browser. A `GET` request is made to the /fruit URL, which returns a `List<string>` that has been JSON-encoded into an array of strings.

You can create a new Web API project in Visual Studio using the same New Project process you saw in chapter 2. Create a new ASP.NET Core application, providing a project name, and, when you reach the New Project dialog, select the API template, as shown in figure 9.4. If you’re using the CLI, you can create a similar template using `dotnet new webapi -o WebApplication1`.



Ensure .NET Core is selected

Ensure ASP.NET Core 3.1 is selected

Ensure the authentication scheme is set to No Authentication

Select API

Ensure HTTPS is checked and Enable Docker Support is unchecked

Click Create to generate the application from the selected template

Create a new ASP.NET Core web application

.NET Core | ASP.NET Core 3.1

Empty
An empty project template for creating an ASP.NET Core application. This template does not have any content in it.

API
A project template for creating an ASP.NET Core application with an example Controller for a RESTful HTTP service. This template can also be used for ASP.NET Core MVC Views and Controllers.

Web Application
A project template for creating an ASP.NET Core application with example ASP.NET Razor Pages content.

Web Application (Model-View-Controller)
A project template for creating an ASP.NET Core application with example ASP.NET Core MVC Views and Controllers. This template can also be used for RESTful HTTP services.

Angular
A project template for creating an ASP.NET Core application with Angular

React.js

Get additional project templates

Authentication
No Authentication
Change

Advanced
☑ Configure for HTTPS
□ Enable Docker Support
(Requires Docker Desktop)
Linux

Author: Microsoft
Source: .NET Core 3.1.4

Figure 9.4 The web application template screen. This screen follows on from the configure your project dialog and lets you customize the template that will generate your application. Choose the API template to create a Web API project.

The API template configures the ASP.NET Core project for Web API controllers only. This configuration occurs in the Startup.cs file, as shown in listing 9.1. If you compare this template to your Razor Pages projects, you’ll see that the API project uses `AddControllers()` instead of `AddRazorPages()` in the `ConfigureServices` method. Also, the API controllers are added instead of Razor Pages by calling `MapControllers()` in the `UseEndpoints` method. If you’re using both Razor Pages and Web APIs in a project, you’ll need to add all these method calls to your application.

Listing 9.1 The Startup class for the default Web API project

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services)
    {
        services.AddControllers();                                  #A
    }

    public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
    {
        if (env.IsDevelopment())
        {
            app.UseDeveloperExceptionPage();
        }

        app.UseHttpsRedirection();
        app.UseRouting();
        app.UseAuthorization();

        app.UseEndpoints(endpoints =>
        {
            endpoints.MapControllers();                            #B
        });
    }
}
```

#A AddControllers adds the necessary services for API controllers to your application
#B MapControllers configures the API controller actions in your app as endpoints

The Startup.cs file in listing 9.1 instructs your application to find all API controllers in your application and to configure them in the `EndpointMiddleware`. Each action method becomes an endpoint and can receive requests when the `RoutingMiddleware` maps an incoming URL to the action method.

> **NOTE** **You don't have to use separate projects for Razor Pages and Web API controllers, but I prefer to do so where possible. There are certain aspects (such as error handling and authentication) that are made easier by taking this approach. Of course, running two separate applications has its own difficulties!**

You can add a Web API controller to your project be creating a new .cs file anywhere in your project. Traditionally these are placed in a folder called Controllers, but that's not a technical requirement. Listing 9.2 shows the code that was used to create the Web API demonstrated in figure 9.3. This trivial example highlights the similarity to traditional MVC controllers.

Listing 9.2 A simple Web API controller

```
[ApiController]                                    #A
public class FruitController : ControllerBase      #B
{
    List<string> _fruit = new List<string>         #C
    {                                              #C
        "Pear",                                    #C
        "Lemon",                                   #C
        "Peach"                                    #C
    };                                             #C

    [HttpGet("fruit")]                             #D
    public IEnumerable<string> Index()             #E
    {                                              #F
        return _fruit;                             #F
    }                                              #F
}
```

#A Web API controllers typically use the [ApiController] attribute to opt-in to common conventions
#B The ControllerBase class provides several useful functions for creating IActionResults

#C The data returned would typically be fetched from the application model in a real app.
#D The [HttpGet] attribute defines the route template used to call the action
#E The name of the action method, Index, isn't used for routing. It can be anything you like.
#F The controller exposes a single action method which returns the list of fruit.

Web APIs typically use the `[ApiController]` attribute (introduced in .NET Core 2.1) on API controllers and derive from the `ControllerBase` class. The base class provides several helper methods for generating results, and the `[ApiController]` attribute automatically applies some common conventions, as you'll see in section 9.5.

> **TIP** There is also a `Controller` base class, which is typically used when you use MVC controllers with Razor views. That's not necessary for Web API controllers, so `ControllerBase` is the better option.

In listing 9.2 you can see that the action method, `Index`, returns a list of strings directly from the action method. When you return data from an action like this, you're providing the *API model* for the request. The client will receive this data. It's formatted into an appropriate response, a JSON representation of the list in the case of figure 9.3, and sent back to the browser with a `200 OK` status code.

> **TIP** ASP.NET Core formats data as JSON by default. You'll see how to format the returned data in other ways in section 9.6.

The URL at which a Web API controller action is exposed is handled in the same way as for traditional MVC controllers and Razor Pages—using routing. The `[HttpGet("fruit")]` attribute applied to the `Index` method indicates the method should use the route template `"fruit"` and should respond to HTTP `GET` requests. You'll learn more about attribute routing in section 9.5.

In listing 9.2, data is returned directly from the action method, but you don't *have* to do that. You're free to return an `ActionResult` instead, and often this is required. Depending on the desired behavior of your API, you may sometimes want to return data, and other times you may want to return a raw HTTP status code, indicating whether the request was successful. For example, if an API call is made requesting details of a product that does not exist, you might want to return a `404 Not Found` status code.

Listing 9.3 shows an example of just such a case. It shows another action on the same `FruitController` as before. This method exposes a way for clients to fetch a specific fruit by an `id`, which we'll assume for this example is its index in the list of `_fruit` you defined in the previous listing. Model binding is used to set the value of the `id` parameter from the request.

> **NOTE** API controllers use model binding, as you saw in chapter 6, to bind action method parameters to the incoming request. Model binding and validation work in exactly the same way as for Razor Pages, you can bind the request to simple primitives, as well as complex C# objects. The only difference is that there isn't a `PageModel` with `[BindProperty]` properties—you can *only* bind to action method parameters.

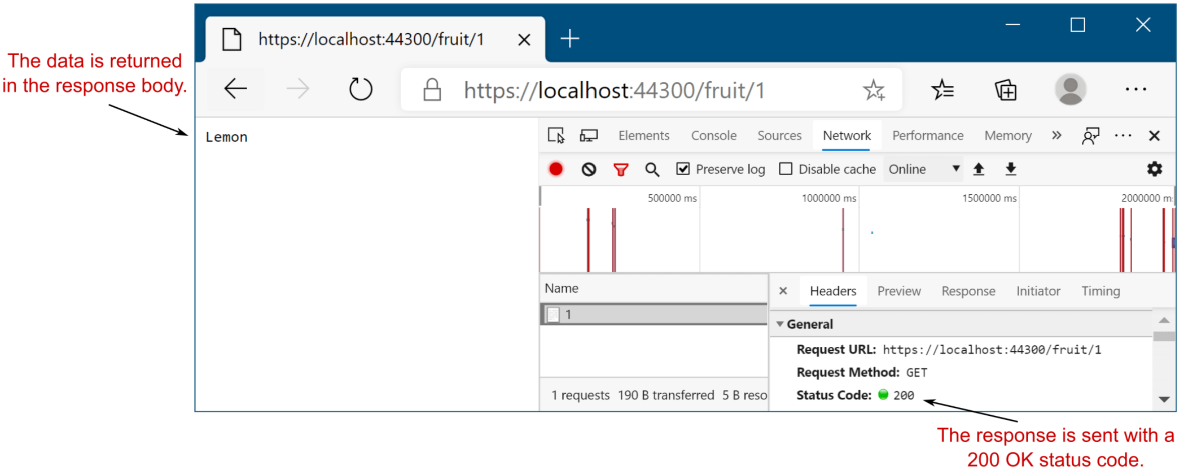
Listing 9.3 A Web API action returning `IActionResult` to handle error conditions

```
[HttpGet("fruit/{id}")]                                  #A
public ActionResult<string> View(int id)                 #B
{
    if (id >= 0 && id < _fruit.Count)                    #C
    {
        return _fruit[id];                                #D
    }
    return NotFound();                                   #E
}
```

#A Defines the route template for the action method
#B The action method returns an ActionResult<string>, so it can return a string or an ActionResult.
#C An element can only be returned if the id value is a valid _fruit element index.
#D Returning the data directly will return the data with a 200 status code.
#D NotFound returns a NotFoundResult, which will send a 404 status code.

In the successful path for the action method, the `id` parameter has a value greater than zero and less than the number of elements in `_fruit`. When that's true, the value of the element is returned to the caller. As in listing 9.2, this is achieved by simply returning the data directly, which generates a 200 status code and returns the element in the response body, as shown in figure 9.5. You could also have returned the data using an `OkResult`, using the `Ok` helper method[37] on the `ControllerBase` class—under the hood the result is identical.

[37] Some people get uneasy when they see the phrase "helper method," but there's nothing magic about the `ControllerBase` helpers—they're shorthand for creating a new `IActionResult` of a given type. You don't have to take my word for it though, you can always view the source code for the base class on GitHub at https://github.com/dotnet/aspnetcore/blob/v3.1.3/src/Mvc/Mvc.Core/src/ControllerBase.cs.



The data is returned in the response body.

Lemon

Request URL: https://localhost:44300/fruit/1

Request Method: GET

Status Code: ● 200

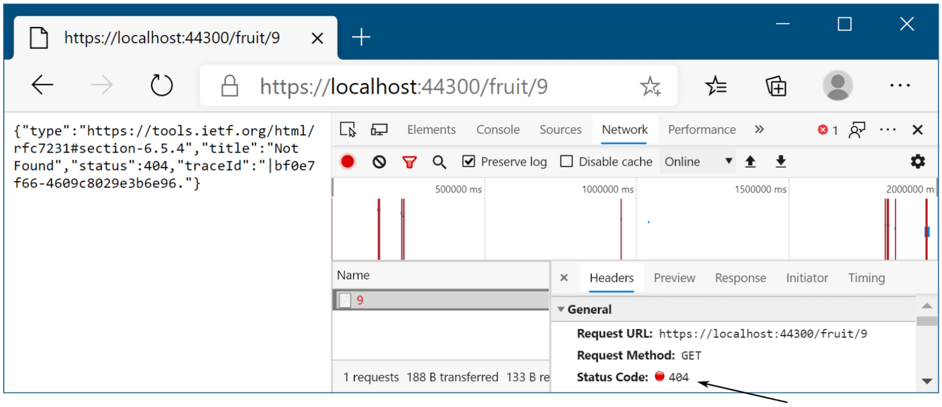
1 requests 190 B transferred 5 B reso

The response is sent with a 200 OK status code.

Figure 9.5 Data returned from an action method is serialized into the response body, and generates a response with status code 200 OK.

If the `id` is outside the bounds of the `_fruit` list, then the method calls `NotFound` to create a `NotFoundResult`. When executed, this method generates a `404 Not Found` status code response. The `[ApiController]` attribute automatically converts the response into a standard `ProblemDetails` instance, as shown in figure 9.6.

> **DEFINITION** `ProblemDetails` **is a web specification for providing machine-readable errors for HTTP APIs. You'll learn more about them in section 9.5.**



```
{"type":"https://tools.ietf.org/html/rfc7231#section-6.5.4","title":"Not Found","status":404,"traceId":"|bf0e7f66-4609c8029e3b6e96."}
```

Request URL: https://localhost:44300/fruit/9
Request Method: GET
Status Code: ● 404

The [ApiResponse] attribute generates a Problem Details JSON as the response body.

The response is sent with a 404 Not Found status code.

Figure 9.6 The `[ApiController]` attribute converts error responses (in this case a 404 response) into the standard `ProblemDetails` format.

One aspect you might find confusing from listing 9.3 is that for the successful case, we return a `string`, but the method signature of `View` says we return an `ActionResult<string>`. How is that possible? Why isn't it a compiler error?

The generic `ActionResult<T>` uses some fancy C# gymnastics with implicit conversions to make this possible[38]. Using `ActionResult<T>` has two benefits:

- You can return either an instance of `T` *or* an `ActionResult` implementation like `NotFoundResult` from the same method. This can be convenient, as in listing 9.3.
- It enables better integration with ASP.NET Core's OpenAPI support (also called Swagger).[39]

You're free to return any type of `ActionResult` from your Web API controllers, but you'll commonly return `StatusCodeResult` instances, which set the response to a specific status code, with or without associated data. `NotFoundResult` and `OkResult` both derive from `StatusCodeResult`, for example. Another commonly used status code is `400 Bad Request`, which is normally returned when the data provided in the request fails validation. This can be generated using a `BadRequestResult`. In many cases the `[ApiController]` attribute can automatically generate `400` responses for you, as you'll see in section 9.5.

[38] You can see how this is achieved in the source code: https://github.com/dotnet/aspnetcore/blob/v3.1.3/src/Mvc/Mvc.Core/src/ActionResultOfT.cs.

[39] OpenAPI is a way of documenting your API controllers, so that you can automatically generate clients for interacting with the API. To learn more, see the documentation at https://docs.microsoft.com/en-us/aspnet/core/tutorials/web-api-help-pages-using-swagger.

TIP You learned about various ActionResults in chapter 4. BadRequestResult, OkResult, and NotFoundResult all inherit from StatusCodeResult, and set the appropriate status code for their type (200, 404, and 400, respectively). Using these wrapper classes makes the intention of your code clearer than relying on other developers to understand the significance of the various status code numbers.

Once you've returned an ActionResult (or other object) from your controller, it's serialized to an appropriate response. This works in several ways, depending on

- The formatters that your app supports
- The data you return from your method
- The data formats the requesting client can handle

You'll learn more about formatters and serializing data in section 9.6, but before we go any further, it's worth zooming out a little, and exploring the parallels between traditional server-side rendered applications and Web API endpoints. The two are similar, so it's important to establish the patterns that they share and where they differ.

9.3 Applying the MVC design pattern to a Web API

In the previous version of ASP.NET, Microsoft commandeered the generic term "Web API" to create the ASP.NET Web API framework. This framework, as you might expect, was used to create HTTP endpoints that could return formatted JSON or XML in response to requests.

The ASP.NET Web API framework was completely separate from the MVC framework, even though it used similar objects and paradigms. The underlying web stacks for them were completely different beasts and couldn't interoperate.

In ASP.NET Core, that all changed. You now have a *single* framework which you can use to build both traditional web applications and Web APIs. The same underlying framework is used in conjunction with Web API controllers, Razor Pages, and MVC controllers with views. You've already seen this yourself; the Web API FruitController you created in section 9.2 look very similar to the MVC controllers you've seen fleetingly in previous chapters.

Consequently, even if you're building an application that consists entirely of Web APIs, using no server-side rendering of HTML, the MVC design pattern still applies. Whether you're building traditional web applications or Web APIs, you can structure your application virtually identically.

After five chapters of it you're, I hope, nicely familiar with how ASP.NET Core handles a request. But just in case you're not, figure 9.7 shows how the framework handles a typical Razor Pages request after passing through the middleware pipeline. This example shows how a request to view the available fruit on a traditional grocery store website might look.

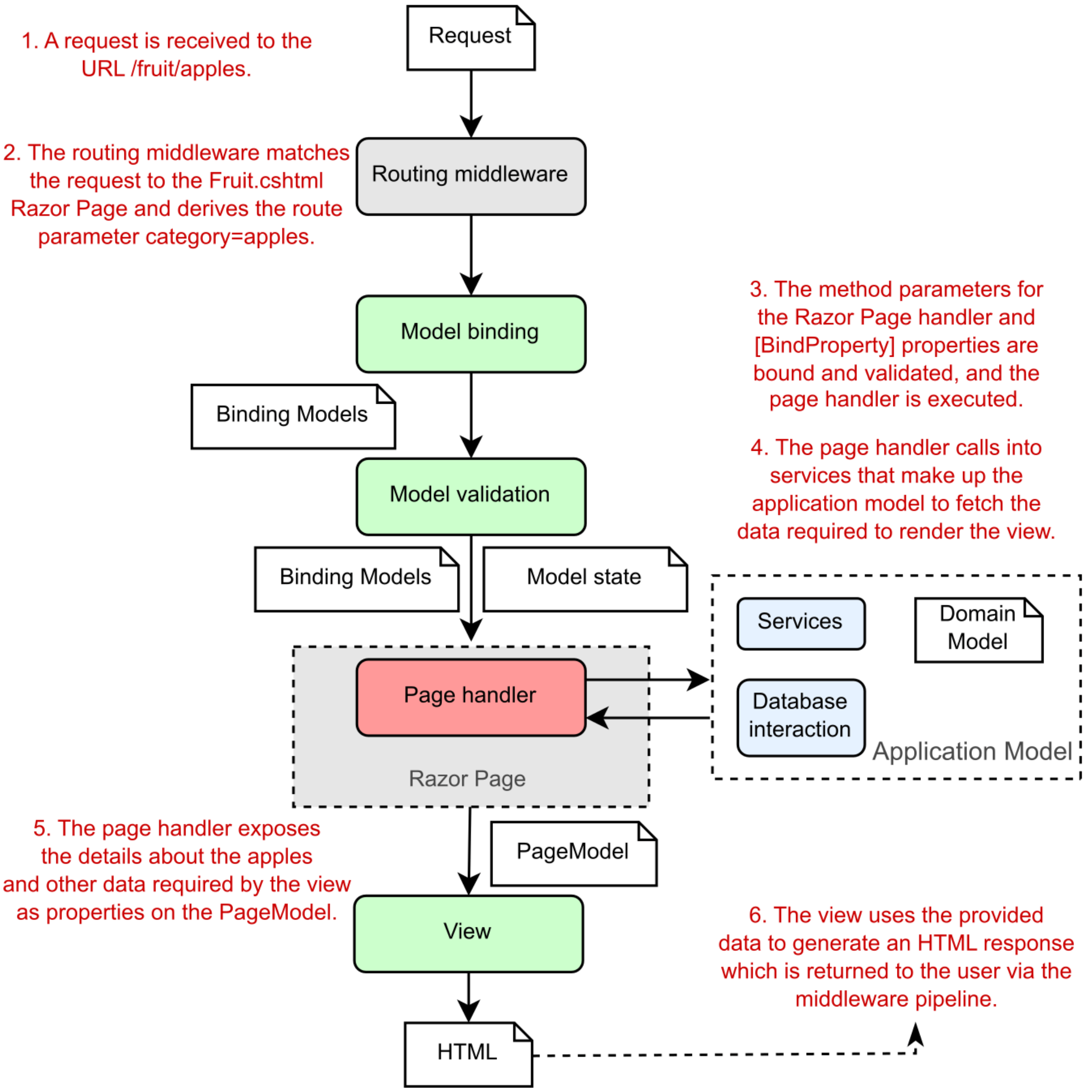

1. A request is received to the URL /fruit/apples.
Request
2. The routing middleware matches the request to the Fruit.cshtml Razor Page and derives the route parameter category=apples.
Routing middleware
Model binding
3. The method parameters for the Razor Page handler and [BindProperty] properties are bound and validated, and the page handler is executed.
Binding Models
Model validation
4. The page handler calls into services that make up the application model to fetch the data required to render the view.
Binding Models
Model state
Services
Domain Model
Page handler
Database interaction
Application Model
Razor Page
5. The page handler exposes the details about the apples and other data required by the view as properties on the PageModel.
PageModel
View
6. The view uses the provided data to generate an HTML response which is returned to the user via the middleware pipeline.
HTML

Figure 9.7 Handling a request to a traditional Razor Pages application, in which the view generates an HTML response that's sent back to the user. This diagram should be very familiar by now!

The `RoutingMiddleware` routes the request to view all the fruit listed in the `apples` category to the Fruit.cshtml Razor Page. The `EndpointMiddleware` then constructs a binding model, validates it, sets it as a property on the Razor Page's `PageModel`, and sets the `ModelState` property on the `PageModel` base class with details of any validation errors. The page handler interacts with the application model by calling into services, talking to a database, and fetching any necessary data.

Finally, the Razor Page executes its Razor view using the `PageModel` to generate the HTML response. The response returns back through the middleware pipeline and out to the user's browser.

How would this change if the request came from a client-side or mobile application? If you want to serve machine-readable JSON instead of HTML, what is different? As shown in figure 9.8, the answer is "very little." The main changes are related to switching from Razor Pages to controllers and actions, but as you saw in chapter 4, both approaches use the same general paradigms.

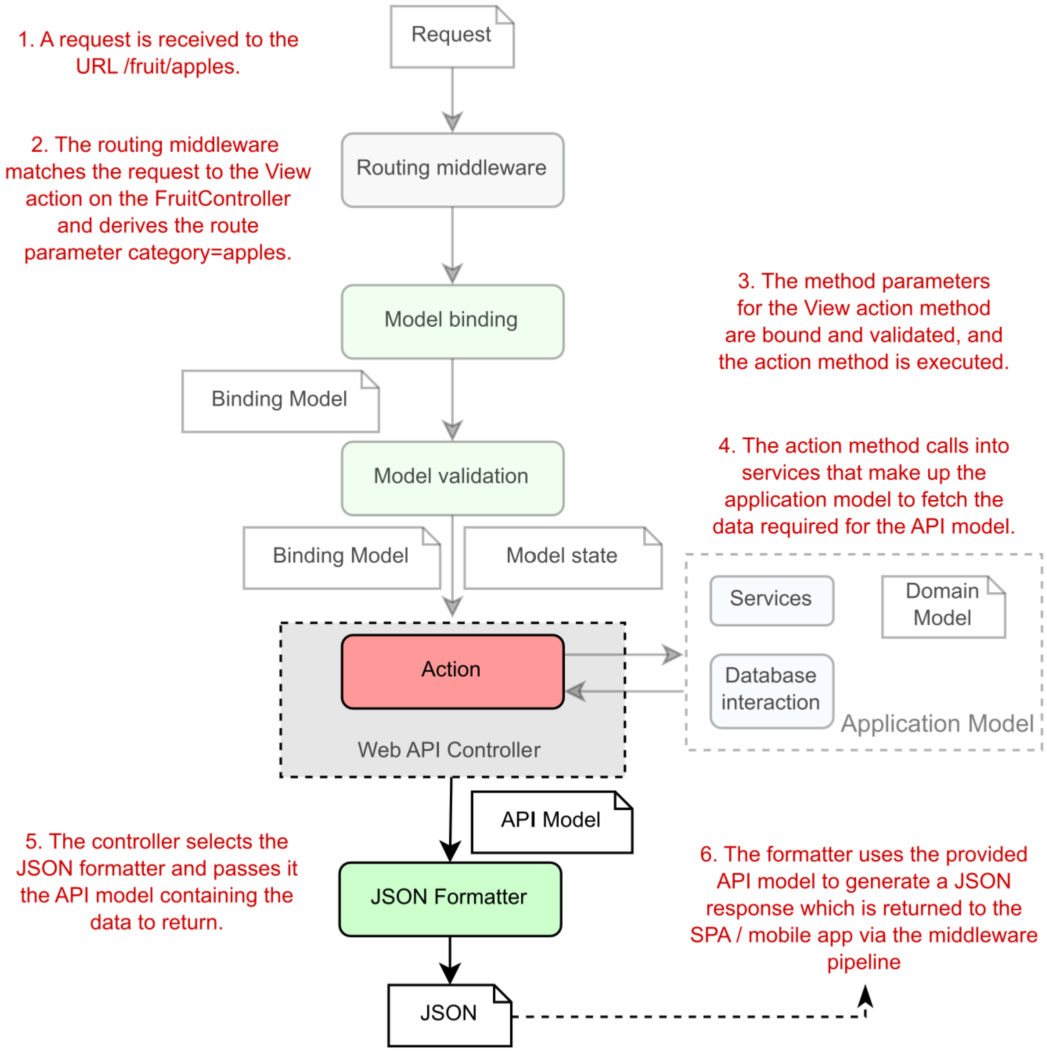

1. A request is received to the URL /fruit/apples.
Request
2. The routing middleware matches the request to the View action on the FruitController and derives the route parameter category=apples.
Routing middleware
3. The method parameters for the View action method are bound and validated, and the action method is executed.
Model binding
Binding Model
Model validation
4. The action method calls into services that make up the application model to fetch the data required for the API model.
Binding Model
Model state
Services
Domain Model
Database interaction
Application Model
Action
Web API Controller
API Model
5. The controller selects the JSON formatter and passes it the API model containing the data to return.
JSON Formatter
6. The formatter uses the provided API model to generate a JSON response which is returned to the SPA / mobile app via the middleware pipeline
JSON

Figure 9.8 A call to a Web API endpoint in an e-commerce ASP.NET Core web application. The ghosted portion of the diagram is identical to figure 9.7.

As before, the routing middleware selects an endpoint to invoke based on the incoming URL. For API Controllers this is a controller and action instead of a Razor Page.

After routing comes model binding, in which the binder creates a binding model and populates it with values from the request, exactly as for the Razor Pages request. Validation occurs in the same way, and the `ModelState` property on the `ControlerBase` base class is populated with any validation errors.

The action method is the equivalent of the Razor Page handler; it interacts with the application model in exactly the same way. This is an important point; by separating the behavior of your app into an application model, instead of incorporating it into your pages and controllers themselves, you're able to reuse the business logic of your application with multiple UI paradigms.

> **TIP** Where possible, keep your page handlers and controllers as simple as possible. Move all your "business logic" decisions into the services that make up your application model, and keep your Razor Pages and API controllers focused on the "mechanics" of interactive with a user.

After the application model has returned the data necessary to service the request—the fruit objects in the `apples` category—you see the first significant difference between API controllers and Razor Pages. Instead of adding values to the `PageModel` to be used in a Razor view, the action method creates an *API model*. This is analogous to the `PageModel`, but rather than containing data used to generate an HTML view, it contains the data that will be sent back in the response.

> **DEFINITION** ***View models*** and `PageModels` contain both ***data*** required to build a response and ***metadata*** about ***how*** to build the response. API Models typically ***only*** contain the data to be returned in the response.

When we looked at the Razor Pages app, we used the `PageModel` in conjunction with a Razor view template to build the final response. With the Web API app, we use the API model in conjunction with a *formatter*. A formatter, as the name suggests, serializes the API model into a machine-readable response, such as JSON or XML. The formatter forms the "V" in the Web API version of MVC, by choosing an appropriate representation for the data to return.

Finally, as for the Razor Pages app, the generated response is then sent back through the middleware pipeline, passing through each of the configured middleware components, and back to the original caller.

Hopefully, the parallels between Razor Pages and Web APIs are clear; the majority of behavior is identical, only the response varies. Everything from when the request arrives to the interaction with the application model is similar between the paradigms.

Most of the differences between Razor Pages and Web APIs are less to do with the way the framework works under the hood and are instead related to how the different paradigms are used. For example, in the next section, you'll learn how the routing constructs you learned about in chapter 5 are used with Web APIs, using attribute routing.

9.4 Attribute routing: linking action methods to URLs

In this section you'll learn about attribute routing: the mechanism for associating API controller actions with a given route template. You'll see how to associate controller actions with specific HTTP verbs like `GET` and `POST` and how to avoid duplication in your templates.

We covered route templates in depth in chapter 5 in the context of Razor Pages, and you'll be pleased to know that you use exactly the same route templates with API controllers. The only difference is how you *specify* the templates: with Razor Pages you use the `@model` directive, with API controllers you use routing attributes.

> **REMINDER** Both Razor Pages and API controllers use *attribute routing* under the hood. The alternative, *conventional* routing, is typically used with traditional MVC controllers and Views. As discussed previously, I don't recommend using that approach, so I don't cover conventional routing in this book.

With attribute routing, you decorate each action method in an API controller with an attribute, and provide the associated route template for the action method, as shown in the following listing.

Listing 9.4 Attribute routing example

```
public class HomeController: Controller
{
    [Route("")]                          #A
    public IActionResult Index()
    {
         /* method implementation*/
    }

    [Route("contact")]                   #B
    public IActionResult Contact()
    {
         /* method implementation*/
    }
}
```

#A The Index action will be executed when the "/" URL is requested.
#B The Contact action will be executed when the "/contact" URL is requested.

Each `[Route]` attribute defines a route template that should be associated with the action method. In the example provided, the `/` URL maps directly to the `Index` method and the `/contact` URL maps to the `Contact` method.

Attribute routing maps URLs to a specific action method, but a single action method can still have multiple route templates, and hence can correspond to multiple URLs. Each template must be declared with its own `RouteAttribute`, as shown in this listing, which shows the skeleton of a Web API for a car-racing game.

Listing 9.5 Attribute routing with multiple attributes

```
public class CarController
{
    [Route("car/start")]                    #A
    [Route("car/ignition")]                 #A
    [Route("start-car")]                    #A
    public IActionResult Start()            #B
    {
        /* method implementation*/
    }

    [Route("car/speed/{speed}")]            #C
    [Route("set-speed/{speed}")]            #C
    public IActionResult SetCarSpeed(int speed)
    {
        /* method implementation*/
    }
}
```

#A The Start method will be executed when any of these route templates are matched.
#B The name of the action method has no effect on the route template.
#C The RouteAttribute template can contain route parameters, in this case {speed}.

The listing shows two different action methods, both of which can be accessed from multiple URLs. For example, the `Start` method will be executed when any of the following URLS are requested:

- `/car/start`
- `/car/ignition`
- `/start-car`

These URLs are completely independent of the controller and action method names; only the value in the `RouteAttribute` matters.

> **NOTE** **By default, the controller and action name have no bearing on the URLs or route templates when** `RouteAttribute`**s are used.**

The templates used in route attributes are standard route templates, the same as you used in chapter 5. You can use literal segments and you're free to define route parameters that will extract values from the URL, as shown by the `SetCarSpeed` method in the previous listing. That method defines two route templates, both of which define a route parameter, `{speed}`.

> **TIP** **I've used multiple** `[Route]` **attributes on each action in this example, but it's best practice to expose your action at a *single* URL. This will make your API easier to understand and consume by other applications.**

Route parameters are handled in the very same way as for Razor Pages—they represent a segment of the URL that can vary. As for Razor Pages, the route parameters in your `RouteAttribute` templates can

- Be optional
- Have default values
- Use route constraints

For example, you could update the `SetCarSpeed` method in the previous listing to constrain `{speed}` to an integer and to default to `20` like so:

```
[Route("car/speed/{speed=20:int}")]
```

```
[Route("set-speed/{speed=20:int}")]
public IActionResult SetCarSpeed(int speed)
```

If you managed to get your head around routing in chapter 5, then routing with API controllers shouldn't hold any surprises for you. One thing you might begin noticing when you start using attribute routing is the amount you repeat yourself. Razor Pages removes a lot of repetition by using conventions to calculate route templates based on the Razor Page's filename.

Luckily, there are a few features available to make your life a little easier. In particular, combining route attributes and token replacement can help reduce duplication in your code.

9.4.1 Combining route attributes to keep your route templates DRY

Adding route attributes to all of your API controllers can get a bit tedious, especially if you're mostly following conventions where your routes have a standard prefix such as `"api"` or the controller name. Generally, you'll want to ensure you don't repeat yourself (DRY) when it comes to these strings. The following listing shows two action methods with a number of `[Route]` attributes. (This is for demonstration purposes only. Stick to one per action if you can!)

Listing 9.6 Duplication in `RouteAttribute` templates

```
public class CarController
{
    [Route("api/car/start")]                       #A
    [Route("api/car/ignition")]                    #A
    [Route("/start-car")]
    public IActionResult Start()
    {
         /* method implementation*/
    }

    [Route("api/car/speed/{speed}")]               #A
    [Route("/set-speed/{speed}")]
    public IActionResult SetCarSpeed(int speed)
    {
         /* method implementation*/
    }
}
```

#A Multiple route templates use the same "api/car" prefix

There's quite a lot of duplication here—you're adding `"api/car"` to most of your routes. Presumably, if you decided to change this to `"api/vehicles"`, you'd have to go through each attribute and update it. Code like that is asking for a typo to creep in!

To alleviate this pain, it's possible to apply `RouteAttribute`s to *controllers*, in addition to action methods, as you saw briefly in chapter 5. When a controller and an action method both have a route attribute, the overall route template for the method is calculated by combining the two templates.

Listing 9.7 Combining RouteAttribute templates

```
[Route("api/car")]
public class CarController
{
    [Route("start")]                              #A
    [Route("ignition")]                           #B
    [Route("/start-car")]                         #C
    public IActionResult Start()
    {
         /* method implementation*/
    }

    [Route("speed/{speed}")]                      #D
    [Route("/set-speed/{speed}")]                 #E
    public IActionResult SetCarSpeed(int speed)
    {
         /* method implementation*/
    }
}
```

#A Combines to give the "api/car/start" template
#B Combines to give the "api/car/ignition" template
#C Does not combine as starts with /, gives the "start-car" template
#D Combines to give the "api/car/speed/{speed}" template
#E Does not combine as starts with /, gives the "set-speed/{speed}" template

Combining attributes in this way can reduce some of the duplication in your route templates and makes it easier to add or change the prefixes (such as switching "car" to "vehicle") for multiple action methods. To ignore the RouteAttribute on the controller and create an absolute route template, start your action method route template with a slash (/). Using a controller RouteAttribute reduces a lot of the duplication, but you can do one better by using token replacement.

9.4.2 Using token replacement to reduce duplication in attribute routing

The ability to combine attribute routes is handy, but you're still left with some duplication if you're prefixing your routes with the name of the controller, or if your route templates always use the action name. Luckily, you can simplify even further!

Attribute routes support the automatic replacement of the [action] and [controller] tokens in your attribute routes. These will be replaced with the name of the action and the controller (without the "Controller" suffix), respectively. The tokens are replaced after all attributes have been combined, so this is useful when you have controller inheritance hierarchies. This listing shows how you can create a BaseController class that you can use to apply a consistent route template prefix to *all* the API controllers in your application.

Listing 9.8 Token replacement in RouteAttributes

```
[Route("api/[controller]")]                      #A
public abstract class BaseController { }         #B
public class CarController : BaseController
{
    [Route("[action]")]                               #C
    [Route("ignition")]                               #D
    [Route("/start-car")]                             #E
    public IActionResult Start()
    {
         /* method implementation*/
    }
}
```

#A You can apply attributes to a base class, and derived classes will inherit them
#B Token replacement happens last, so [controller] is replaced with "car" not "base"
#C Combines and replaces tokens to give the "api/car/start" template
#D Combines and replaces tokens to give the "api/car/ignition" template
#E Does not combine with base attributes as it starts with /, so remains as "start-car"

When combined with everything you learned in chapter 5, we've covered pretty much everything there is to know about attribute routing now. There's just one more thing to consider: handling different HTTP request types like `GET` and `POST`.

9.4.3 Handling HTTP verbs with attribute routing

In Razor Pages, the HTTP verb, `GET` or `POST` for example, isn't part of the routing process. The `RoutingMiddleware` determines which Razor Page to execute based solely on the route template associated with the Razor Page. It's only when a Razor Page is about to be executed that the HTTP verb is used to decide which page handler to execute: `OnGet` for the `GET` verb, or `OnPost` for the `POST` verb for example.

With API controllers, things work a bit differently. For API controllers, the HTTP verb takes part in the routing process itself, so a `GET` request may be routed to one action, and a `POST` request may be routed to a different action, *even though the request used the same URL*. This pattern, where the HTTP verb is an important part of routing, is common in HTTP API design.

For example, imagine you're building an API to manage your calendar. You want to be able to list and create appointments. Well, a traditional HTTP REST service might define the following URLs and HTTP verbs to achieve this:

- `GET /appointments`—List all your appointments
- `POST /appointments`—Create a new appointment

Note that these two endpoints use the same URL, only the HTTP verb differs. The `[Route]` attribute we've used so far responds to *all* HTTP verbs which is no good for us here—we want to select a different action based on the combination or the URL *and* the verb. This pattern is common when building Web APIs and, luckily, it's easy to model in ASP.NET Core.

ASP.NET Core provides a set of attributes that you can use to indicate which verb an action should respond to. For example:

- `[HttpPost]` handles `POST` requests only
- `[HttpGet]` handles `GET` requests only

- `[HttpPut]` handles `PUT` requests only

There are similar attributes for all the standard HTTP verbs, like `DELETE` and `OPTIONS`. You can use these attributes instead of the `[Route]` attribute to specify that an action method should correspond to a single verb, as shown in the listing below.

Listing 9.9 Using HTTP verb attributes with attribute routing

```
public class AppointmentController
{
    [HttpGet("/appointments")]                    #A
    public IActionResult ListAppointments()       #A
    {                                             #A
        /* method implementation */               #A
    }                                             #A

    [HttpPost("/appointments")]                   #B
    public IActionResult CreateAppointment()      #B
    {                                             #B
        /* method implementation */               #B
    }                                             #B
}
```

#A Only executed in response to GET /appointments
#B Only executed in response to POST /appointments

If your application receives a request that matches the route template of an action method, but which *doesn't* match the required HTTP verb, you'll get a `405 Method not allowed` error response. For example, if you send a `DELETE` request to the `/appointments` URL in the previous listing, you'll get a `405` error response.

Attribute routing has been used with API controllers since the first days of ASP.NET Core, as it allows tight control over the URLs that your application exposes. When you're building API controllers, there is some code that you find yourself writing repeatedly. The `[ApiController]` attribute, introduced in ASP.NET Core 2.1 is designed to handle some of these for you, and reduce the amount of boilerplate you need.

9.5 Using common conventions with ApiControllerAttribute

In this section you'll learn about the `[ApiController]` attribute and how it can reduce the amount of code you need to write to create consistent Web API controllers. You'll learn about the conventions it applies, why they're useful, and how to turn them off if you need to.

The `[ApiController]` attribute was introduced in .NET Core 2.1 to simplify the process of creating Web API controllers. To understand what it does, it's useful to look at an example of how you might write a Web API controller *without* the `[ApiController]` attribute, and compare that to the code required to achieve the same thing with the attribute.

Listing 9.10 Creating a Web API controller without the [ApiController] attribute

```
public class FruitController : ControllerBase
```

```
{
    List<string> _fruit = new List<string>                          #A
    {                                                               #A
        "Pear", "Lemon", "Peach"                                    #A
    };                                                              #A

    [HttpPost("fruit")]                                             #B
    public ActionResult Update([FromBody] UpdateModel model)        #C
    {
        if (!ModelState.IsValid)                                    #D
        {                                                           #D
             return BadRequest(                                     #D
                new ValidationProblemDetails(ModelState));          #D
        }                                                           #D

        if (model.Id < 0 || model.Id > _fruit.Count)
        {
            return NotFound(new ProblemDetails()                    #E
            {                                                       #E
                Status = 404,                                       #E
                Title = "Not Found",                                #E
                Type = "https://tools.ietf.org/html/rfc7231"        #E
                       + "#section-6.5.4",                          #E
            });                                                     #E
        }                                                           #E

        _fruit[model.Id] = model.Name;                              #F
        return Ok();                                                #F
    }

    public class UpdateModel
    {
        public int Id { get; set; }

        [Required]                                                  #G
        public string Name { get; set; }                            #G
    }
}
```

#A The list of strings serves as the application model in this example.
#B Web APIs use attribute routing to define the route templates
#C The [FromBody] attribute indicates the parameter should be bound to the request body
#D You need to check if model validation succeeded, and return a 400 response if it failed
#E If the data sent does not contain a valid ID, return a 404 ProblemDetails response
#F Update the model, and return a 200 Response
#G The UpdateModel is only valid if the Name value is provided, as set by the [Required] attribute

This example demonstrates many common features and patterns used with Web API controllers:

- Web API controllers read data from the body of a request, typically sent as JSON. To ensure the body is read as JSON and not as form values, you have to apply the `[FromBody]` attribute to the method parameters to ensure it is model bound correctly.
- As discussed in chapter 6, after model binding, the model is validated, but it's up to you to act on the validation results. You should return a `400 Bad Request` response if

the values provided failed validation. You typically want to provide details of *why* the request was invalid: this is done in listing 9.10 by returning a `ValidationProblemDetails` object, built from the `ModelState`.

- Whenever you return an error status, such as a `404 Not Found`, where possible you should return details of the problem that allow the caller to diagnose the issue. The `ProblemDetails` class is the recommended way of doing that in ASP.NET Core.

The code in listing 9.10 is representative of what you might see in an ASP.NET Core API controller, *prior* to .NET Core 2.1. The introduction of the `[ApiController]` attribute in .NET Core 2.1 (and subsequent refinement in later versions), makes this *same* code much simpler, as shown in the following listing:

Listing 9.11 Creating a Web API controller with the [ApiController] attribute

```
[ApiController]                                         #A
public class FruitController : ControllerBase
{
    List<string> _fruit = new List<string>
    {
        "Pear", "Lemon", "Peach"
    };

    [HttpPost("fruit")]
    public ActionResult Update(UpdateModel model)       #B
    {                                                   #C
        if (model.Id < 0 || model.Id > _fruit.Count)
        {
            return NotFound();                          #D
        }

        _fruit[model.Id] = model.Name;

        return Ok();
    }

    public class UpdateModel
    {
        public int Id { get; set; }

        [Required]
        public string Name { get; set; }
    }
}
```

#A Adding the [ApiController] attribute applies several conventions common to API controllers
#B The [FromBody] attribute is assumed for complex action parameter arguments
#C The model validation is automatically checked, and if invalid, returns a 400 response
#D Error status codes are automatically converted to a ProblemDetails object

If you compare listing 9.10 to listing 9.11, you’ll see that all the highlighted code can be removed and replaced with the `[ApiController]` attribute. The `[ApiController]` attribute automatically applies several conventions to your controllers:

- *Attribute routing*. You must use attribute routing with your controllers, you can’t use conventional routing. Not that you would, as we’ve only discussed this approach for API controllers anyway!
- *Automatic 400 responses*. I said in chapter 6 that you should *always* check the value of `ModelState.IsValid` in your Razor Page handlers and MVC actions, but the `[ApiController]` attribute does this for you, by adding a *filter*. We’ll cover filters in detail in chapter 13.
- *Model binding source inference*. Without the `[ApiController]` attribute, complex types are assumed to be passed as *form* values in the request body. For Web APIs, it’s much more common to pass data as JSON, which ordinarily requires adding the `[FromBody]` attribute. The `[ApiController]` attribute takes care of that for you.
- `ProblemDetails` *for error codes*. You often want to return a consistent set of data when an error occurs in your API. `ProblemDetails` is a type based on a web standard that serves as this consistent data. The `[ApiController]` attribute will intercept any error status codes returned by your controller (for example, a 404 Not Found response), and convert them into the `ProblemDetails` type automatically.

A key feature of the `[ApiController]` attribute is using the *Problem Details*[40] format to return errors in a consistent format across all your controllers. A typical `ProblemDetails` object looks something like the following, for example when a `ValidationProblemDetails` object is generated automatically for an invalid request:

```
{
  type: "https://tools.ietf.org/html/rfc7231#section-6.5.1"
  title: "One or more validation errors occurred."
  status: 400
  traceId: "|17a2706d-43736ad54bed2e65."
  errors: {
    name: ["The name field is required."]
  }
}
```

The `[ApiController]` conventions can significantly reduce the amount of boilerplate code you have to write. They also ensure consistency across your whole application. For example, you can be sure that all your controllers will return the same error type, `ValidationProblemDetails` (a sub-type of `ProblemDetails`) when a bad request is received.

Converting all your errors to ProblemDetails

The `[ApiController]` attribute ensures that all error responses returned by your API controllers are converted into `ProblemDetails` objects, which keeps the error responses consistent across your application.

[40] Problem Details is a proposed standard for handling errors in a machine-readable way that is gaining popularity. You can find the specification here, but be warned, it makes for dry reading https://tools.ietf.org/html/rfc7807.

The only problem with this is that your API controllers aren't the *only* thing that could generate errors. For example, if a URL is received that doesn't match any action in your controllers, the "end-of-the-pipeline" middleware we discussed in chapter 3 would generate a 404 Not Found response. As this error is generated *outside* of the API controllers, it won't use `ProblemDetails`. Similarly, when your code throws an exception, you want this to be returned as a `ProblemDetails` object too, but this doesn't happen by default.

In chapter 3 I described several types of error handling middleware that you could use to handle these cases, but it can be complicated to handle all the edge cases. I prefer to use a community-created package, *Hellang.Middleware.ProblemDetails*, which takes care of this for you. You can read about how to use this package at https://andrewlock.net/handling-web-api-exceptions-with-problemdetails-middleware/.

As is common in ASP.NET Core, you will be most productive if you follow the conventions rather than trying to fight them. However, if you don't like some of the conventions, or want to customize them, then you can easily do so.

You can customize the conventions your application uses by calling `ConfigureApiBehaviorOptions()` on the `IMvcBuilder` object returned from the `AddControllers()` method in your Startup.cs file. For example, you could disable the automatic `400` responses on validation failure, as shown in the listing below.

Listing 9.12 Customizing [ApiAttribute] behaviors

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services)
    {
        services.AddControllers()
            .ConfigureApiBehaviorOptions(options =>                #A
            {
                options.SuppressModelStateInvalidFilter = true;    #B
            })
    }

    // ...
}
```

#A Control which conventions are applied by providing a configuration lambda
#B This would disable the automatic 400 responses for invalid requests

The ability to customize each aspect of ASP.NET Core is one of the features that sets it apart from the previous version of ASP.NET. ASP.NET Core configures the vast majority of its internal components using one of two mechanisms—dependency injection or by configuring an `Options` object when you add the service to your application, as you'll see in chapters 10 (dependency injection) and 11 (`Options` object).

In the next section you'll learn how to control the format of the data returned by your Web API controllers—whether that's JSON, XML, or a different, custom format.

9.6 Generating a response from a model

This brings us to the final section in this chapter: formatting a response. It’s common for API controllers to return JSON these days, but that’s not *always* the case. In this section you’ll learn about content negotiation and how to enable additional output formats such as XML. You’ll also learn about an important change in the JSON formatter for ASP.NET Core 3.0.

Consider this scenario: You’ve created a Web API action method for returning a list of cars, as in the following listing. It invokes a method on your application model, which hands back the list of data to the controller. Now you need to format the response and return it to the caller.

Listing 9.13 A Web API controller to return a list of cars

```
[ApiController]
public class CarsController : Controller
{
    [HttpGet("api/cars")]                           #A
    public IEnumerable<string> ListCars()           #B
    {
        return new string[]                         #C
            { "Nissan Micra", "Ford Focus" };       #C
    }
}
```

#A The action is executed with a request to GET /api/cars.
#B The API Model containing the data is an IEnumerable<string>.
#C This data would normally be fetched from the application model.

You saw in section 9.2 that it’s possible to return data directly from an action method, in which case, the middleware formats it and returns the formatted data to the caller. But how does the middleware know which format to use? After all, you could serialize it as JSON, as XML, even with a simple `ToString()` call.

The process of determining the format of data to send to clients is known generally as *content negotiation* (conneg). At a high level, the client sends a header indicating the types of content it can understand—the `Accept` header—and the server picks one of these, formats the response, and sends a `content-type` header in the response, indicating which it chose.

The accept and content-type headers

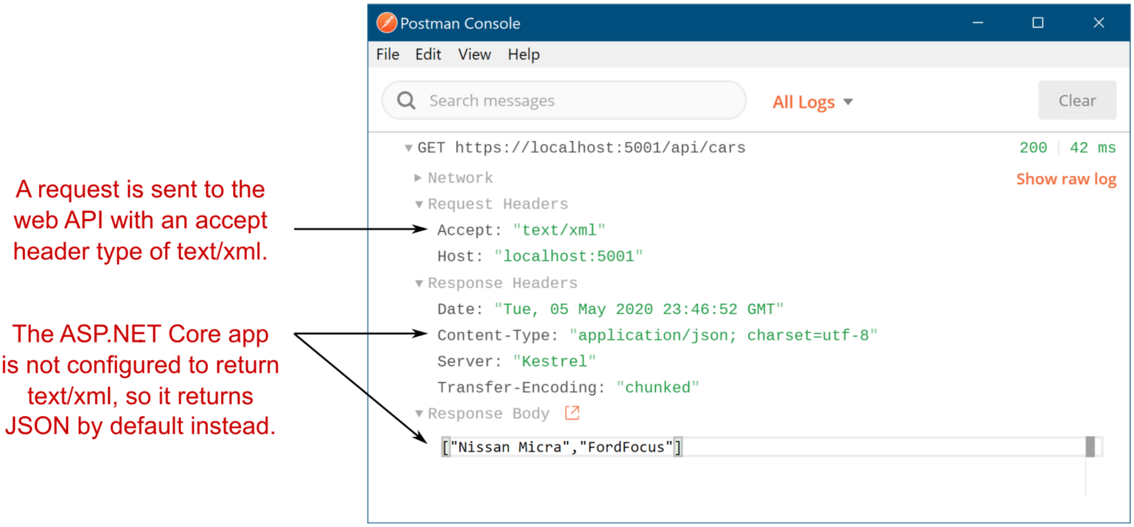
The `accept` header is sent by a client as part of a request to indicate the type of content that the client can handle. It consists of a number of MIME types,[a] with optional weightings (from 0 to 1) to indicate which type would be preferred. For example, the `application/json,text/xml;q=0.9,text/plain;q=0.6` header indicates that the client can accept JSON, XML, and plain text, with weightings of 1.0, 0.9, and 0.6, respectively. JSON has a weighting of 1.0, as no explicit weighting was provided. The weightings can be used during content negotiation to choose an optimal representation for both parties.

The `content-type` header describes the data sent in a request or response. It contains the MIME type of the data, with an optional character encoding. For example, the `application/json; charset=utf-8` header would indicate that the body of the request or response is JSON, encoded using UTF-8.

[a] For more on MIME types see https://developer.mozilla.org/en-US/docs/Web/HTTP/Basics_of_HTTP/MIME_types.

You're not forced into *only* sending a `content-type` the client expects and, in some cases, you may not even be *able* to handle the types it requests. What if a request stipulates it can only accept Excel spreadsheets? It's unlikely you'd support that, even if that's the only `content-type` the request contains!

When you return an API model from an action method, whether directly (as in the listing 9.13) or via an `OkResult` or other `StatusCodeResult`, ASP.NET Core will always return *something*. If it can't honor any of the types stipulated in the `Accept` header, it will fall back to returning JSON by default. Figure 9.9 shows that even though XML was requested, the API controller formatted the response as JSON.



```
▼ GET https://localhost:5001/api/cars                         200 | 42 ms
  ▸ Network
  ▼ Request Headers
      Accept: "text/xml"
      Host: "localhost:5001"
  ▼ Response Headers
      Date: "Tue, 05 May 2020 23:46:52 GMT"
      Content-Type: "application/json; charset=utf-8"
      Server: "Kestrel"
      Transfer-Encoding: "chunked"
  ▼ Response Body
      ["Nissan Micra","FordFocus"]
```

A request is sent to the web API with an accept header type of text/xml.

The ASP.NET Core app is not configured to return text/xml, so it returns JSON by default instead.

Figure 9.9 Even though the request was made with an `Accept` header of `text/xml`, the response returned was JSON, as the server was not configured to return XML.

> **NOTE** In the previous version of ASP.NET, objects were serialized to JSON using PascalCase, where properties start with a capital letter. In ASP.NET Core, objects are serialized using camelCase by default, where properties start with a lowercase letter.

However, the data is sent, it's serialized by an `IOutputFormatter` implementation. ASP.NET Core ships with a limited number of output formatters out of the box, but as always, it's easy to add additional ones, or change the way the defaults work.

9.6.1 Customizing the default formatters: adding XML support

As with most of ASP.NET Core, the Web API formatters are completely customizable. By default, only formatters for plain text (`text/plain`), HTML (`text/html`), and JSON (`application/json`) are configured. Given the common use-case of SPAs and mobile applications, this will get you a long way. But sometimes you need to be able to return data in a different format, such as XML.

Newtonsoft.Json vs System.Text.Json

Newtonsoft.Json, also known as Json.NET, has for a long time been the canonical way to work with JSON in .NET. It's compatible with every version of .NET under the sun, and will no doubt be familiar to virtually all .NET developers. Its reach was so great, that even ASP.NET Core took a dependency on it!

In ASP.NET Core 3.0, that all changed with the introduction of System.Text.Json. This is a new library which focuses on performance and is built in to .NET Core 3.0. In ASP.NET Core 3.0 onwards, ASP.NET Core uses System.Text.Json by default instead of Newronsoft.Json.

The main difference between the libraries is that System.Text.Json is very picky about its JSON. It will generally only deserialize JSON that matches its expectations. For example, System.Text.Json won't deserialize JSON that uses single quotes around strings; you have to use double quotes.

If you're creating a new application, this is generally not a problem—you quickly learn to generate the correct JSON! But if you're migrating an application from ASP.NET Core 2.0, or are receiving JSON from a third-party, these limitations can be real stumbling blocks.

Luckily, you can easily switch back to the Newtonsoft.Json library instead. Install the *Microsoft.AspNetCore.Mvc.NewtonsoftJson* package into your project, and update the `AddControllers()` method in Startup.cs to the following:

```
services.AddControllers()
    .AddNewtonsoftJson();
```

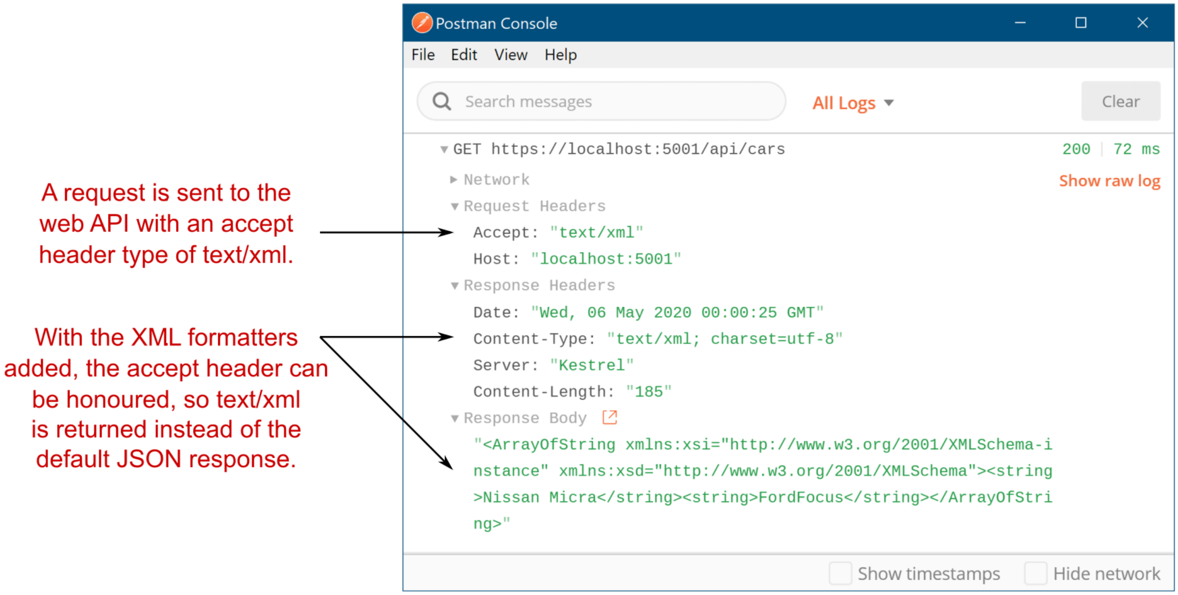
This will switch ASP.NET Core's formatters to use Newtonsoft.Json behind the scenes, instead of System.Text.Json. For more details on the differences between the libraries, see https://docs.microsoft.com/en-us/dotnet/standard/serialization/system-text-json-migrate-from-newtonsoft-how-to. For more advice on when to switch to the Newtonsoft.Json formatter, see https://docs.microsoft.com/en-us/aspnet/core/web-api/advanced/formatting#add-newtonsoftjson-based-json-format-support.

You can add XML output to your application by adding an *output formatter*. You configure your application's formatters in Startup.cs, by customizing the `IMvcBuilder` object returned from `AddControllers()`. To add the XML output formatter[41], use the following:

[41] Technically this also adds an XML *input formatter* as well, which means your application can now *receive* XML in requests too. For a detailed look at formatters, including creating a custom formatter, see the documentation at https://docs.microsoft.com/en-us/aspnet/core/web-api/advanced/custom-formatters.

```
services.AddControllers()
    .AddXmlSerializerFormatters();
```

With this simple change, your API controllers can now format responses as XML. Running the same request as shown in figure 9.9 with XML support enabled means the app will respect the `text/xml accept` header. The formatter serializes the `string` array to XML as requested instead of defaulting to JSON, as shown in figure 9.10.



```
▾ GET https://localhost:5001/api/cars                              200 | 72 ms
  ▸ Network
  ▾ Request Headers
      Accept: "text/xml"
      Host: "localhost:5001"
  ▾ Response Headers
      Date: "Wed, 06 May 2020 00:00:25 GMT"
      Content-Type: "text/xml; charset=utf-8"
      Server: "Kestrel"
      Content-Length: "185"
  ▾ Response Body
      "<ArrayOfString xmlns:xsi="http://www.w3.org/2001/XMLSchema-i
      nstance" xmlns:xsd="http://www.w3.org/2001/XMLSchema"><string
      >Nissan Micra</string><string>FordFocus</string></ArrayOfStri
      ng>"
```

A request is sent to the web API with an accept header type of text/xml.

With the XML formatters added, the accept header can be honoured, so text/xml is returned instead of the default JSON response.

Figure 9.10 With the XML output formatters added, the `text/xml Accept` header is respected and the response can be serialized to XML.

This is an example of content negotiation, where the client has specified what formats it can handle and the server selects one of those, based on what it can produce. This approach is part of the HTTP protocol, but there are some quirks to be aware of when relying on it in ASP.NET Core. You won't often run into these, but if you're not aware of them when they hit you, they could have you scratching your head for hours!

9.6.2 Choosing a response format with content negotiation

Content negotiation is where a client says which types of data it can accept using the `accept` header and the server picks the best one it can handle. Generally speaking, this works as you'd hope: the server formats the data using a type the client can understand.

The ASP.NET Core implementation has some special cases that are worth bearing in mind:

- By default, the middleware will only return `application/json`, `text/plain` and `text/html` MIME types. You can add additional `IOutputFormatters` to make other types available, as you saw in the previous section for `text/xml`.
- By default, if you return `null` as your API model, whether from an action method, or by passing `null` in a `StatusCodeResult`, the middleware will return a `204 No Content` response.
- When you return a `string` as your API model, if no `Accept` header is set, the middleware will format the response as `text/plain`.
- When you use any other class as your API model and there's either no `Accept` header or none of the supported formats were requested, the first formatter that can generate a response will be used (typically JSON by default).
- If the middleware detects that the request is probably from a browser (the `accept` header contains `*/*`), then it will *not* use conneg. Instead, it will format the response as though no `accept` header was provided, using the default formatter (typically JSON).

These defaults are relatively sane, but they can certainly bite you if you're not aware of them. The last point in particular, where the response to a request from a browser is virtually always formatted as JSON has certainly caught me out when trying to test XML requests locally!

As you should expect by now, all of these rules are configurable; you can easily change the default behavior in your application if it doesn't fit your requirements. For example, the following listing, taken from Startup.cs, shows how you can force the middleware to respect the browser's `Accept` header, and remove the `text/plain` formatter for `string`s.

Listing 9.14 Customizing MVC to respect the browser `Accept` header in Web APIs

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllers(options =>                          #A
    {
        options.RespectBrowserAcceptHeader = true;                  #B
         options.OutputFormatters.RemoveType<StringOutputFormatter>();    #C
    });
}
```

#A AddControllers has an overload that takes a lambda function
#B False by default, a number of other properties are also available to be set
#C Removes the output formatter that formats strings as text/plain

In most cases, conneg should work well for you out of the box, whether you're building an SPA or a mobile application. In some cases, you may find you need to bypass the usual conneg mechanisms for specific action methods, and there are a number of ways to achieve this, but I won't cover them in this book as I've found I rarely need to use them. For details, see the documentation at https://docs.microsoft.com/en-us/aspnet/core/web-api/advanced/formatting.

That brings us to the end of this chapter on Web APIs and, with it, part 1 of this book! It's been a pretty intense tour of ASP.NET Core, with a heavy focus on Razor Pages and the MVC pattern. By making it this far, you now have all the knowledge you need to start building simple applications using Razor Pages, or to create a Web API server for your SPA or mobile app.

In part 2, you'll get into some juicy topics, in which you'll learn the details needed to build complete apps, like adding users to your application, saving data to a database, and how to deploy your application.

In chapter 10, we'll look at dependency injection in ASP.NET Core and how it helps create loosely coupled applications. You'll learn how to register the ASP.NET Core framework services with a container and set up your own classes as dependency-injected services. Finally, you'll see how to replace the built-in container with a third-party alternative.

9.7 Summary

- A Web API exposes a number of methods or endpoints that can be used to access or change data on a server. It's typically accessed using HTTP by mobile or client-side web applications.
- Web API action methods can return data directly or can use `ActionResult<T>` to generate an arbitrary response.
- If you return more than one type of result from an action method, the method signature must return `ActionResult<T>`.
- Web APIs follow the same MVC design pattern as traditional web applications. The formatters which generate the final response form the view.
- The data returned by a Web API action is called an API model. It contains the data the middleware will serialize and send back to the client. This differs from view models and `PageModel`s which contain both data and metadata about how to generate the response.
- Web APIs are associated with route templates by applying `RouteAttribute`s to your action methods. These give you complete control over the URLs that make up your application's API.
- Route attributes applied to a controller combine with attributes on action methods to form the final template. These are also combined with attributes on inherited base classes. You can use inherited attributes to reduce the amount of duplication in the attributes where you're using a common prefix on your routes, for example.
- By default, the controller and action name have no bearing on the URLs or route templates when you use attribute routing. However, you can use the `"[controller]"` and `"[action]"` tokens in your route templates to reduce repetition. They'll be replaced with the current controller and action name.
- The `[HttpPost]` and `[HttpGet]` attributes allow choosing between actions based on the request's HTTP verb when two actions correspond to the same URL. This is a common pattern in RESTful applications.

- The `[ApiController]` attribute applies several common conventions to your controllers. Controllers decorated with the attribute will automatically bind to a request's body instead of using form values, automatically generates a `400 Bad Request` response for invalid requests, and will return `ProblemDetails` objects for status code errors. This can dramatically reduce the amount of boilerplate code you must write.
- You can control which of the conventions to apply by using the `ConfigureApiBehaviorOptions()` method and providing a configuration lambda. This is useful if you need to fit your API to an existing specification for example.
- By default, ASP.NET Core formats the API model returned from a Web API controller as JSON. Virtually every platform can handle JSON, making your API highly interoperable.
- In contrast to the previous version of ASP.NET, JSON data is serialized using camelCase rather than PascalCase. You should consider this change if you get errors or missing values when migrating from ASP.NET to ASP.NET Core.
- ASP.NET Core 3.0 uses System.Text.Json for JSON serialization and deserialization, which is a high performance, strict library that is part of .NET Core 3.0. You can replace this serializer with the common Newtonsoft.Json formatter, by calling `AddNewtonsoftJson()`, on the return value from `services.AddControllers()`.
- Content negotiation occurs when the client specifies the type of data it can handle and the server chooses a return format based on this. It allows multiple clients to call your API and receive data in a format they can understand.
- By default, ASP.NET Core can return `text/plain`, `text/html`, and `application/ json`, but you can add additional formatters if you need to support other formats.
- You can add XML formatters by calling `AddXmlSerializerFormatters()` on the return value from `services.AddControllers()` in your Startup class. These let you format the response as XML, as well as receive XML in a request body.
- Content negotiation isn't used when the accept header contains `*/*`, such as in most browsers. Instead, your application will use the default formatter, JSON. You can disable this option by modifying the `RespectBrowserAcceptHeader` option when adding your MVC controller services in Startup.cs.

Part 2

Building complete applications

We covered a lot of ground in part 1. You saw how an ASP.NET Core application is composed of middleware and we focused heavily on the Razor Pages framework. You saw how to use it to build traditional server-side-rendered apps using Razor syntax and how to build APIs for mobile and client-side apps.

In part 2, we dive deeper into the framework and look at a variety of components that you'll inevitably need when you want to build more complex apps. By the end of this part, you'll be able to build dynamic applications, customized to specific users, that can be deployed to multiple environments, each with a different configuration.

ASP.NET Core uses dependency injection (DI) throughout its libraries, so it's important that you understand how this design pattern works. In chapter 10, I introduce DI, why it is used, and how to configure the services in your applications to use DI.

Chapter 11 looks at the ASP.NET Core configuration system, which lets you pass configuration values to your app from a range of sources—JSON files, environment variables, and many more. You'll learn how to configure your app to use different values depending on the environment in which it is running, and how to bind strongly typed objects to your configuration to help reduce runtime errors.

Most web applications require some sort of data storage, so in chapter 12, I introduce Entity Framework Core (EF Core). This is a new, cross-platform library that makes it easier to connect your app to a database. EF Core is worthy of a book in and of itself, so I only provide a brief introduction. I show you how to create a database and how to insert, update, and query simple data.

In chapters 13 through 15, we look at how to build more complex applications. You'll see how you can add ASP.NET Core Identity to your apps so that users can log in and enjoy a customized experience. You'll learn how to protect your app using authorization to ensure only certain users can access certain action methods, and you'll see how to refactor your app to extract common code out of your Razor Pages and API controllers using filters.

In the final chapter of this part, I cover the steps required to make an app live, including how to publish your app to IIS, how to configure the URLs your app listens on, and how to optimize your client-side assets for improved performance.

10

Service configuration with dependency injection

This chapter covers

- **Understanding the benefits of dependency injection**
- **How ASP.NET Core uses dependency injection**
- **Configuring your services to work with dependency injection**
- **Choosing the correct lifetime for your services**

In part 1 of this book, you saw the bare bones of how to build applications with ASP.NET Core. You learned how to compose middleware to create your application and how to use the MVC pattern to build traditional web applications with Razor Pages and Web APIs. This gave you the tools to start building simple applications.

In this chapter, you'll see how to use *dependency injection* (DI) in your ASP.NET Core applications. DI is a design pattern that helps you develop loosely coupled code. ASP.NET Core uses the pattern extensively, both internally in the framework and in the applications you build, so you'll need to use it in all but the most trivial of applications.

You may have heard of DI before, and possibly even used it in your own applications. If so, this chapter shouldn't hold many surprises for you. If you haven't used DI before, never fear, I'll make sure you're up to speed by the time the chapter is done!

This chapter starts by introducing DI in general, the principles it drives, and why you should care about it. You'll see how ASP.NET Core has embraced DI throughout its implementation and why you should do the same when writing your own applications.

Once you have a solid understanding of the concept, you'll see how to apply DI to your own classes. You'll learn how to configure your app so that the ASP.NET Core framework can create your classes for you, removing the pain of having to create new objects manually in your code. Toward the end of the chapter, you'll learn how to control how long your objects are used for and some of the pitfalls to be aware of when you come to write your own applications.

In chapter 19, we'll revisit some of the more advanced ways to use DI, including how to wire up a third-party DI container. For now though, let's get back to basics: what is DI and why should you care about it?

10.1 Introduction to dependency injection

This section aims to give you a basic understanding of what dependency injection is, why you should care about it, and how ASP.NET Core uses it. The topic itself extends far beyond the reach of this single chapter. If you want a deeper background, I highly recommend checking out Martin Fowler's articles online.[42]

> **TIP** For a more directly applicable read with many examples in C#, I recommend picking up *Dependency Injection Principles, Practices, and Patterns* by Steven van Deursen and Mark Seemann (Manning, 2019).

The ASP.NET Core framework has been designed from the ground up to be modular and to adhere to "good" software engineering practices. As with anything in software, what is considered best practice varies over time, but for object-oriented programming, the SOLID[43] principles have held up well.

On that basis, ASP.NET Core has *dependency injection* (sometimes called *dependency inversion*, *DI*, or *inversion of control*[44]) baked into the heart of the framework. Whether or not you want to use it within your own application code, the framework libraries themselves depend on it as a concept.

I begin this section by starting with a common scenario: a class in your application depends on a different class, which in turn depends on another. You'll see how dependency injection can help alleviate this chaining of dependencies for you and provide a number of extra benefits.

10.1.1 Understanding the benefits of dependency injection

When you first started programming, the chances are you didn't immediately use a DI framework. That's not surprising, or even a bad thing; DI adds a certain amount of extra

[42] Martin Fowler's website at https://martinfowler.com is a gold mine of best-practice goodness. One of the most applicable articles to this chapter can be found at www.martinfowler.com/articles/injection.html.

[43] SOLID is a mnemonic for Single responsibility, Open-closed, Liskov substitution, Interface segregation, and Dependency inversion: https://en.wikipedia.org/wiki/SOLID_(object-oriented_design).

[44] Although related, dependency injection and dependency inversion are two different things. I cover both in a general sense in this chapter, but for a good explanation of the differences, see this post by Derick Bailey: https://lostechies.com/derickbailey/2011/09/22/dependency-injection-is-not-the-same-as-the-dependency-inversion-principle/.

wiring that's often not warranted in simple applications or when you're getting started. But when things start to get more complex, DI comes into its own as a great tool to help keep that complexity in check.

Let's consider a simple example, written without any sort of DI. Imagine a user has registered on your web app and you want to send them an email. This listing shows how you might approach this initially in an API controller.

NOTE I'm using an API controller for this example, but I could just as easily have used a Razor Page. Razor Pages and API controllers both use constructor dependency injection, as you'll see in section 10.2.

Listing 10.1 Sending an email without DI when there are no dependencies

```
public class UserController : ControllerBase
{
    [HttpPost("register")]
    public IActionResult RegisterUser(string username)      #A
    {
        var emailSender = new EmailSender();            #B
        emailSender.SendEmail(username);                #C
        return Ok();
    }
}
```

#A The action method is called when a new user is created
#B Creates a new instance of EmailSender
#C Uses the new instance to send the email

In this example, the `RegisterUser` action on `UserController` executes when a new user registers on your app. This creates a new instance of an `EmailSender` class, and calls `SendEmail()` to send the email. The `EmailSender` class is the one that does the sending of the email. For the purposes of this example, you can imagine it looks something like this:

```
public class EmailSender
{
    public void SendEmail(string username)
    {
        Console.WriteLine($"Email sent to {username}!");
    }
}
```

`Console.Writeline` "stands in" for the real process of sending the email.

NOTE Although I'm using sending email as a simple example, in practice you might want to move this code out of your Razor Page and controller classes entirely. This type of asynchronous task is well suited to using message queues and a background process. For more details, see https://docs.microsoft.com/dotnet/architecture/microservices/.

If the `EmailSender` class is as simple as the previous example and it has no dependencies, then you might not see any need to adopt a different approach to creating objects. And to an extent, you'd be right. But what if you later update your implementation of `EmailSender` so that it doesn't implement the whole email-sending logic itself?

In practice, `EmailSender` would need to do many things to send an email. It would need to

- Create an email message
- Configure the settings of the email server
- Send the email to the email server

Doing all of that in one class would go against the single responsibility principle (SRP), so you'd likely end up with `EmailSender` depending on other services. Figure 10.1 shows how this web of dependencies might look. `UserController` wants to send an email using `EmailSender`, but to do so, it also needs to create the `MessageFactory`, `NetworkClient`, and `EmailServerSettings` objects that `EmailSender` depends on.

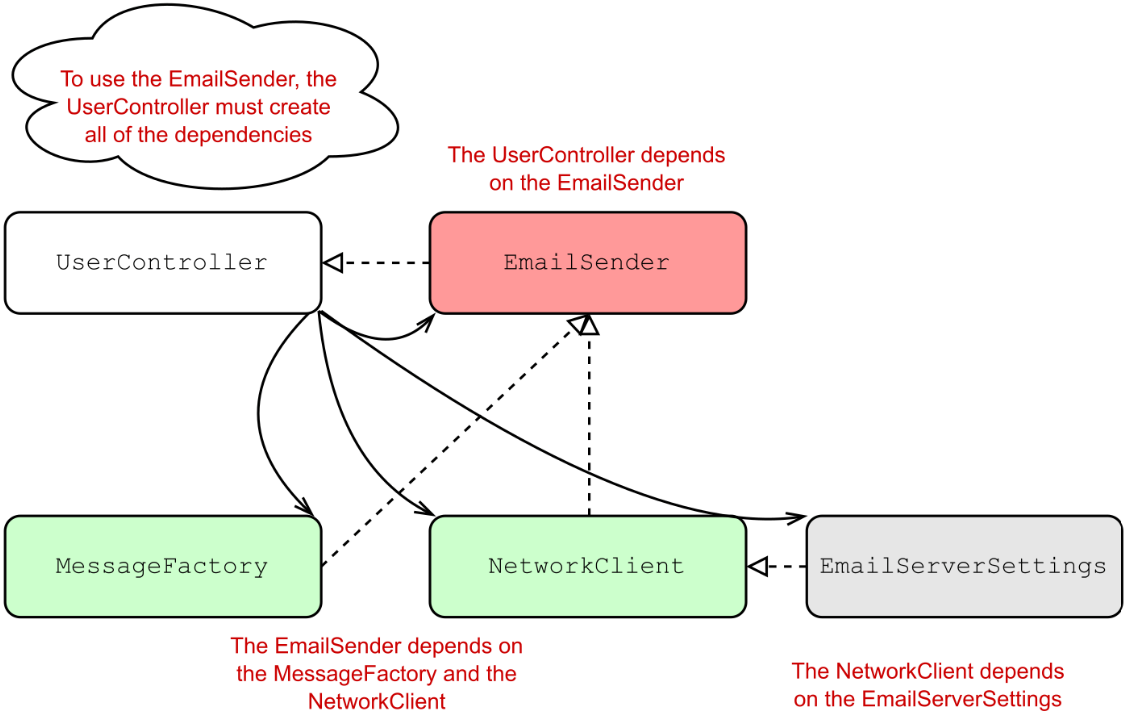

To use the EmailSender, the UserController must create all of the dependencies
The UserController depends on the EmailSender
UserController
EmailSender
MessageFactory
NetworkClient
EmailServerSettings
The EmailSender depends on the MessageFactory and the NetworkClient
The NetworkClient depends on the EmailServerSettings

Figure 10.1 Dependency diagram without dependency injection. `UserController` indirectly depends on all the other classes; so, it has to create them all.

Each class has a number of dependencies, so the "root" class, in this case `UserController`, needs to know how to create every class it depends on, as well as every class its *dependencies* depend on. This is sometimes called the *dependency graph*.

> **DEFINITION** **The *dependency graph* is the set of objects that must be created in order to create a specific requested "root" object.**

`EmailSender` depends on the `MessageFactory` and `NetworkClient` objects, so they're provided via the constructor, as shown here.

Listing 10.2 A service with multiple dependencies

```
public class EmailSender
{
    private readonly NetworkClient _client;                             #A
    private readonly MessageFactory _factory;                           #A
    public EmailSender(MessageFactory factory, NetworkClient client)    #B
    {                                                                   #B
        _factory = factory;                                             #B
        _client = client;                                               #B
    }                                                                   #B
    public void SendEmail(string username)
    {
        var email = _factory.Create(username);                          #C
        _client.SendEmail(email);                                       #C
        Console.WriteLine($"Email sent to {username}!");
    }
}
```

#A The EmailSender now depends on two other classes.
#B Instances of the dependencies are provided in the constructor.
#C The EmailSender coordinates the dependencies to create and send an email.

On top of that, the `NetworkClient` class that `EmailSender` depends on also has a dependency on an `EmailServerSettings` object:

```
public class NetworkClient
{
    private readonly EmailServerSettings _settings;
    public NetworkClient(EmailServerSettings settings)
    {
        _settings = settings;
    }
}
```

This might feel a little contrived, but it's common to find this sort of chain of dependencies. In fact, if you *don't* have this in your code, it's probably a sign that your classes are too big and aren't following the single responsibility principle.

So, how does this affect the code in `UserController`? The following listing shows how you now have to send an email, if you stick to `new`-ing up objects in the controller.

Listing 10.3 Sending email without DI when you manually create dependencies

```
public IActionResult RegisterUser(string username)
{
    var emailSender = new EmailSender(                         #A
        new MessageFactory(),                                  #B
        new NetworkClient(                        #C
            new EmailServerSettings               #D
            (                                     #D
                host: "smtp.server.com",          #D
                port: 25                          #D
            ))                                    #D
        );
    emailSender.SendEmail(username);              #E
    return Ok();
}
```

#A To create EmailSender, you must create all of its dependencies.
#B You need a new MessageFactory.
#C The NetworkClient also has dependencies.
#D You're already two layers deep, but there could feasibly be more.
#E Finally, you can send the email.

This is turning into some gnarly code. Improving the design of `EmailSender` to separate out the different responsibilities has made calling it from `UserController` a real chore. This code has several issues, among them:

- *Not obeying the single responsibility principle*—Our code is now responsible for both *creating* an `EmailSender` object and *using* it to send an email.
- *Considerable ceremony*—Of the 11 lines of code in the `RegisterUser` method, only the last two are doing anything useful. This makes it harder to read and harder to understand the intent of the method.
- *Tied to the implementation*—If you decide to refactor `EmailSender` and add another dependency, you'd need to update every place it's used. Likewise, if any of the *dependencies* are refactored, you would need to update this code too.

`UserController` has an *implicit* dependency on the `EmailSender` class, as it manually creates the object itself as part of the `RegisterUser` method. The only way to know that `UserController` uses `EmailSender` is to look at its source code. In contrast, `EmailSender` has *explicit* dependencies on `NetworkClient` and `MessageFactory`, which must be provided in the constructor. Similarly, `NetworkClient` has an *explicit* dependency on the `EmailServerSettings` class.

> **TIP** **Generally speaking, any dependencies in your code should be explicit, not implicit. Implicit dependencies are hard to reason about and difficult to test, so you should avoid them wherever you can. DI is useful for guiding you along this path.**

Dependency injection aims to solve the problem of building a dependency graph by *inverting* the chain of dependencies. Instead of the `UserController` creating its dependencies manually, deep inside the implementation details of the code, an already-created instance of `EmailSender` is injected via the constructor.

Now, obviously *something* needs to create the object, so the code to do that has to live somewhere. The service responsible for creating an object is called a *DI container* or an *IoC container*, as shown in figure 10.2.

> **DEFINITION** **The *DI container* or *IoC container* is responsible for creating instances of services. It knows how to construct an instance of a service by creating all its dependencies and passing these to the constructor. I'll refer to it as a DI container throughout this book.**

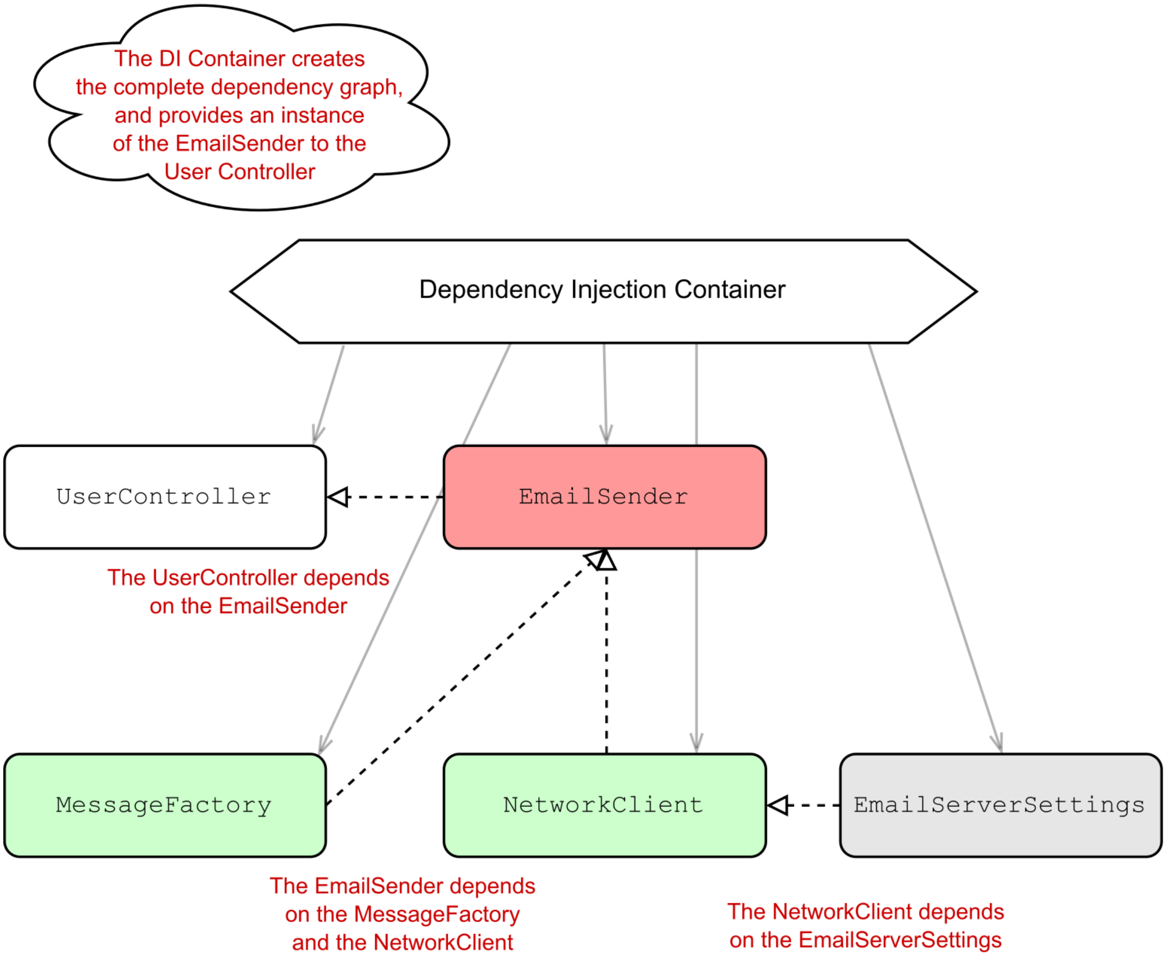


Figure 10.2 Dependency diagram using dependency injection. `UserController` **indirectly depends on all the other classes but doesn't need to know how to create them.** `UserController` **declares that it requires** `EmailSender` **and the container provides it.**

The term dependency injection is often used interchangeably with *inversion of control* (IoC). DI is a specific version of the more general principle of IoC. IoC describes the pattern where the *framework* calls your code to handle a request, instead of you writing the code to parse the request from bytes on the network card yourself. DI takes this further, where you allow the framework to create your dependencies too: instead of your `UserController` controlling how to create an `EmailSender` instance, it's provided one by the framework instead.

NOTE Many DI containers are available for .NET: Autofac, Lamar, Unity, Ninject, Simple Injector… The list goes on! In chapter 19, you'll see how to replace the default ASP.NET Core container with one of these alternatives.

The advantage of adopting this pattern becomes apparent when you see how much it simplifies using dependencies. The following listing shows how `UserController` would look if you used DI to create `EmailSender` instead of doing it manually. All of the `new` cruft has gone, and you can focus purely on what the controller is doing—calling `EmailSender` and returning an `OkResult`.

Listing 10.4 Sending an email using DI to inject dependencies

```
public class UserController : ControllerBase
{
    private readonly EmailSender _emailSender;              #A
    public UserController(EmailSender emailSender)          #A
    {                                                       #A
        _emailSender = emailSender;                         #A
    }                                                       #A

    [HttpPost("register")]
    public IActionResult RegisterUser(string username)      #B
    {                                                       #B
        _emailSender.SendEmail(username);                   #B
        return Ok();                                        #B
    }
}
```

#A Instead of creating the dependencies implicitly, they're injected via the constructor.
#B The action method is easy to read and understand again.

One of the advantages of a DI container is that it has a single responsibility: creating objects or services. You ask a container for an instance of a service and it takes care of figuring out how to create the dependency graph, based on how you configure it.

NOTE It's common to refer to *services* when talking about DI containers, which is slightly unfortunate as it's one of the most overloaded terms in software engineering! In this context, a service refers to any class or interface that the DI container creates when required.

The beauty of this approach is that by using explicit dependencies, you never have to write the mess of code you saw in listing 10.3. The DI container can inspect your service's constructor and work out how to write much of the code itself. DI containers are always configurable, so if you *want* to describe how to manually create an instance of a service you can, but by default you shouldn't need to.

TIP You can inject dependencies into a service in other ways; for example, by using property injection. But constructor injection is the most common and is the only one supported out of the box in ASP.NET Core, so I'll only be using that in this book.

Hopefully, the advantages of using DI in your code are apparent from this quick example, but DI provides additional benefits that you get for free. In particular, it helps keep your code loosely coupled by coding to interfaces.

10.1.2 Creating loosely coupled code

Coupling is an important concept in object-oriented programming. It refers to how a given class depends on other classes to perform its function. Loosely coupled code doesn't need to know a lot of details about a particular component to use it.

The initial example of `UserController` and `EmailSender` was an example of tight coupling; you were creating the `EmailSender` object directly and needed to know exactly how to wire it up. On top of that, the code was difficult to test. Any attempts to test `UserController` would result in an email being sent. If you were testing the controller with a suite of unit tests, that seems like a surefire way to get your email server blacklisted for spam!

Taking `EmailSender` as a constructor parameter and removing the responsibility of creating the object helps reduce the coupling in the system. If the `EmailSender` implementation changes so that it has another dependency, you no longer have to update `UserController` at the same time.

One issue that remains is that `UserController` is still tied to an *implementation* rather than an *interface*. Coding to interfaces is a common design pattern that helps further reduce the coupling of a system, as you're not tied to a single implementation. This is particularly useful in making classes testable, as you can create "stub" or "mock" implementations of your dependencies for testing purposes, as shown in figure 10.3.

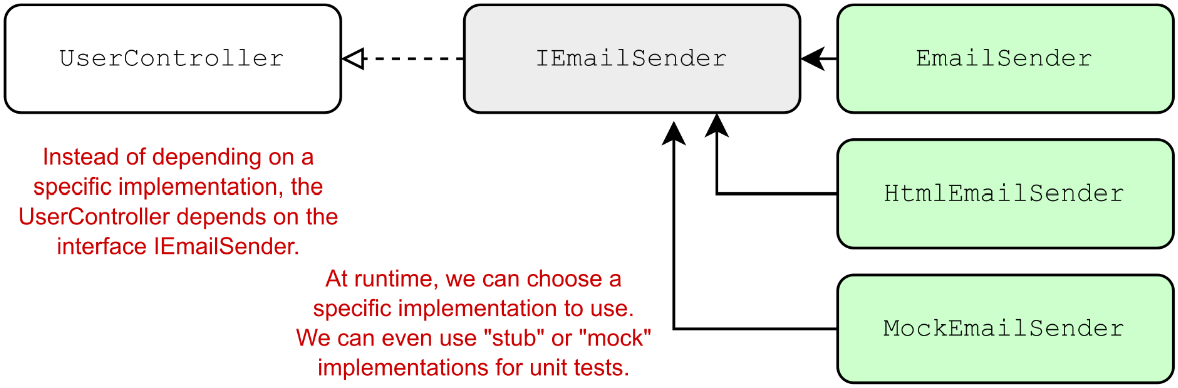

UserController
IEmailSender
EmailSender
HtmlEmailSender
MockEmailSender
Instead of depending on a specific implementation, the UserController depends on the interface IEmailSender.
At runtime, we can choose a specific implementation to use. We can even use "stub" or "mock" implementations for unit tests.

Figure 10.3 By coding to interfaces instead of an explicit implementation, you can use different `IEmailSender` implementations in different scenarios, for example a `MockEmailSender` in unit tests.

TIP You can choose from many different mocking frameworks. My favorite is Moq, but NSubstitute and FakeItEasy are also popular options.

As an example, you might create an `IEmailSender` interface, which `EmailSender` would implement:

```
public interface IEmailSender
{
    public void SendEmail(string username);
}
```

`UserController` could then depend on this interface instead of the specific `EmailSender` implementation, as shown here. That would allow you to use a different implementation during unit tests, a `DummyEmailSender` for example.

Listing 10.5 Using interfaces with dependency injection

```
public class UserController : ControllerBase
{
    private readonly IEmailSender _emailSender;           #A
    public UserController(IEmailSender emailSender)       #A
    {                                                    #A
        _emailSender = emailSender;                      #A
    }                                                    #A

    [HttpPost("register")]
       public IActionResult RegisterUser(string username)
    {
        _emailSender.SendEmail(username);                #B
        return Ok();
    }
}
```

#A You now depend on IEmailSender instead of the specific EmailSender implementation.
#B You don't care what the implementation is, as long as it implements IEmailSender.

The key point here is that the consuming code, `UserController`, doesn't care how the dependency is implemented, only that it implements the `IEmailSender` interface and exposes a `SendEmail` method. The application code is now independent of the implementation.

Hopefully, the principles behind DI seem sound—by having loosely coupled code, it's easy to change or swap out implementations completely. But this still leaves you with a question: how does the application know to use `EmailSender` in production instead of `DummyEmailSender`? The process of telling your DI container, "when you need `IEmailSender`, use `EmailSender`" is called *registration*.

> **DEFINITION** **You *register* services with a DI container so that it knows which implementation to use for each requested service. This typically takes the form of, "for interface X, use implementation Y."**

Exactly how you register your interfaces and types with a DI container can vary depending on the specific DI container implementation, but the principles are generally all the same. ASP.NET Core includes a simple DI container out of the box, so let's look at how it's used during a typical request.

10.1.3 Dependency injection in ASP.NET Core

ASP.NET Core was designed from the outset to be modular and composable, with an almost plugin-style architecture, which is generally complemented by DI. Consequently, ASP.NET Core includes a simple DI container that all the framework libraries use to register themselves and their dependencies.

This container is used, for example, to register the Razor Pages and Web API infrastructure—the formatters, the view engine, the validation system, and so on. It's only a basic container, so it only exposes a few methods for registering services, but you can also replace it with a third-party DI container. This can give you extra capabilities, such as auto-registration or setter injection. The DI container is built into the ASP.NET Core hosting model, as shown in figure 10.4.

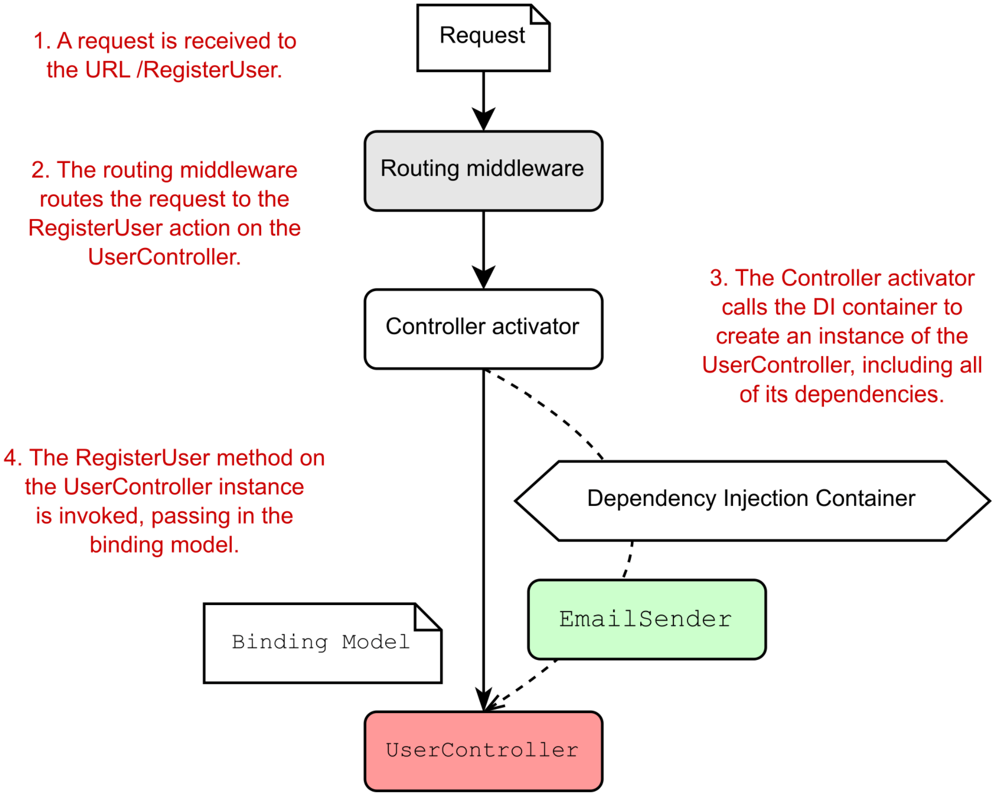

1. A request is received to the URL /RegisterUser.
Request
2. The routing middleware routes the request to the RegisterUser action on the UserController.
Routing middleware
Controller activator
3. The Controller activator calls the DI container to create an instance of the UserController, including all of its dependencies.
4. The RegisterUser method on the UserController instance is invoked, passing in the binding model.
Dependency Injection Container
EmailSender
Binding Model
UserController

Figure 10.4 The ASP.NET Core hosting model uses the DI container to fulfill dependencies when creating controllers.

The hosting model pulls dependencies from the DI container when they're needed. If the framework determines that `UserController` is required due to the incoming URL/route, the controller activator responsible for creating an API controller instance will ask the DI container for an `IEmailSender` implementation.

> **NOTE** This approach, where a class calls the DI container directly to ask for a class is called the *service locator* pattern. Generally speaking, you should try to avoid this pattern in your code; include your dependencies as constructor arguments directly and let the DI container provide them for you.[45]

The DI container needs to know what to create when asked for `IEmailSender`, so you must have registered an implementation, such as `EmailSender`, with the container. Once an implementation is registered, the DI container can inject it anywhere. That means you can inject framework-related services into your own custom services, as long as they are registered with the container. It also means you can register alternative versions of framework services and have the framework automatically use those in place of the defaults.

The flexibility to choose exactly how and which components you combine in your applications is one of the selling points of DI. In the next section, you'll learn how to configure DI in your own ASP.NET Core application, using the default, built-in container.

10.2 Using the dependency injection container

In previous versions of ASP.NET, using dependency injection was entirely optional. In contrast, to build all but the most trivial ASP.NET Core apps, some degree of DI is required. As I've mentioned, the underlying framework depends on it, so things like using Razor Pages and API controllers require you to configure the required services.

In this section, you'll see how to register these framework services with the built-in container, as well as how to register your own services. Once services are registered, you can use them as dependencies and inject them into any of the services in your application.

10.2.1 Adding ASP.NET Core framework services to the container

As I described earlier, ASP.NET Core uses DI to configure its internal components as well as your own custom services. To use these components at runtime, the DI container needs to know about all the classes it will need. You register these in the `ConfigureServices` method of your `Startup` class.

> **NOTE** The dependency injection container is set up in the `ConfigureServices` method of your `Startup` class in Startup.cs.

[45] You can read about the Service Locator antipattern in *Dependency Injection Principles, Practices, and Patterns* by Steven van Deursen and Mark Seemann (Manning, 2019) https://livebook.manning.com/book/dependency-injection-principles-practices-patterns/chapter-5/section-5-2.

Now, if you're thinking, "Wait, I have to configure the internal components myself?" then don't panic. Although true in one sense—you do need to explicitly register the components with the container in your app—all the libraries you'll use expose handy extension methods to take care of the nitty-gritty details for you. These extension methods configure everything you'll need in one fell swoop, instead of leaving you to manually wire everything up.

For example, the Razor Pages framework exposes the `AddRazorPages()` extension method that you saw in chapters 2, 3, and 4. Invoke the extension method in `ConfigureServices` of `Startup`.

Listing 10.6 Registering the MVC services with the DI container

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddRazorPages();           #A
}
```

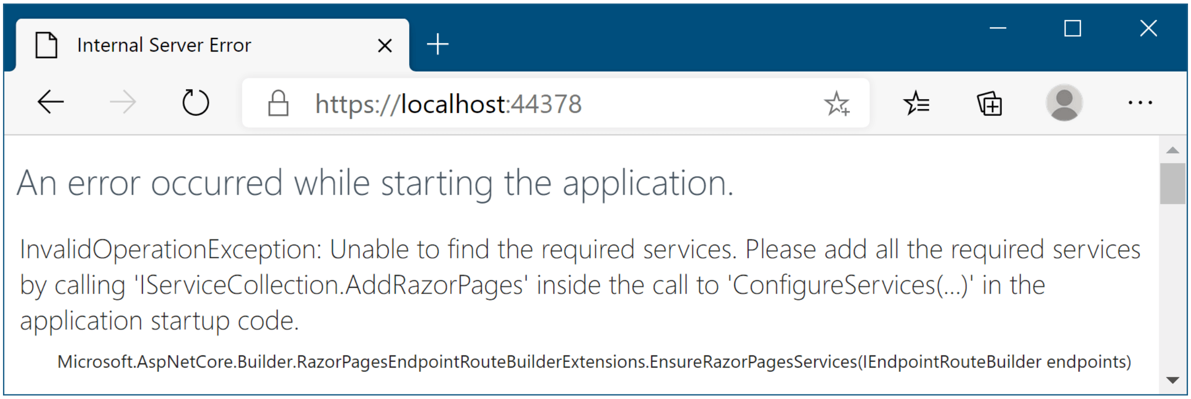
#A The AddRazorPages extension method adds all necessary services to the IServiceCollection.

It's as simple as that. Under the hood, this call is registering multiple components with the DI container, using the same APIs you'll see shortly for registering your own services.

> **TIP The `AddControllers()` method registers the required services for API controllers, as you saw in chapter 9. There is a similar method, `AddControllersWithViews()` if you're using MVC controllers with Razor views, and an `AddMvc()` method to add all of them, and the kitchen sink!**

Most nontrivial libraries that you add to your application will have services that you need to add to the DI container. By convention, each library that has necessary services should expose an `Add*()` extension method that you can call in `ConfigureServices`.

There's no way of knowing exactly which libraries will require you to add services to the container, it's generally a case of checking the documentation for any libraries you use. If you forget to add them, then you may find the functionality doesn't work, or you might get a handy exception like the one shown in figure 10.5. Keep an eye out for these and be sure to register any services that you need!



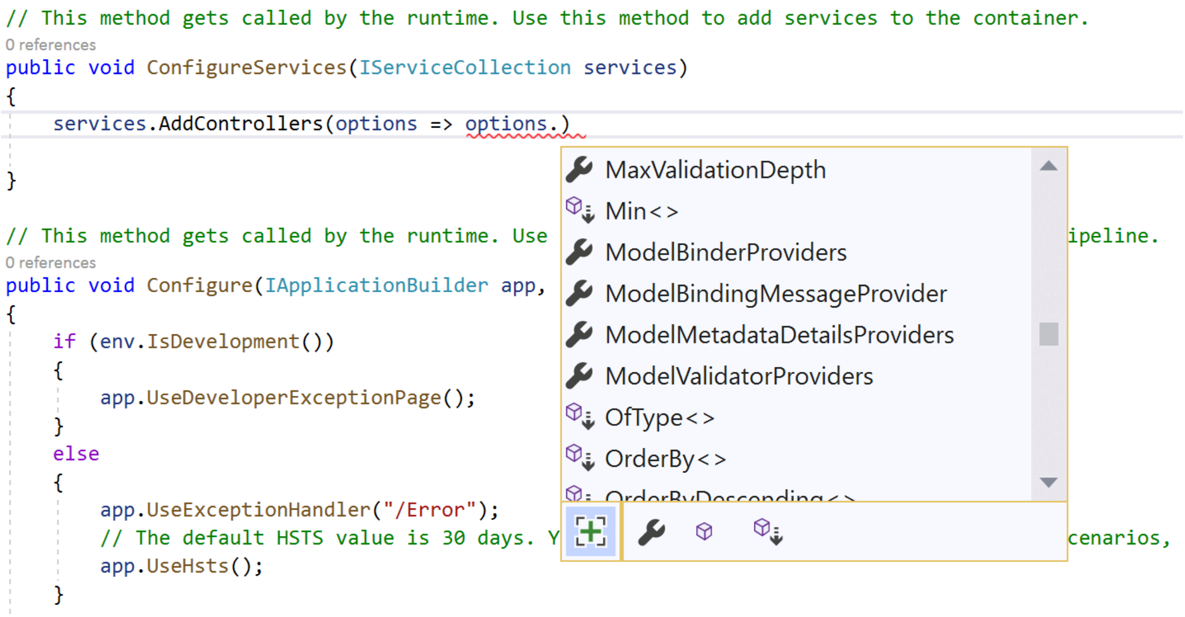
An error occurred while starting the application.

InvalidOperationException: Unable to find the required services. Please add all the required services by calling 'IServiceCollection.AddRazorPages' inside the call to 'ConfigureServices(...)' in the application startup code.

Microsoft.AspNetCore.Builder.RazorPagesEndpointRouteBuilderExtensions.EnsureRazorPagesServices(IEndpointRouteBuilder endpoints)

Figure 10.5 If you fail to call `AddRazorPages` in the `ConfigureServices` of `Startup`, you'll get a friendly exception message at runtime.

It's also worth noting that some of the `Add*()` extension methods allow you to specify additional options when you call them, often by way of a lambda expression. You can think of these as configuring the installation of a service into your application. The `AddControllers` method, for example, provides a wealth of options for fine-tuning its behavior if you want to get your fingers dirty, as shown by the IntelliSense snippet in figure 10.6.



```
// This method gets called by the runtime. Use this method to add services to the container.
0 references
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllers(options => options.)

}

// This method gets called by the runtime. Use                                        ipeline.
0 references
public void Configure(IApplicationBuilder app,
{
    if (env.IsDevelopment())
    {
        app.UseDeveloperExceptionPage();
    }
    else
    {
        app.UseExceptionHandler("/Error");
        // The default HSTS value is 30 days. Y                                       cenarios,
        app.UseHsts();
    }
```

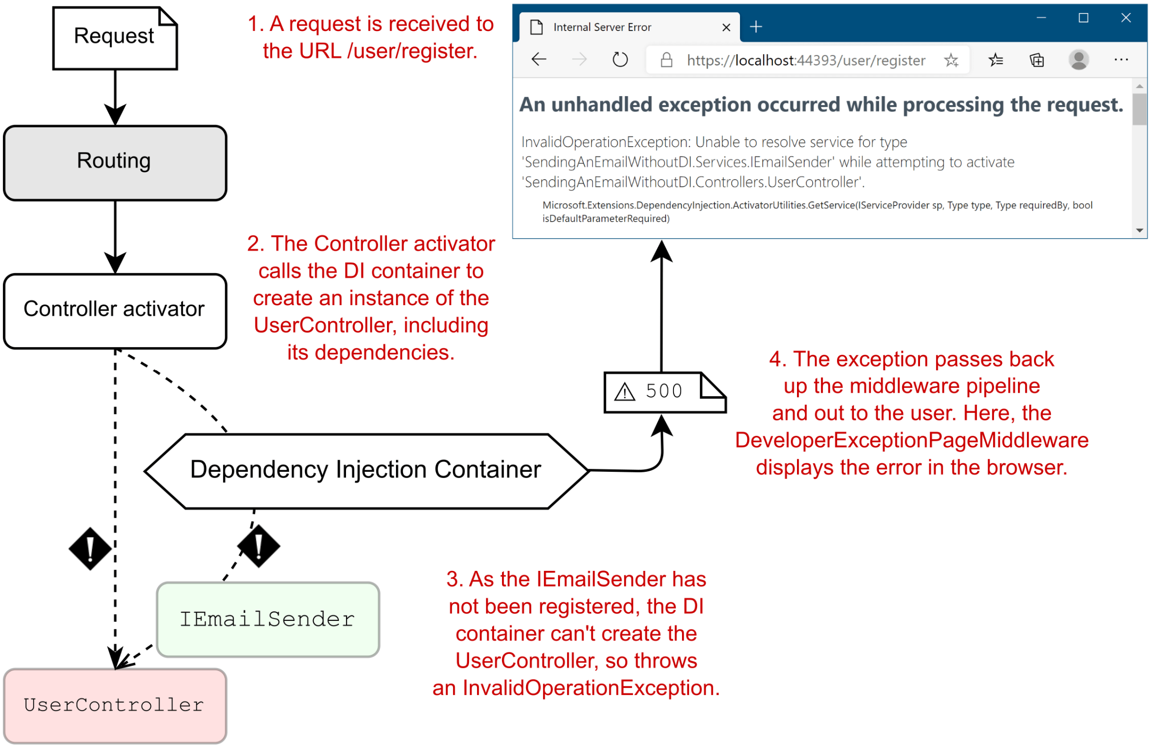
Figure 10.6 Configuring services when adding them to the service collection. The `AddControllers()` function allows you to configure a wealth of the internals of the API controller services. Similar configuration options are available in the `AddRazorPages()` function.

Once you've added the required framework services, you can get down to business and register your own services, so you can use DI in your own code.

10.2.2 Registering your own services with the container

In the first section of this chapter, I described a system for sending emails when a new user registers on your application. Initially, `UserController` was manually creating an instance of `EmailSender`, but you subsequently refactored this, so you inject an instance of `IEmailSender` into the constructor instead.

The final step to make this refactoring work is to configure your services with the DI container. This lets the DI container know what to use when it needs to fulfill the `IEmailSender` dependency. If you don't register your services, then you'll get an exception at runtime, like the one in figure 10.7. Luckily, this exception is useful, letting you know which service wasn't registered (`IEmailSender`) and which service needed it (`UserController`).



1. A request is received to the URL /user/register.

2. The Controller activator calls the DI container to create an instance of the UserController, including its dependencies.

3. As the IEmailSender has not been registered, the DI container can't create the UserController, so throws an InvalidOperationException.

4. The exception passes back up the middleware pipeline and out to the user. Here, the DeveloperExceptionPageMiddleware displays the error in the browser.

An unhandled exception occurred while processing the request.

InvalidOperationException: Unable to resolve service for type 'SendingAnEmailWithoutDI.Services.IEmailSender' while attempting to activate 'SendingAnEmailWithoutDI.Controllers.UserController'.

Microsoft.Extensions.DependencyInjection.ActivatorUtilities.GetService(IServiceProvider sp, Type type, Type requiredBy, bool isDefaultParameterRequired)

Figure 10.7 If you don't register all your required dependencies in `ConfigureServices`, you'll get an exception at runtime, telling you which service wasn't registered.

In order to completely configure the application, you need to register `EmailSender` and all of its dependencies with the DI container, as shown in figure 10.8.

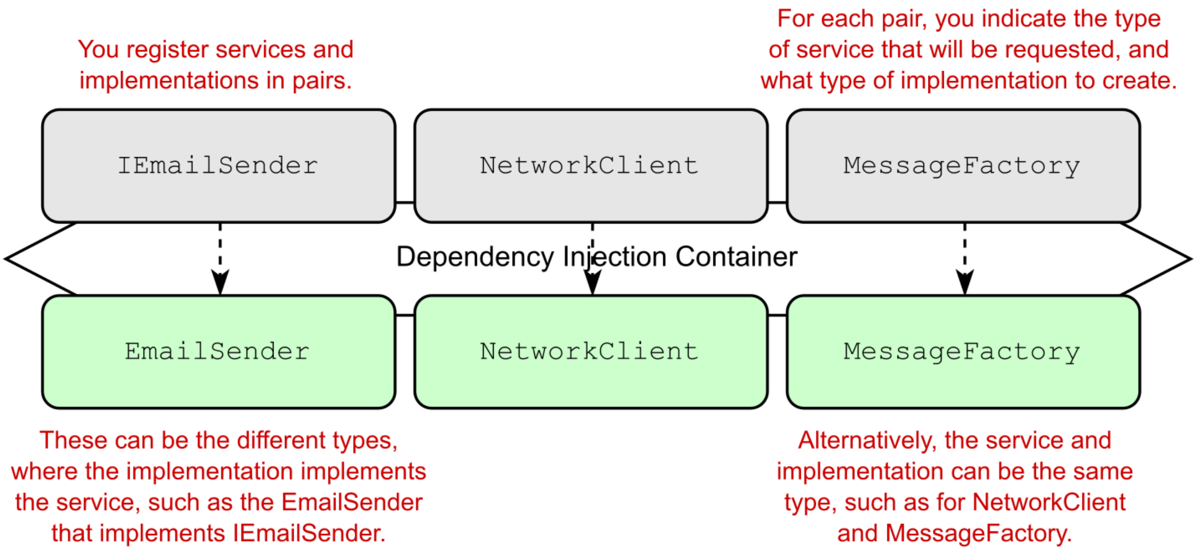

You register services and implementations in pairs.
For each pair, you indicate the type of service that will be requested, and what type of implementation to create.
IEmailSender
NetworkClient
MessageFactory
Dependency Injection Container
EmailSender
NetworkClient
MessageFactory
These can be the different types, where the implementation implements the service, such as the EmailSender that implements IEmailSender.
Alternatively, the service and implementation can be the same type, such as for NetworkClient and MessageFactory.

Figure 10.8 Configuring the DI container in your application involves telling it what type to use when a given service is requested; for example, "Use `EmailSender` when `IEmailSender` is required."

Configuring DI consists of making a series of statements about the services in your app. For example:

- When a service requires `IEmailSender`, use an instance of `EmailSender`
- When a service requires `NetworkClient`, use an instance of `NetworkClient`
- When a service requires `MessageFactory`, use an instance of `MessageFactory`

> **NOTE** You'll also need to register the `EmailServerSettings` object with the DI container—we'll do that slightly differently, in the next section.

These statements are made by calling various `Add*` methods on `IServiceCollection` in the `ConfigureServices` method. Each method provides three pieces of information to the DI container:

- *Service type*—`TService`. This is the class or interface that will be requested as a dependency. Often an interface, such as `IEmailSender`, but sometimes a concrete type, such as `NetworkClient` or `MessageFactory`.
- *Implementation type*—`TService` or `TImplementation`. This is the class the container should create to fulfill the dependency. Must be a concrete type, such as `EmailSender`. May be the same as the service type, as for `NetworkClient` and `MessageFactory`.
- *Lifetime—Transient, Singleton, or Scoped*. This defines how long an instance of the service should be used for. I'll discuss lifetimes in detail in section 10.3.

The following listing shows how you can configure EmailSender and its dependencies in your application using three different methods: AddScoped<TService>, AddSingleton<TService>, and AddScoped<TService, TImplementation>. This tells the DI container how to create each of the TService instances when they're required.

Listing 10.7 Registering services with the DI container

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllers();                              #A

    services.AddScoped<IEmailSender, EmailSender>();        #B
    services.AddScoped<NetworkClient>();                    #C
    services.AddSingleton<MessageFactory>();                #D
}
```

#A You're using API controllers, so must call AddControllers.
#B Whenever you require an IEmailSender, use EmailSender.
#C Whenever you require a NetworkClient, use NetworkClient.
#D Whenever you require a MessageFactory, use MessageFactory.

And that's all there is to dependency injection! It may seem a little bit like magic,[46] but you're just giving the container instructions on how to make all the constituent parts. You give it a recipe for how to cook the chili, shred the lettuce, and grate the cheese, so that when you ask for a burrito, it can put all the parts together and hand you your meal!

The service type and implementation type are the same for NetworkClient and MessageFactory, so there's no need to specify the same type twice in the AddScoped method, hence the slightly simpler signature. These generic methods aren't the only way to register services with the container, you can also provide objects directly, or by using lambdas, as you'll see in the next section.

10.2.3 Registering services using objects and lambdas

As I mentioned earlier, I didn't *quite* register all the services required by UserController. In all my previous examples, NetworkClient depends on EmailServerSettings, which you'll also need to register with the DI container for your project to run without exceptions.

I avoided registering this object in the preceding example because you have to use a slightly different approach. The preceding Add* methods use generics to specify the Type of the class to register, but they don't give any indication of *how* to construct an instance of that type. Instead, the container makes a number of assumptions that you have to adhere to:

- The class must be a concrete type.

[46] Under the hood, the built-in ASP.NET Core DI container uses optimized reflection to create dependencies, but different DI containers may use other approaches.

- The class must only have a single "valid" constructor that the container can use.
- For a constructor to be "valid," all constructor arguments must be registered with the container, or must be an argument with a default value.

> **NOTE** **These limitations apply to the simple built-in DI container. If you choose to use a third-party container in your app, then they may have a different set of limitations.**

The `EmailServerSettings` class doesn't meet these requirements, as it requires you to provide a `host` and `port` in the constructor, which are `string`s without default values:

```
public class EmailServerSettings
{
    public EmailServerSettings(string host, int port)
    {
        Host = host;
        Port = port;
    }
    public string Host { get; }
    public int Port { get; }
}
```

You can't register these primitive types in the container; it would be weird to say, "For every `string` constructor argument, in any type, use the `"smtp.server.com"` value!"

Instead, you can create an instance of the `EmailServerSettings` object yourself and provide *that* to the container, as shown next. The container uses the pre-constructed object whenever an instance of the `EmailServerSettings` object is required.

Listing 10.8 Providing an object instance when registering services

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllers();

    services.AddScoped<IEmailSender, EmailSender>();
    services.AddSingleton<NetworkClient>();
    services.AddScoped<MessageFactory>();
    services.AddSingleton(
        new EmailServerSettings          #A
        (                                #A
            host: "smtp.server.com",     #A
            port: 25                     #A
        ));                              #A
}
```

#A This instance of EmailServerSettings will be used whenever an instance is required.

This works fine if you only want to have a single instance of `EmailServerSettings` in your application—*the same object* will be shared everywhere. But what if you want to create a *new* object each time one is requested?

NOTE When the same object is used whenever it's requested, it's known as a singleton. I'll discuss singletons along with other *lifetimes* in detail in the next section. The lifetime is how long the DI container should use a given object to fulfill a service's dependencies.

Instead of providing a single instance that the container will always use, you can also provide a *function* that the container invokes when it needs an instance of the type, as shown in figure 10.9.

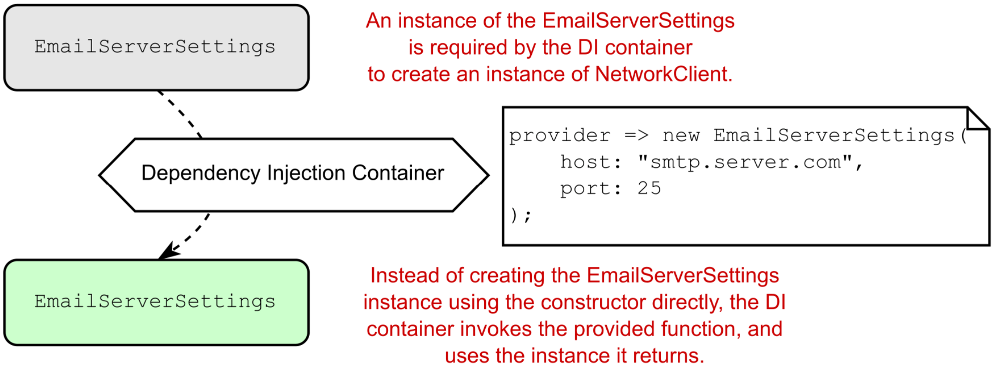

EmailServerSettings
An instance of the EmailServerSettings is required by the DI container to create an instance of NetworkClient.
Dependency Injection Container
provider => new EmailServerSettings(host: "smtp.server.com", port: 25);
EmailServerSettings
Instead of creating the EmailServerSettings instance using the constructor directly, the DI container invokes the provided function, and uses the instance it returns.

Figure 10.9 You can register a function with the DI container that will be invoked whenever a new instance of a service is required.

The easiest way to do this is to use a lambda function (an anonymous delegate), in which the container creates a new `EmailServerSettings` object when it's needed.

Listing 10.9 Using a lambda factory function to register a dependency

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddMvc();
    services.AddScoped<IEmailSender, EmailSender>();
    services.AddSingleton<NetworkClient>();
    services.AddScoped<MessageFactory>();
    services.AddScoped(                          #A
        provider =>                                #B
            new EmailServerSettings          #C
            (                                #C
                host: "smtp.server.com",     #C
                port: 25                     #C
            ));                              #C
}
```

#A Because you're providing a function to create the object, you aren't restricted to singleton.
#B The lambda is provided an instance of IServiceProvider.
#C The constructor is called every time an EmailServerSettings is required, instead of only once.

In this example, I've changed the lifetime of the created EmailServerSettings object to be *scoped* instead of *singleton* and provided a factory lambda function that returns a new EmailServerSettings object. Every time the container requires a new EmailServerSettings, it executes the function and uses the new object it returns.

> **NOTE** I'll discuss lifetimes shortly, but it's important to notice that there are two concepts of a singleton here. If you create an object and pass it to the container, it's *always* registered as a singleton. You can also register *any* arbitrary class as a singleton and the container will only use one instance throughout your application.

When you use a lambda to register your services, you're provided with an IServiceProvider instance at runtime, called provider in listing 10.9. This is the public API of the DI container itself which exposes the GetService() function. If you need to obtain dependencies to create an instance of your service, you can reach into the container at runtime in this way, but you should avoid doing so if possible.

> **TIP** Avoid calling GetService() in your factory functions if possible. Instead, favor constructor injection—it's more performant, as well as being simpler to reason about.

Open generics and dependency injection

As already mentioned, you couldn't use the generic registration methods with EmailServerSettings because it uses primitive dependencies (in this case, string) in its constructor. You also can't use the generic registration methods to register *open generics*.

Open generics are types that contain a generic type parameter, such as Repository <T>. You normally use this sort of type to define a base behavior that you can use with multiple generic types. In the Repository<T> example, you might inject IRepository<Customer> into your services, which should inject an instance of DbRepository<Customer>, for example.

To register these types, you must use a different overload of the Add* methods. For example,

```
services.AddScoped(typeof(IRespository<>), typeof(DbRepository<>));
```

This ensures that whenever a service constructor requires IRespository<T>, the container injects an instance of DbRepository<T>.

At this point, all your dependencies are registered. But ConfigureServices is starting to look a little messy, isn't it? It's entirely down to personal preference, but I like to group my services into logical collections and create extension methods for them, as in the following listing. This creates an equivalent of the framework's AddControllers() extension method—a nice, simple, registration API. As you add more and more features to your app, I think you'll appreciate it too.

Listing 10.10 Creating an extension method to tidy up adding multiple services

```
public static class EmailSenderServiceCollectionExtensions
{
    public static IServiceCollection AddEmailSender(
        this IServiceCollection services)                    #A
    {
        services.AddScoped<IEmailSender, EmailSender>();     #B
        services.AddSingleton<NetworkClient>();              #B
        services.AddScoped<MessageFactory>();                #B
        services.AddSingleton(                               #B
            new EmailServerSettings                          #B
            (                                                #B
                host: "smtp.server.com",                     #B
                port: 25                                     #B
            ));                                              #B
        return services;                                     #C
    }
}
```

#A Extend the IServiceCollection that's provided in the ConfigureServices method.
#B Cut and paste your registration code from ConfigureServices.
#C By convention, return the IServiceCollection to allow method chaining.

With the preceding extension method created, the `ConfigureServices` method is much easier to grok!

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllers();
    services.AddEmailSender();
}
```

So far, you've seen how to register the simple DI cases where you have a single implementation of a service. In some scenarios, you might find you have multiple implementations of an interface. In the next section, you'll see how to register these with the container to match your requirements.

10.2.4 Registering a service in the container multiple times

One of the advantages of coding to interfaces is that you can create multiple implementations of a service. For example, imagine you want to create a more generalized version of `IEmailSender` so that you can send messages via SMS or Facebook, as well as by email. You create an interface for it

```
public interface IMessageSender
{
    public void SendMessage(string message);
}
```

as well as several implementations: `EmailSender`, `SmsSender`, and `FacebookSender`. But how do you register these implementations in the container? And how can you inject these implementations into your UserController? The answer varies slightly depending if you want to use all the implementations in your consumer or only one of them.

INJECTING MULTIPLE IMPLEMENTATIONS OF AN INTERFACE

Imagine you want to send a message using each of the IMessageSender implementations whenever a new user registers, so they get an email, an SMS, and a Facebook message, as shown in figure 10.10.

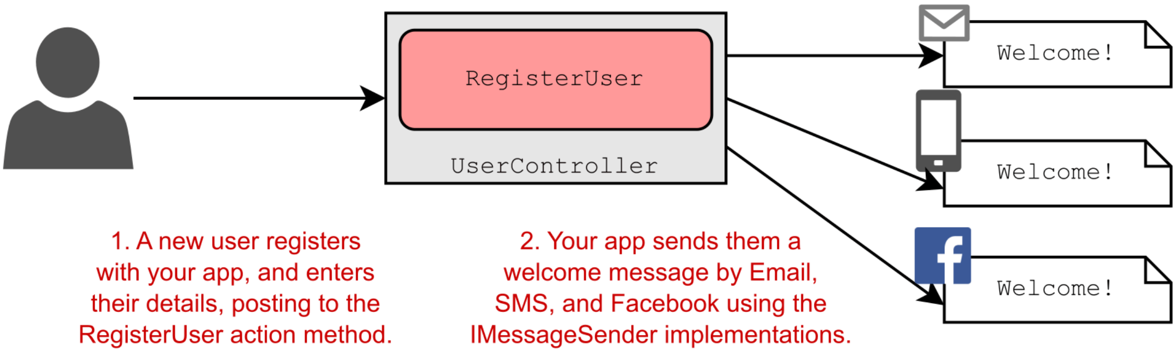
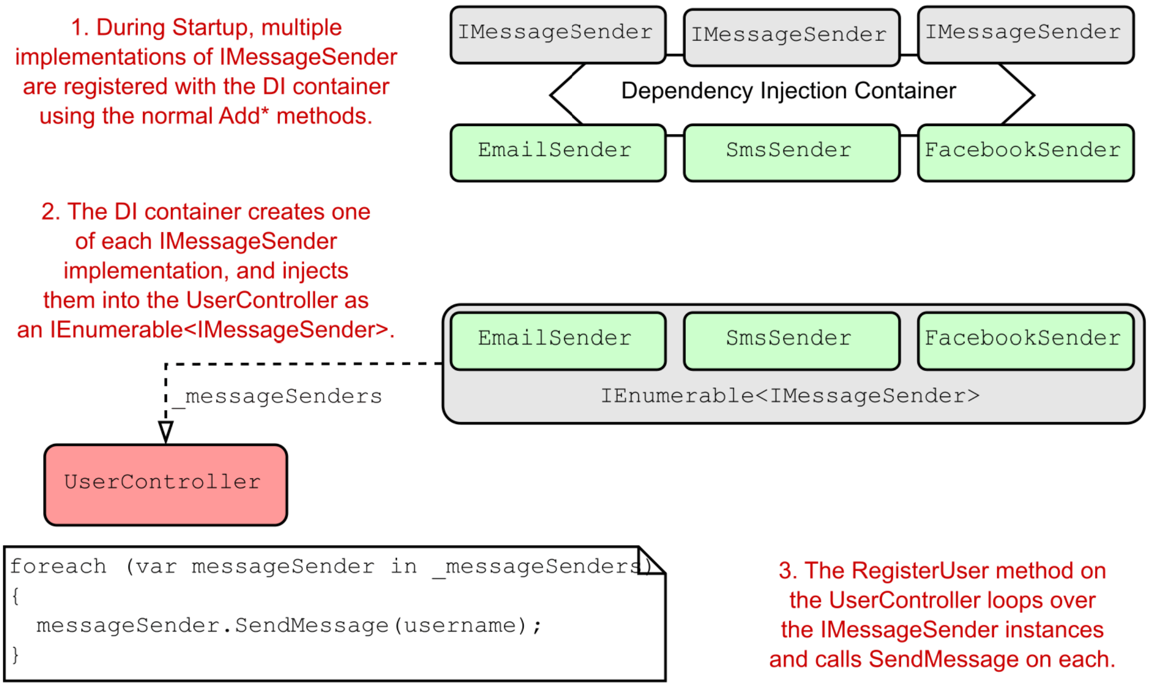

RegisterUser
UserController
Welcome!
Welcome!
Welcome!
1. A new user registers with your app, and enters their details, posting to the RegisterUser action method.
2. Your app sends them a welcome message by Email, SMS, and Facebook using the IMessageSender implementations.

Figure 10.10 When a user registers with your application, they call the RegisterUser **method. This sends them an email, an SMS, and a Facebook message using the** IMessageSender **classes.**

The easiest way to achieve this is to register all the service implementations in your DI container and have it inject one of each type into UserController. UserController can then use a simple foreach loop to call SendMessage() on each implementation, as in figure 10.11.



1. During Startup, multiple implementations of IMessageSender are registered with the DI container using the normal Add* methods.

2. The DI container creates one of each IMessageSender implementation, and injects them into the UserController as an IEnumerable<IMessageSender>.

```
foreach (var messageSender in _messageSenders)
{
  messageSender.SendMessage(username);
}
```

3. The RegisterUser method on the UserController loops over the IMessageSender instances and calls SendMessage on each.

Figure 10.11 You can register multiple implementations of a service with the DI container, such as `IEmailSender` in this example. You can retrieve an instance of each of these implementations by requiring `IEnumerable<IMessageSender>` in the `UserController` constructor.

You register multiple implementations of the same service with a DI container in exactly the same way as for single implementations, using the `Add*` extension methods. For example:

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllers();
    services.AddScoped<IMessageSender, EmailSender>();
    services.AddScoped<IMessageSender, SmsSender>();
    services.AddScoped<IMessageSender, FacebookSender>();
}
```

You can then inject `IEnumerable<IMessageSender>` into `UserController`, as shown in the following listing. The container injects an array of `IMessageSender` containing one of each of the implementations you have registered, in the same order as you registered them. You can then use a standard `foreach` loop in the `RegisterUser` method to call `SendMessage` on each implementation.

Listing 10.11 Injecting multiple implementations of a service into a consumer

```
public class UserController : ControllerBase
```

```
{
    private readonly IEnumerable<IMessageSender> _messageSenders;     #A
    public UserController(                                            #A
        IEnumerable<IMessageSender> messageSenders)                   #A
    {                                                                 #A
        _messageSenders = messageSenders;                             #A
    }                                                                 #A

    [HttpPost("register")]
    public IActionResult RegisterUser(string username)
    {
        foreach (var messageSender in _messageSenders)            #B
        {                                                        #B
            messageSender.SendMessage(username);                 #B
        }                                                        #B

        return Ok();
    }
}
```

#A Requesting an IEnumerable will inject an array of IMessageSender.
#B Each IMessageSender in the IEnumerable is a different implementation.

> **WARNING** You must use `IEnumerable<T>` as the constructor argument to inject all the registered types of a service, `T`. Even though this will be injected as a `T[]` array, you can't use `T[]` or `ICollection<T>` as your constructor argument. Doing so will cause an `InvalidOperationException`, similar to that in figure 10.7.

It's simple enough to inject all the registered implementations of a service, but what if you only need one? How does the container know which one to use?

INJECTING A SINGLE IMPLEMENTATION WHEN MULTIPLE SERVICES ARE REGISTERED

Imagine you've already registered all the `IMessageSender` implementations, what happens if you have a service that requires only one of them? For example

```
public class SingleMessageSender
{
    private readonly IMessageSender _messageSender;
    public SingleMessageSender(IMessageSender messageSender)
    {
        _messageSender = messageSender;
    }
}
```

The container needs to pick a *single* `IMessageSender` to inject into this service, out of the three implementations available. It does this by using the *last* registered implementation—the `FacebookSender` from the previous example.

> **NOTE** The DI container will use the last registered implementation of a service when resolving a single instance of the service.

This can be particularly useful for replacing built-in DI registrations with your own services. If you have a custom implementation of a service that you know is registered within a library's `Add*` extension method, you can override that registration by registering your own implementation afterwards. The DI container will use your implementation whenever a single instance of the service is requested.

The main disadvantage with this approach is that you still end up with *multiple* implementations registered—you can inject an `IEnumerable<T>` as before. Sometimes you want to conditionally register a service, so you only ever have a single registered implementation.

CONDITIONALLY REGISTERING SERVICES USING TRYADD

Sometimes, you'll only want to add an implementation of a service if one hasn't already been added. This is particularly useful for library authors; they can create a default implementation of an interface and only register it if the user hasn't already registered their own implementation.

You can find several extension methods for conditional registration in the `Microsoft.Extensions.DependencyInjection.Extensions` namespace, such as `TryAddScoped`. This checks to make sure a service hasn't been registered with the container before calling `AddScoped` on the implementation. The following listing shows you conditionally adding `SmsSender`, only if there are no existing `IMessageSender` implementations. As you previously registered `EmailSender`, the container will ignore the `SmsSender` registration, so it won't be available in your app.

Listing 10.12 Conditionally adding a service using `TryAddScoped`

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddScoped<IMessageSender, EmailSender>();    #A
    services.TryAddScoped<IMessageSender, SmsSender>();   #B
}
```

#A EmailSender is registered with the container.
#B There's already an IMessageSender implementation, so SmsSender isn't registered.

Code like this often doesn't make a lot of sense at the application level, but it can be useful if you're building libraries for use in multiple apps. The ASP.NET Core framework, for example, uses `TryAdd*` in many places, which lets you easily register alternative implementations of internal components in your own application if you want.

You can also *replace* a previously registered implementation by using the `Replace()` extension method. Unfortunately, the API for this method isn't as friendly as the `TryAdd` methods. To replace a previously registered `IMessageSender` with the `SmsSender`, you would use

```
services.Replace(new ServiceDescriptor(
    typeof(IMessageSender), typeof(SmsSender), ServiceLifetime.Scoped
));
```

TIP When using Replace, you must provide the same lifetime as was used to register the service that is being replaced.

That pretty much covers registering dependencies. Before we look in more depth at the “lifetime” aspect of dependencies, we’ll take a quick detour and look at two ways other than a constructor to inject dependencies in your app.

10.2.5 Injecting services into action methods, page handlers, and views

I mentioned in section 10.1 that the ASP.NET Core DI container only supports constructor injection, but there are three additional locations where you can use dependency injection:

1. Action methods
2. Page handler methods
3. View templates

In this section, I’ll briefly discuss these three situations, how they work, and when you might want to use them.

INJECTING SERVICES DIRECTLY INTO ACTION METHODS AND PAGE HANDLERS USING [FROMSERVICES]

API controllers typically contain multiple action methods that logically belong together. You might group all the action methods related to managing user accounts into the same controller, for example. This allows you to apply filters and authorization to all the action methods collectively, as you’ll see in chapter 13.

As you add additional action methods to a controller, you may find the controller needs additional services to implement new action methods. With constructor injection, all these dependencies are provided via the constructor. That means the DI container must create *all* the dependencies for *every* action method in a controller, even if none of them are required by the action method being called.

Consider listing 10.13 for example. This shows `UserController` with two stub methods: `RegisterUser` and `PromoteUser`. Each action method requires a different dependency, so both dependencies will be created and injected, whichever action method is called by the request. If `IPromotionService` or `IMessageSender` have lots of dependencies themselves, the DI container may have to create lots of objects for a service that is often not used.

Listing 10.13 Injecting services into a controller via the constructor

```
public class UserController : ControllerBase
{
    private readonly IMessageSender _messageSender;          #A
    private readonly IPromotionService _promoService;          #A
    public UserController(
        IMessageSender messageSender, IPromotionService promoService)
    {
        _messageSender = messageSender;
        _promoService = promoService;
    }

    [HttpPost("register")]
    public IActionResult RegisterUser(string username)
    {
        _messageSender.SendMessage(username);         #B
        return Ok();
    }

    [HttpPost("promote")]
    public IActionResult PromoteUser(string username, int level)
    {
        _promoService.PromoteUser(username, level);      #C
        return Ok();
    }
}
```

#A Both IMessageSender and IPromotionService are injected into the constructor every time.
#B The RegisterUser method only uses IMessageSender.
#C The PromoteUser method only uses IPromotionService.

If you know a service is particularly expensive to create, you can choose to inject it as a dependency *directly* into the action method, instead of into the controller's constructor. This ensures the DI container only creates the dependency when the *specific* action method is invoked, as opposed to when *any* action method on the controller is invoked.

> **NOTE** **Generally speaking, your controllers should be sufficiently cohesive that this approach isn't necessary. If you find you have a controller that's dependent on many services, each of which is used by a single action method, you might want to consider splitting up your controller.**

You can directly inject a dependency into an action method by passing it as a parameter to the method and using the `[FromServices]` attribute. During model binding, the framework will resolve the parameter from the DI container, instead of from the request values. This listing shows how you could rewrite listing 10.13 to use `[FromServices]` instead of constructor injection.

Listing 10.14 Injecting services into a controller using the `[FromServices]` attribute

```
public class UserController : ControllerBase
{
    [HttpPost("register")]
    public IActionResult RegisterUser(                    #A
        [FromServices] IMessageSender messageSender,      #A
        string username)                                  #A
    {
        messageSender.SendMessage(username);              #B
        return Ok();
    }
    [HttpPost("promote")]
    public IActionResult PromoteUser(                       #C
        [FromServices] IPromotionService promoService,      #C
        string username, int level)                         #C
    {
        promoService.PromoteUser(username, level);          #D
        return Ok();
    }
}
```

#A The [FromServices] attribute ensures IMessageSender is resolved from the DI container.
#B IMessageSender is only available in RegisterUser.
#C IPromotionService is resolved from the DI container and injected as a parameter.
#D Only the PromoteUser method can use IPromotionService.

You might be tempted to use the `[FromServices]` attribute in all your action methods, but I'd encourage you to use standard constructor injection most of the time. Having the constructor as a single location that declares all the dependencies of a class can be useful, so I only use `[FromServices]` in the rare cases where creating an instance of a dependency is expensive and is only used in a single action method.

The `[FromServices]` attribute can be used in exactly the same way with Razor Pages. You can inject services into a Razor Page's page handler, instead of into the constructor, as shown in the following listing.

> **TIP** Just because you *can* inject services into page handlers like this, doesn't mean you *should*. Razor Pages are inherently designed to be small and cohesive, so it's better to just use constructor injection.

Listing 10.15 Injecting services into a Razor Page using the `[FromServices]` attribute

```
public class PromoteUserModel: PageModel
{
    public void OnGet()                                     #A
    {
    }

    public IActionResult OnPost(                            #B
        [FromServices] IPromotionService promoService,      #B
        string username, int level)                         #B
    {
        promoService.PromoteUser(username, level);          #C
        return RedirectToPage("success");
    }

}
```

#A The OnGet handler does not require any services
#C IPromotionService is resolved from the DI container and injected as a parameter.
#D Only the OnPost page handler can use IPromotionService.

Generally speaking, if you find you need to use the `[FromServices]` attribute then you should step back and look at your controller/Razor Page. It's likely that you're trying to do too much in one class. Instead of working around the issue with `[FromServices]`, consider splitting the class up, or pushing some behavior down into your application model services.

INJECTING SERVICES INTO VIEW TEMPLATES

Injecting dependencies into the constructor is recommended, but what if you don't *have* a constructor? In particular, how do you go about injecting services into a Razor view template when you don't have control over how the template is constructed?

Imagine you have a simple service, `HtmlGenerator`, to help you generate HTML in your view templates. The question is, how do you pass this service to your view templates, assuming you've already registered it with the DI container?

One option is to inject the `HtmlGenerator` into your Razor Page using constructor injection and expose the service as a property on your `PageModel`, as you saw in chapter 7. This will often be the easiest approach, but in some cases, you might not want to have references to the `HtmlGenerator` service in your `PageModel` at all. In those cases, you can directly inject `HtmlGenerator` into your view templates.

> **NOTE** Some people take offense to injecting services into views in this way. You definitely shouldn't be injecting services related to business logic into your views, but I think it makes sense for services that are related to HTML generation.

You can inject a service into a Razor template with the `@inject` directive, by providing the type to inject and a name for the injected service in the template.

Listing 10.16 Injecting a service into a Razor view template with `@inject`

```
@inject HtmlGenerator htmlHelper    #A
<h1>The page title</h1>
<footer>
    @htmlHelper.Copyright()         #B
</footer>
```

#A Injects an instance of HtmlGenerator into the view, named htmlHelper
#B Uses the injected service by calling the htmlHelper instance

Injecting services directly into views can be a useful way of exposing UI-related services to your view templates without having to take a dependency on the service in your `PageModel`. You probably won't find you need to rely on it too much, but it's a useful tool to have.

That pretty much covers registering and using dependencies, but there's one important aspect I've only vaguely touched on: lifetimes, or, when does the container create a new instance of a service? Understanding lifetimes is crucial to working with DI containers, so it's important to pay close attention to them when registering your services with the container.

10.3 Understanding lifetimes: when are services created?

Whenever the DI container is asked for a particular registered service, for example an instance of `IMessageSender`, it can do one of two things:

- Create and return a new instance of the service
- Return an existing instance of the service

The *lifetime* of a service controls the behavior of the DI container with respect to these two options. You define the lifetime of a service during DI service registration. This dictates when a DI container will reuse an existing instance of the service to fulfill service dependencies, and when it will create a new one.

> **DEFINITION** The lifetime of a service is how long an instance of a service should *live* in a container before it creates a new instance.

It's important to get your head around the implications for the different lifetimes used in ASP.NET Core, so this section looks at each available lifetime option and when you should use it. In particular, you'll see how the lifetime affects how often the DI container creates new objects. In section 10.3.4, I show you a pattern of lifetimes to look out for, where a short-lifetime dependency is "captured" by a long-lifetime dependency. This can cause some hard-to-debug issues, so it's important to bear in mind when configuring your app!

In ASP.NET Core, you can specify three different lifetimes when registering a service with the built-in container:

- *Transient*—Every time a service is requested, a new instance is created. This means you can potentially have different instances of the same class within the same dependency graph.
- *Scoped*—Within a *scope*, all requests for a service will give you the same object. For different scopes you'll get different objects. In ASP.NET Core, each web request gets its own scope.
- *Singleton*—You'll always get the same instance of the service, no matter which scope.

> **NOTE** These concepts align well with most other DI containers, but the terminology often differs. If you're familiar with a third-party DI container, be sure you understand how the lifetime concepts align with the built-in ASP.NET Core DI container.

To illustrate the behavior of each lifetime, in this section, I'll use a simple representative example. Imagine you have `DataContext`, which has a connection to a database, as shown in listing 10.17. It has a single property, `RowCount`, which displays the number of rows in the `Users` table of a database. For the purposes of this example, we emulate calling the database, by setting the number of rows in the constructor, so you will get the same value every time you call `RowCount` on a given `DataContext` instance. *Different* instances of `DataContext` will return a *different* `RowCount` value.

Listing 10.17 `DataContext` **generating a random** `RowCount` **in its constructor**

```
public class DataContext
{
    static readonly Random _rand = new Random();
    public DataContext()
    {
        RowCount = _rand.Next(1, 1_000_000_000);     #A
    }

    public int RowCount { get; }                     #B
}
```

#A Generates a random number between 1 and 1,000,000,000
#B Read-only property set in the constructor, so always returns the same value.

You also have a `Repository` class that has a dependency on the `DataContext`, as shown in the next listing. This also exposes a `RowCount` property, but this property delegates the call to its instance of `DataContext`. Whatever value `DataContext` was created with, the `Repository` will display the same value.

Listing 10.18 Repository service that depends on an instance of `DataContext`

```
public class Repository
{
    private readonly DataContext _dataContext;    #A
    public Repository(DataContext dataContext)    #A
    {                                                 #A
        _dataContext = dataContext;                   #A
    }                                                 #A
    public int RowCount => _dataContext.RowCount;     #B
}
```

#A An instance of DataContext is provided using DI.
#B RowCount returns the same value as the current instance of DataContext.

Finally, you have the Razor Page `RowCountModel`, which takes a dependency on both `Repository` and on `DataContext` directly. When the Razor Page activator creates an instance of `RowCountModel`, the DI container injects an instance of `DataContext` and an instance of `Repository`. To create `Repository`, it also creates a second instance of `DataContext`. Over the course of two requests, a total of *four* instances of `DataContext` will be required, as shown in figure 10.12.

`RowCountModel` records the value of `RowCount` returned from both `Repository` and `DataContext` as properties on the `PageModel`. These are then rendered using a Razor template (not shown).

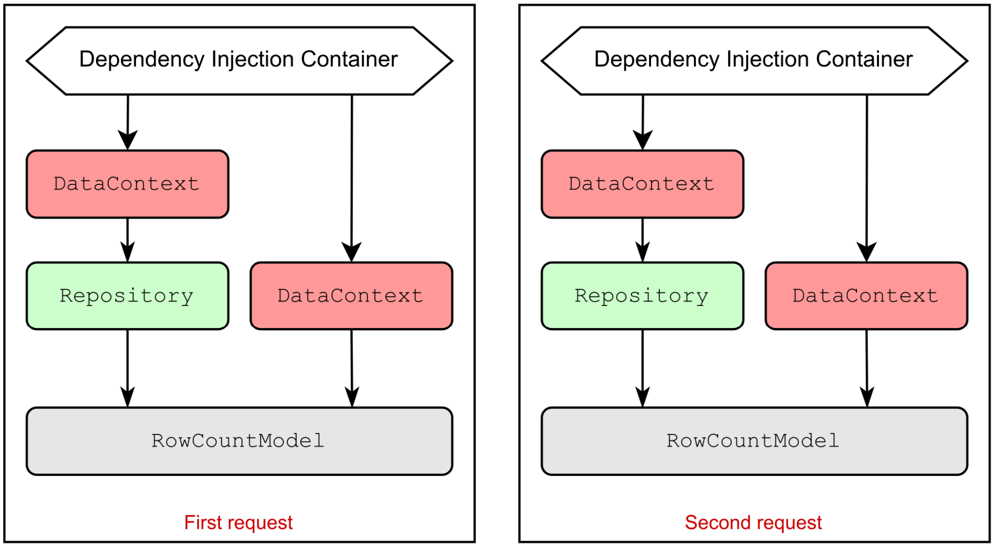
Listing 10.19 `RowCountModel` **depends on** `DataContext` **and** `Repository`

```
public class RowCountModel : PageModel
{
    private readonly Repository _repository;       #A
    private readonly DataContext _dataContext;     #A
    public RowCountPageModel(                      #A
        Repository repository,                     #A
        DataContext dataContext)                   #A
    {                                              #A
        _repository = repository;                  #A
        _dataContext = dataContext;                #A
    }                                              #A

     public void OnGet()
    {
        DataContextCount = _dataContext.RowCount;    #B
        RepositoryCount = _repository.RowCount;      #B
    }

    public int DataContextCount { get; set ;}      #C
    public int RepositoryCount { get; set ;}       #C
}
```

#A DataContext and Repository are passed in using DI.
#B When invoked, the page handler retrieves and records RowCount from both dependencies.
#C The counts are exposed on the PageModel and are rendered to HTML in the Razor view.

The purpose of this example is to explore the relationship between the four `DataContext` instances, depending on the lifetimes you use to register the services with the container. I'm generating a random number in `DataContext` as a way of uniquely identifying a `DataContext` instance, but you can think of this as being a point-in-time snapshot of the number of users logged in to your site, for example, or the amount of stock in a warehouse.

I'll start with the shortest-lived lifetime, "transient", move on to the common "scoped" lifetime, and then take a look at "singletons". Finally, I'll show an important trap you should be on the lookout for when registering services in your own apps.



For each request, two instances of DataContext are required to build the RowCountModel instance.

A total of four DataContext instances are required for two requests.

Figure 10.12 The DI Container uses two instances of `DataContext` for each request. Depending on the lifetime with which the `DataContext` type is registered, the container might create one, two, or four different instances of `DataContext`.

10.3.1 Transient: everyone is unique

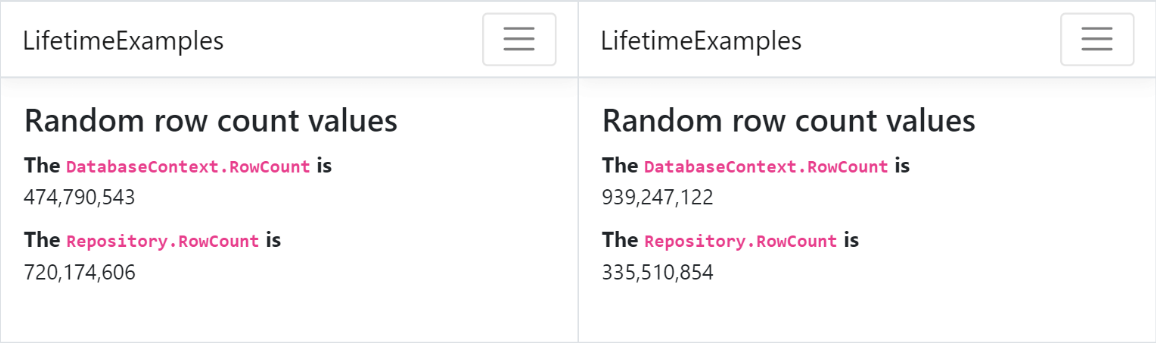
In the ASP.NET Core DI container, transient services are always created new, whenever they're needed to fulfill a dependency. You can register your services using the `AddTransient` extension methods:

```
services.AddTransient<DataContext>();
services.AddTransient<Repository>();
```

When registered in this way, every time a dependency is required, the container will create a new one. This applies both *between* requests but also *within* requests; the `DataContext` injected into the Repository will be a different instance to the one injected into the `RowCountModel`.

> **NOTE** **Transient dependencies can result in different instances of the same type within a single dependency graph.**

Figure 10.13 shows the results you get from two consecutive requests when you use the transient lifetime for both services. Note that, by default, Razor Page and API controller instances are also transient and are always created anew.



LifetimeExamples

Random row count values

The `DatabaseContext.RowCount` is

474,790,543

The `Repository.RowCount` is

720,174,606

LifetimeExamples

Random row count values

The `DatabaseContext.RowCount` is

939,247,122

The `Repository.RowCount` is

335,510,854

Figure 10.13 When registered using the transient lifetime, all four `DataContext` objects are different. That can be seen by the four different numbers displayed over the course of two requests.

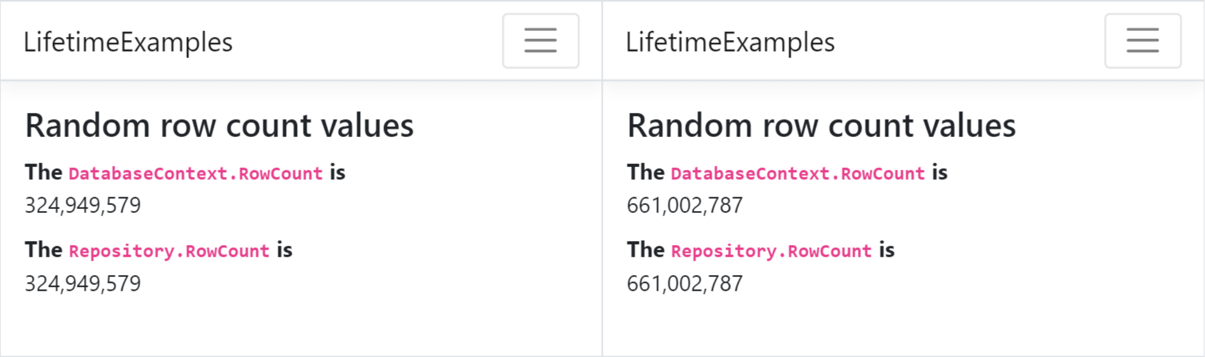
Transient lifetimes can result in a lot of objects being created, so they make the most sense for lightweight services with little or no state. It's equivalent to calling `new` every time you need a new object, so bear that in mind when using it. You probably won't use the transient lifetime too often; the majority of your services will probably be *scoped* instead.

10.3.2 Scoped: let's stick together

The scoped lifetime states that a *single* instance of an object will be used *within* a given scope, but a *different* instance will be used *between different scopes*. In ASP.NET Core, a scope maps to a request, so within a single request the container will use the same object to fulfill all dependencies.

For the row count example, that means that, within a single request (a single scope), the same `DataContext` will be used throughout the dependency graph. The `DataContext` injected into the `Repository` will be the same instance as that injected into `RowCountModel`.

In the next request, you'll be in a different scope, so the container will create a new instance of `DataContext`, as shown in figure 10.14. A different instance means a different `RowCount` for each request, as you can see.



LifetimeExamples

Random row count values

The DatabaseContext.RowCount is
324,949,579

The Repository.RowCount is
324,949,579

LifetimeExamples

Random row count values

The DatabaseContext.RowCount is
661,002,787

The Repository.RowCount is
661,002,787

Figure 10.14 Scoped dependencies use the same instance of `DataContext` within a single request, but a new instance for a separate request. Consequently, the `RowCount`s are identical within a request.

You can register dependencies as scoped using the `AddScoped` extension methods. In this example, I registered `DataContext` as scoped and left `Repository` as transient, but you'd get the same results in this case if they were both scoped:

```
services.AddScoped<DataContext>();
```

Due to the nature of web requests, you'll often find services registered as scoped dependencies in ASP.NET Core. Database contexts and authentication services are common examples of services that should be scoped to a request—anything that you want to share across your services *within* a single request, but that needs to change *between* requests.

Generally speaking, you'll find a lot of services registered using the scoped lifetime—especially anything that uses a database or is dependent on a specific request. But some services don't need to change between requests, such as a service that calculates the area of a circle, or that returns the current time in different time zones. For these, a singleton lifetime might be more appropriate.

10.3.3 Singleton: there can be only one

The singleton is a pattern that came before dependency injection; the DI container provides a robust and easy-to-use implementation of it. The singleton is conceptually simple: an instance of the service is created when it's first needed (or during registration, as in section 10.2.3) and that's it: you'll always get the same instance injected into your services.

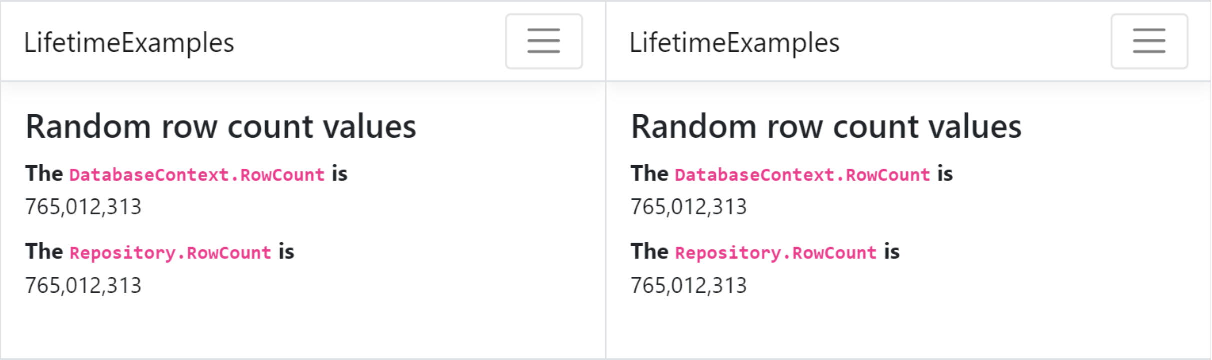
The singleton pattern is particularly useful for objects that are either expensive to create, contain data that must be shared across requests, or that don't hold state. The latter two points are important—any service registered as a singleton should be thread-safe.

> **WARNING** Singleton services must be thread-safe in a web application, as they'll typically be used by multiple threads during concurrent requests.

Let's consider what using singletons means for the row count example. I can update the registration of `DataContext` to be a singleton in `ConfigureServices`, using

```
services.AddSingleton<DataContext>();
```

We then call the `RowCountModel` Razor Page twice and observe the results shown in figure 10.15. You can see that every instance has returned the same value, indicating that all four instances of `DataContext` are the same single instance.



LifetimeExamples

Random row count values

The `DatabaseContext.RowCount` is

765,012,313

The `Repository.RowCount` is

765,012,313

LifetimeExamples

Random row count values

The `DatabaseContext.RowCount` is

765,012,313

The `Repository.RowCount` is

765,012,313

Figure 10.15 Any service registered as a singleton will always return the same instance. Consequently, all the calls to `RowCount` return the same value, both within a request and between requests.

Singletons are convenient for objects that need to be shared or that are immutable and expensive to create. A caching service should be a singleton, as all requests need to share it. It must be thread-safe though. Similarly, you might register a settings object loaded from a remote server as a singleton, if you loaded the settings once at startup and reused them through the lifetime of your app.

On the face of it, choosing a lifetime for a service might not seem too tricky, but there's an important "gotcha" that can come back to bite you in subtle ways, as you'll see shortly.

10.3.4 Keeping an eye out for captured dependencies

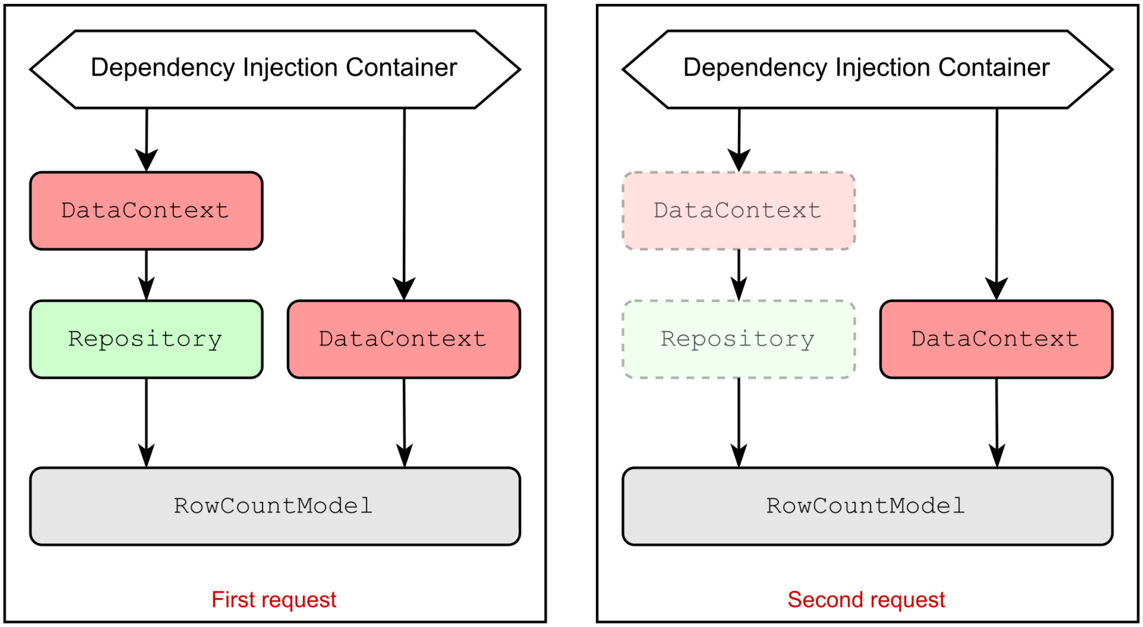
Imagine you're configuring the lifetime for the `DataContext` and `Repository` examples. You think about the suggestions I've provided and decide on the following lifetimes:

- `DataContext`—*Scoped*, as it should be shared for a single request
- `Repository`—*Singleton*, as it has no state of its own and is thread-safe, so why not?

> **WARNING** This lifetime configuration is to explore a bug—don't use it in your code or you'll experience a similar problem!

Unfortunately, you've created a *captured dependency* because you're injecting a *scoped* object, `DataContext`, into a *singleton*, `Repository`. As it's a singleton, the same

`Repository` instance is used throughout the lifetime of the app, so the `DataContext` that was injected into it will *also* hang around, *even though a new one should be used with every request*. Figure 10.16 shows this scenario, where a new instance of `DataContext` is created for each scope, but the instance inside `Repository` hangs around for the lifetime of the app.



As the repository has been registered as a singleton, the DataContext it uses will act also as a singleton, even though it is registered as scoped.

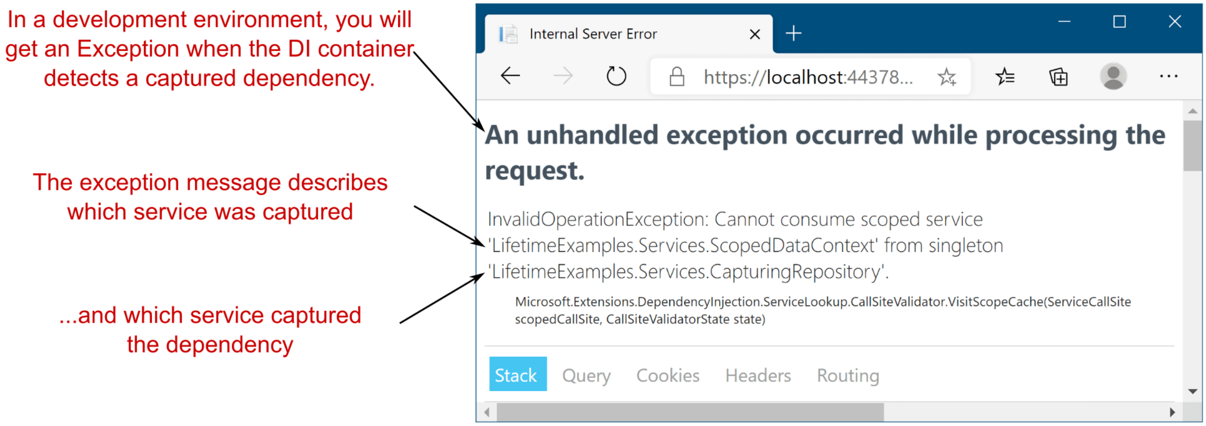
The DataContext dependency has been captured by the repository, breaking the scoped lifetime.

Figure 10.16 `DataContext` **is registered as a scoped dependency, but** `Repository` **is a singleton. Even though you expect a new** `DataContext` **for every request,** `Repository` ***captures*** **the injected** `DataContext` **and causes it to be reused for the lifetime of the app.**

Captured dependencies can cause subtle bugs that are hard to root out, so you should always keep an eye out for them. These captured dependencies are relatively easy to introduce, so always think carefully when registering a singleton service.

> **WARNING** A service should only use dependencies with a lifetime longer than or equal to the lifetime of the service. A service registered as a singleton can only safely use singleton dependencies. A service registered as scoped can safely use scoped or singleton dependencies. A transient service can use dependencies with any lifetime.

At this point, I should mention that there’s one glimmer of hope in this cautionary tale. ASP.NET Core automatically checks for these kinds of captured dependencies and will throw an exception on application startup if it detects them, as shown in figure 10.17.



In a development environment, you will get an Exception when the DI container detects a captured dependency.

The exception message describes which service was captured

...and which service captured the dependency

An unhandled exception occurred while processing the request.

InvalidOperationException: Cannot consume scoped service 'LifetimeExamples.Services.ScopedDataContext' from singleton 'LifetimeExamples.Services.CapturingRepository'.

Microsoft.Extensions.DependencyInjection.ServiceLookup.CallSiteValidator.VisitScopeCache(ServiceCallSite scopedCallSite, CallSiteValidatorState state)

Figure 10.17 When `ValidateScopes` is enabled, the DI container will throw an exception when it creates a service with a captured dependency. By default, this check is only enabled for development environments.

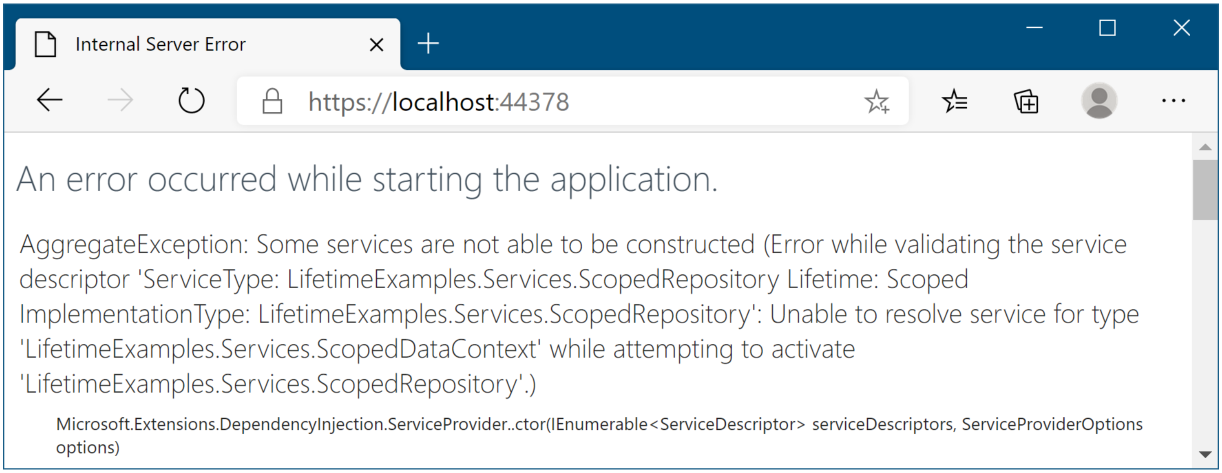
This scope validation check has a performance impact, so by default it’s only enabled when your app is running in a development environment, but it should help you catch most issues of this kind. You can enable or disable this check regardless of environment by setting the `ValidateScopes` option when creating your `HostBuilder` in Program.cs, as shown in the following listing.

Listing 10.20 Setting the `ValidateScopes` property to always validate scopes

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>
        Host.CreateDefaultBuilder(args)                          #A
            .ConfigureWebHostDefaults(webBuilder =>
            {
                webBuilder.UseStartup<Startup>();
            })
            .UseDefaultServiceProvider(options =>          #B
            {
                options.ValidateScopes = true;             #C
                options.ValidateOnBuild = true;            #D
            });
}
```

#A The default builder sets ValidateScopes to validate only in development environments.
#B You can override the validation check with the UseDefaultServiceProvider extension.
#C Setting to true will validate scopes in all environments. This has performance implications.
#D ValidateOnBuild checks that every registered service has all its dependencies registered.

Listing 10.20 shows another setting you can enable, `ValidateOnBuild`, that goes one step further. When enabled, the DI container checks on application startup that it has dependencies registered for every service it needs to build. If it doesn't, it throws an exception, as shown in figure 10.18, letting you know about the misconfiguration. This also has a performance impact, so it's only enabled in development environments by default, but it's very useful for pointing out any missed service registrations![47]



An error occurred while starting the application.

AggregateException: Some services are not able to be constructed (Error while validating the service descriptor 'ServiceType: LifetimeExamples.Services.ScopedRepository Lifetime: Scoped ImplementationType: LifetimeExamples.Services.ScopedRepository': Unable to resolve service for type 'LifetimeExamples.Services.ScopedDataContext' while attempting to activate 'LifetimeExamples.Services.ScopedRepository'.)

Microsoft.Extensions.DependencyInjection.ServiceProvider..ctor(IEnumerable<ServiceDescriptor> serviceDescriptors, ServiceProviderOptions options)

Figure 10.17 When `ValidateOnBuild` is enabled, the DI container will check on app start up that it can create all of the registered services. If it finds a service it can't create, it throws an exception. By default, this check is only enabled for development environments.

With that, you've reached the end of this introduction to DI in ASP.NET Core. You now know how to add framework services to your app using `Add*` extension methods like `AddRazorPages()`, as well as how to register your own services with the DI container. Hopefully, that will help you keep your code loosely coupled and easy to manage.

In the next chapter, we'll look at the ASP.NET Core configuration model. You'll see how to load settings from a file at runtime, how to store sensitive settings safely, and how to make

[47] **Unfortunately, the container can't catch everything. For a list of caveats and exceptions, see this post: https://andrewlock.net/new-in-asp-net-core-3-service-provider-validation/.**

your application behave differently depending on which machine it's running on. We'll even use a bit of DI; it gets everywhere in ASP.NET Core!

10.4 Summary

- Dependency injection is baked into the ASP.NET Core framework. You need to ensure your application adds all the framework's dependencies in `Startup` otherwise you will get exceptions at runtime when the DI container can't find the required services.
- The dependency graph is the set of objects that must be created in order to create a specific requested "root" object. The DI container handles creating all these dependencies for you.
- You should aim to use explicit dependencies over implicit dependencies in most cases. ASP.NET Core uses constructor arguments to declare explicit dependencies.
- When discussing DI, the term *service* is used to describe any class or interface registered with the container.
- You register services with a DI container so it knows which implementation to use for each requested service. This typically takes the form of, "for interface X, use implementation Y."
- The DI or IoC container is responsible for creating instances of services. It knows how to construct an instance of a service by creating all the service's dependencies and passing these in the service constructor.
- The default built-in container only supports constructor injection. If you require other forms of DI, such as property injection, you can use a third-party container.
- You must register services with the container by calling `Add*` extension methods on `IServiceCollection` in `ConfigureServices` in `Startup`. If you forget to register a service that's used by the framework or in your own code, you'll get an `InvalidOperationException` at runtime.
- When registering your services, you describe three things: the service type, the implementation type, and the lifetime. The service type defines which class or interface will be requested as a dependency. The implementation type is the class the container should create to fulfil the dependency. The lifetime is how long an instance of the service should be used for.
- You can register a service using generic methods if the class is concrete and all its constructor arguments are registered with the container or have default values.
- You can provide an instance of a service during registration, which will register that instance as a singleton. This can be useful when you already have an instance of the service available.
- You can provide a lambda factory function that describes how to create an instance of a service with any lifetime you choose. You can use this approach when your services depend on other services, which are only accessible once your application is running.
- Avoid calling `GetService()` in your factory functions if possible. Instead, favor constructor injection—it's more performant, as well as being simpler to reason about.

- You can register multiple implementations for a service. You can then inject `IEnumerable<T>` to get access to all the implementations at runtime.
- If you inject a single instance of a multiple-registered service, the container injects the last implementation registered.
- You can use the `TryAdd*` extension methods to ensure that an implementation is only registered if no other implementation of the service has been registered. This can be useful for library authors to add "default" services while still allowing consumers to override the registered services.
- You define the lifetime of a service during DI service registration. This dictates when a DI container will reuse an existing instance of the service to fulfil service dependencies and when it will create a new one.
- The transient lifetime means that every single time a service is requested, a new instance is created.
- The scoped lifetime means that within a scope, all requests for a service will give you the same object. For different scopes, you'll get different objects. In ASP.NET Core, each web request gets its own scope.
- You'll always get the same instance of a singleton service, no matter which scope.
- A service should only use dependencies with a lifetime longer than or equal to the lifetime of the service.

11

Configuring an ASP.NET Core application

This chapter covers

- **Loading settings from multiple configuration providers**
- **Storing sensitive settings safely**
- **Using strongly typed settings objects**
- **Using different settings in different hosting environments**

In part 1 of this book, you learned the basics of getting an ASP.NET Core app up and running and how to use the MVC design pattern to create a traditional web app or a Web API. Once you start building real applications, you will quickly find that you want to tweak various settings at deploy time, without necessarily having to recompile your application. This chapter looks at how you can achieve this in ASP.NET Core using configuration.

I know. Configuration sounds boring, right? But I have to confess, the configuration model is one of my favorite parts of ASP.NET Core. It's so easy to use, and so much more elegant than the previous version of ASP.NET. In section 11.2, you'll learn how to load values from a plethora of sources—JSON files, environment variables, and command-line arguments—and combine them into a unified configuration object.

On top of that, ASP.NET Core brings the ability to easily bind this configuration to strongly typed *options* objects. These are simple, POCO classes that are populated from the configuration object, which you can inject into your services, as you'll see in section 11.3. This lets you nicely encapsulate settings for different features in your app.

In the final section of this chapter, you'll learn about the ASP.NET Core *hosting environments*. You often want your app to run differently in different situations such as when running on your developer machine compared to when you deploy it to a production server.

These different situations are known as *environments*. By letting the app know in which environment it's running, it can load a different configuration and vary its behavior accordingly.

Before we get to that, let's go back to basics: what is configuration, why do we need it, and how does ASP.NET Core handle these requirements?

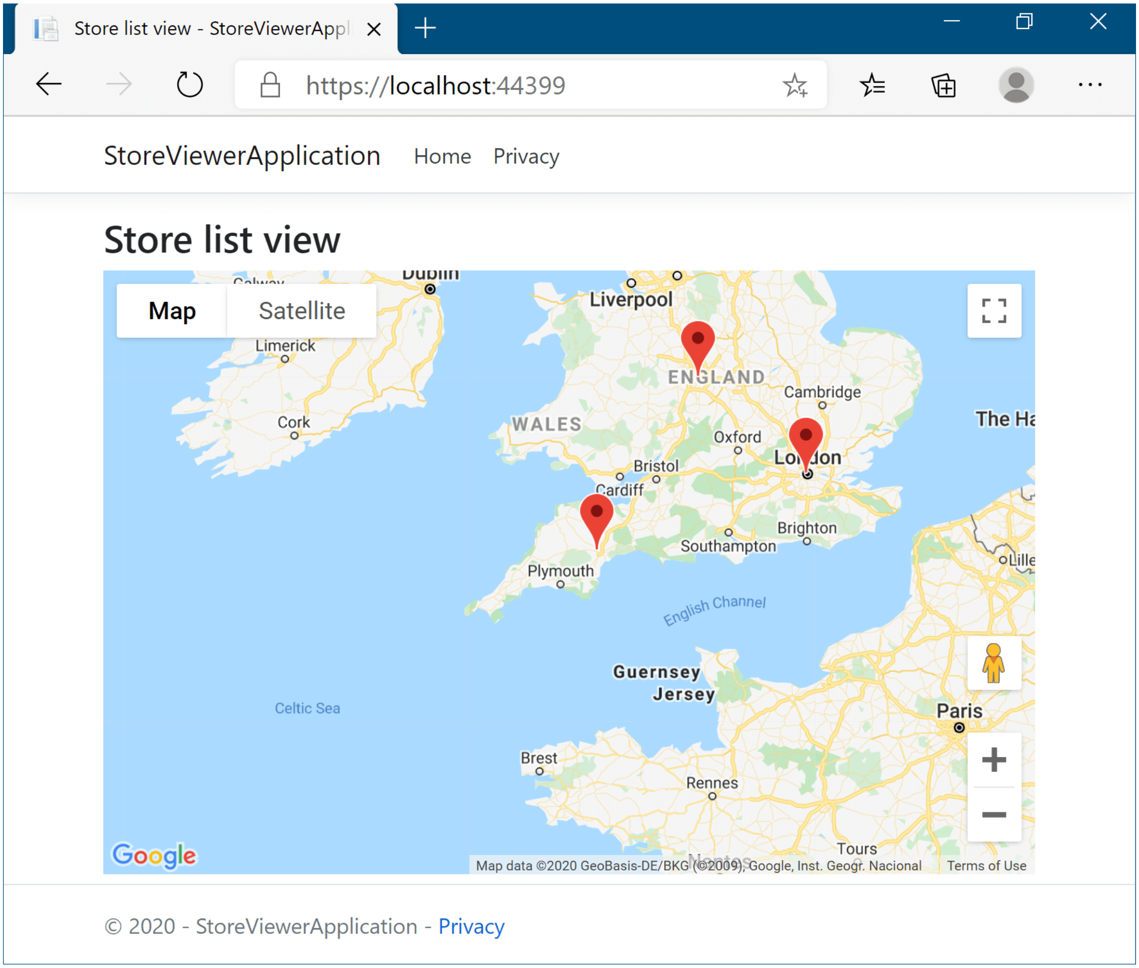
11.1 Introducing the ASP.NET Core configuration model

In this section I provide a brief description of what we mean by configuration and what you can use it for in ASP.NET Core applications. Configuration is the set of external parameters provided to an application that controls the application's behavior in some way. It typically consists of a mixture of *settings* and *secrets* that the application will load at runtime.

> **DEFINITION** A *setting* is any value that changes the behavior of your application. A *secret* is a special type of setting that contains sensitive data, such as a password, an API key for a third-party service, or a connection string.

The obvious question before we get started is to consider why you need app configuration, and what sort of things you need to configure. You should normally move anything that you can consider a setting or a secret out of your application code. That way, you can easily change these values at deploy time, without having to recompile your application.

You might, for example, have an application that shows the locations of your brick-and-mortar stores. You could have a setting for the connection string to the database in which you store the details of the stores, but also settings such as the default location to display on a map, the default zoom level to use, and the API key for accessing the Google Maps API, as shown in figure 11.1. Storing these settings and secrets outside of your compiled code is good practice as it makes it easy to tweak them without having to recompile your code.



Store list view

Figure 11.1 You can store the default map location, zoom level, and mapping API Key in configuration and load them at runtime. It's important to keep secrets like API keys in configuration and out of your code.

There's also a security aspect to this; you don't want to hardcode secret values like API keys or passwords into your code, where they could be committed to source control and made publicly available. Even values embedded in your compiled application can be extracted, so it's best to externalize them whenever possible.

Virtually every web framework provides a mechanism for loading configuration and the previous version of ASP.NET was no different. It used the `<appsettings>` element in a web.config file to store key-value configuration pairs. At runtime, you'd use the static (*wince*) `ConfigurationManager` to load the value for a given key from the file. You could do more advanced things using custom configuration sections, but this was painful, and so was rarely used, in my experience.

ASP.NET Core gives you a totally revamped experience. At the most basic level, you’re still specifying key-value pairs as strings, but instead of getting those values from a single file, you can now load them from multiple sources. You can load values from files, but they can now be any format you like: JSON, XML, YAML, and so on. On top of that, you can load values from environment variables, from command-line arguments, from a database, or from a remote service. Or you could create your own custom *configuration provider*.

> **DEFINITION** ASP.NET Core uses *configuration providers* to load key-value pairs from a variety of sources. Applications can use many different configuration providers.

The ASP.NET Core configuration model also has the concept of *overriding* settings. Each configuration provider can define its own settings, or it can overwrite settings from a previous provider. You’ll see this incredibly-useful feature in action in section 11.3.

ASP.NET Core makes it simple to bind these key-value pairs, which are defined as `strings`, to POCO-setting classes you define in your code. This model of strongly typed configuration makes it easy to logically group settings around a given feature and lends itself well to unit testing.

Before we get into the details of loading configuration from providers, we’ll take a step back and look at *where* this process happens—inside `HostBuilder`. For ASP.NET Core 3.1 apps built using the default templates, that’s invariably inside the `Host.CreateDefaultBuilder()` method in Program.cs.

11.2 Configuring your application with CreateDefaultBuilder

As you saw in chapter 2, the default templates in ASP.NET Core 3.1 use the `CreateDefaultBuilder` method. This is an opinionated helper method that sets up a number of defaults for your app. In this section we’ll look inside this method to see all the things it configures, and what they’re used for.

Listing 11.1 Using `CreateDefaultBuilder` to set up configuration

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();                #A
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>
        Host.CreateDefaultBuilder(args)                   #B
            .ConfigureWebHostDefaults(webBuilder =>
            {
                webBuilder.UseStartup<Startup>();
            });
}
```

#A The entry point for your application creates an IHostBuilder, builds an IHost, and calls Run.
#B CreateDefaultBuilder sets up a number of defaults, including configuration.

In chapter 2, I glossed over this method, as you will only rarely need to change it for simple apps. But as your application grows, and if you want to change how configuration is loaded for your application, you may find you need to break it apart.

This listing shows an overview of the `CreateDefaultBuilder` method, so you can see how `HostBuilder` is constructed.

Listing 11.2 The `WebHost.CreateDefaultBuilder` method

```
public static IHostBuilder CreateDefaultBuilder(string[] args)
{
  var builder = new HostBuilder()                                #A
    .UseContentRoot(Directory.GetCurrentDirectory())             #B
    .ConfigureHostConfiguration(config =>                        #C
    {                                                            #C
        // Configuration provider setup                          #C
    })                                                           #C
    .ConfigureAppConfiguration((hostingContext, config) =>       #D
    {                                                            #D
        // Configuration provider setup                          #D
    })                                                           #D
    .ConfigureLogging((hostingContext, logging) =>               #E
    {                                                            #E
        logging.AddConfiguration(                                #E
          hostingContext.Configuration.GetSection("Logging"));   #E
        logging.AddConsole();                                    #E
        logging.AddDebug();                                      #E
    })                                                           #E
    .UseDefaultServiceProvider((context, options) =>             #F
    {                                                            #F
        var isDevelopment = context.HostingEnvironment           #F
                                    .IsDevelopment();            #F
        options.ValidateScopes = isDevelopment;                  #F
        options.ValidateOnBuild = isDevelopment;                 #F
    });                                                          #F

  return builder;                                                #G
}
```

#A Creating an instance of HostBuilder
#B The content root defines the directory where configuration files can be found.
#C Configures hosting settings such as determining the hosting environment
#D Configures application settings, the topic of this chapter
#E Sets up the logging infrastructure
#F Configures the DI container, optionally enabling verification settings
#G Returns HostBuilder for further configuration by calling extra methods before calling Build()

The first method called on `HostBuilder` is `UseContentRoot`. This tells the application in which directory it can find any configuration or view files it will need later. This is typically the folder in which the application is running, hence the call to `GetCurrentDirectory`.

TIP ContentRoot is *not* where you store static files that the browser can access directly—that's the *WebRoot*, typically wwwroot.

The `ConfigureHostingConfiguration()` method is where your application determines which `HostingEnvironment` it's currently running in. The framework looks for environment variables and command line arguments by default, to determine if it's running in a development or production environment. You'll learn more about hosting environments in section 11.5.

`ConfigureLogging` is where you can specify the logging settings for your application. We'll look at logging in detail in chapter 17; for now, it's enough to know that `CreateDefaultBuilder` sets this up for you.

The last method call in `CreateDefaultBuilder`, `UseDefaultServiceProvider`, configures your app to use the built-in DI container. It also sets the `ValidateScopes` and `ValidateOnBuild` options based on the current `HostingEnvironment`. When running the application in the development environment, the app will automatically check for captured dependencies, as you learned about in chapter 10.

The `ConfigureAppConfiguration()` method is the focus of section 11.3. It's where you load the settings and secrets for your app, whether they're in JSON files, environment variables, or command-line arguments. In the next section, you'll see how to use this method to load configuration values from various configuration providers using the ASP.NET Core `ConfigurationBuilder`.

11.3 Building a configuration object for your app

In this section we get into the meat of the configuration system. You'll learn how to load settings from multiple sources, how they're stored internally in ASP.NET Core, and how settings can override other values to give "layers" of configuration. You'll also learn how to store secrets securely, while ensuring they're still available when you run your app.

In section 11.2 you saw how the `CreateDefaultBuilder` method can be used to create an instance of `IHostBuilder`. `IHostBuilder` is responsible for setting up many things about your app, including the configuration system in the `ConfigureAppConfiguration` method. This method is passed an instance of a `ConfigurationBuilder`, which is used to define your app's configuration.

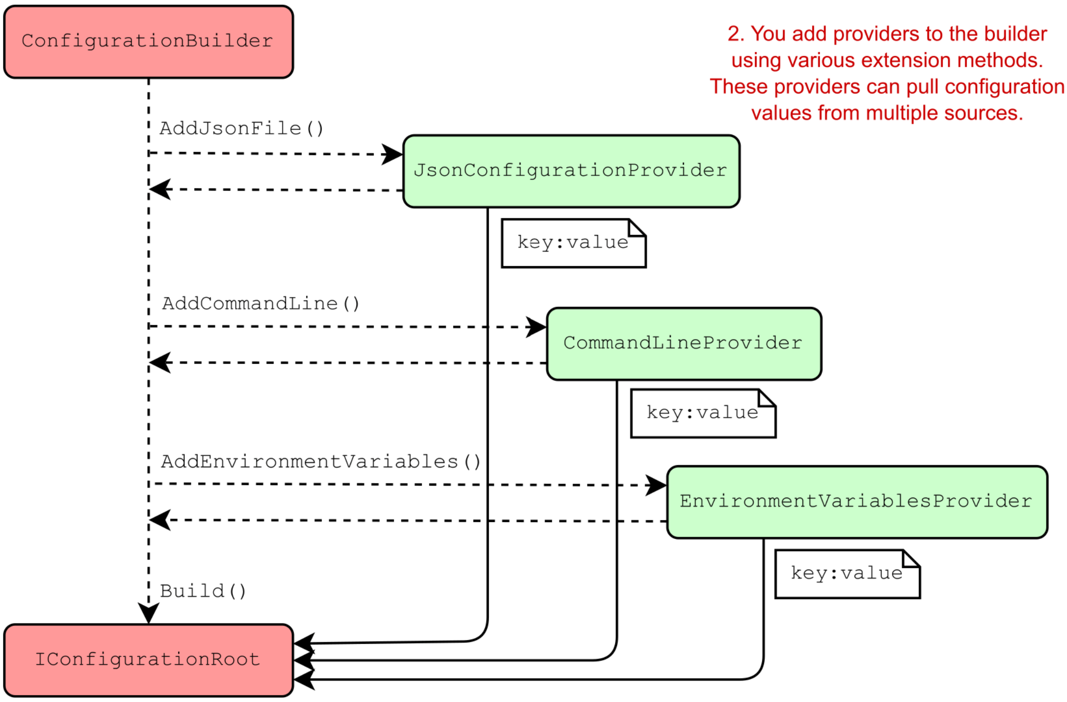
The ASP.NET Core configuration model centers on two main constructs: `ConfigurationBuilder` and `IConfiguration`.

NOTE `ConfigurationBuilder` **describes how to construct the final configuration representation for your app, and** `IConfiguration` **holds the configuration values themselves.**

You describe your configuration setup by adding a number of `IConfigurationProviders` to the `ConfigurationBuilder` in `ConfigureAppConfiguration`. These describe how to load the key-value pairs from a particular source; for example, a JSON file or from environment variables, as shown in figure 11.2. Calling `Build()` on `ConfigurationBuilder` queries each of these providers for the values they contain to create the `IConfigurationRoot` instance.

> **NOTE** Calling `Build()` creates an `IConfigurationRoot` instance, which implements `IConfiguration`. You will generally work with the `IConfiguration` interface in your code.

1. You start by creating an instance of the ConfigurationBuilder.



2. You add providers to the builder using various extension methods. These providers can pull configuration values from multiple sources.

3. Calling Build() on the ConfigurationBuilder loads the values from each provider and stores them in the IConfigurationRoot.

Figure 11.2 Using `ConfigurationBuilder` to create an instance of `IConfiguration`. Configuration providers are added to the builder with extension methods. Calling `Build()` queries each provider to create the `IConfigurationRoot` which implements `IConfiguration`.

ASP.NET Core ships with configuration providers for loading data from common locations:

- JSON files
- XML files
- Environment variables
- Command-line arguments

- INI files

If these don’t fit your requirements, you can find a whole host of alternatives on GitHub and NuGet, and it’s not difficult to create your own custom provider. For example, you could use the official Azure KeyVault provider NuGet package[48], or the YAML file provider I wrote.[49]

In many cases, the default providers will be sufficient. In particular, most templates start with an appsettings.json file, which contains a variety of settings, depending on the template you choose. This listing below shows the default file generated by the ASP.NET Core 3.1 Web app template without authentication.

Listing 11.3 Default appsettings.json file created by an ASP.NET Core Web template

```
{
  "Logging": {
    "LogLevel": {
      "Default": "Information",
      "Microsoft": "Warning",
      "Microsoft.Hosting.Lifetime": "Information"
    }
  },
  "AllowedHosts": "*"
}
```

As you can see, this file mostly contains settings to control logging, but you can add additional configuration for your app here too.

WARNING Don’t store sensitive values, such as passwords, API keys, or connection strings, in this file. You’ll see how to store these securely in section 11.3.3.

Adding your own configuration values involves adding a key-value pair to the JSON. It’s a good idea to “namespace” your settings by creating a base object for related settings, as in the `MapSettings` object shown here.

Listing 11.4 Adding additional configuration values to an appsettings.json file

```
{
  "Logging": {
    "LogLevel": {
      "Default": "Information",
      "Microsoft": "Warning",
      "Microsoft.Hosting.Lifetime": "Information"
    }
  },
  "AllowedHosts": "*",
  "MapSettings": {                #A
    "DefaultZoomLevel": 9,        #B
```

[48] The Azure KeyVault provider is available on NuGet: https://www.nuget.org/packages/Microsoft.Extensions.Configuration.AzureKeyVault/.
[49] You can find my YAML provider on GitHub at https://github.com/andrewlock/NetEscapades.Configuration.

```
    "DefaultLocation": {       #C
      "latitude": 50.500,      #C
      "longitude": -4.000      #C
    }
  }
}
```

#A Nest all the configuration under the MapSettings key.
#B Values can be numbers in the JSON file, but they'll be converted to strings when they're read.
#C You can create deeply nested structures to better organize your configuration values.

I've nested the new configurtation inside the `MapSettings` parent key; this creates a "section" which will be useful later when it comes to binding your values to a POCO object. I also nested the `latitude` and `longitude` keys under the `DefaultLocation` key. You can create any structure of values that you like; the configuration provider will read them just fine. Also, you can store them as any data type—numbers, in this case—but be aware that the provider will read and store them internally as strings.

> **TIP The configuration keys are *not* case-sensitive in your app, so bear that in mind when loading from providers in which the keys *are* case-sensitive.**

Now that you have a configuration file, it's time for your app to load it using `ConfigurationBuilder`! For this, return to the `ConfigureAppConfiguration()` method exposed by `HostBuilder` in Program.cs.

11.3.1 Adding a configuration provider in Program.cs

The default templates in ASP.NET Core use the `CreateDefaultBuilder` helper method to bootstrap `HostBuilder` for your app, as you saw in section 11.2. As part of this configuration, the `CreateDefaultBuilder` method calls `ConfigureAppConfiguration` and sets up a number of default configuration providers, which we'll look at in more detail throughout this chapter:

- *JSON file provider*—Loads settings from an optional JSON file called appsettings.json.
- *JSON file provider*—Loads settings from an optional environment-specific JSON file called appsettings.*ENVIRONMENT*.json. I'll show how to use environment-specific files in section 11.5.
- *User Secrets*—Loads secrets that are stored safely during development.
- *Environment variables*—Loads environment variables as configuration variables. Great for storing secrets in production.
- *Command-line arguments*—Uses values passed as arguments when you run your app.

Using the default builder ties you to this default set, but the default builder is optional. If you want to use different configuration providers, you can create your own `HostBuilder` instance instead if you wish. If you take this approach, you'll need to set up everything that `CreateHostBuilder` does: logging, hosting configuration, service provider configuration, as well as your app configuration.

An alternative approach is to add *additional* configuration providers by adding an extra call to ConfigureAppConfiguration, as shown in the following listing. This allows you to add extra providers, on top of those added by CreateHostBuilder. In the listing below, you explicitly clear the default providers, which lets you completely customize where configuration is loaded from, without having to replace the defaults CreateHostBuilder adds for logging and so on.

Listing 11. 5 Loading appsettings.json using a custom WebHostBuilder

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>
        Host.CreateDefaultBuilder(args)
            .ConfigureAppConfiguration(AddAppConfiguration)    #A
            .ConfigureWebHostDefaults(webBuilder =>
            {
                webBuilder.UseStartup<Startup>();
            });

    public static void AddAppConfiguration(                        #B
        HostBuilderContext hostingContext,                         #B
        IConfigurationBuilder config)                              #B
    {
        config.Sources.Clear();                                    #C
        config.AddJsonFile("appsettings.json", optional: true);    #D
    }
```

#A Adds the configuration setup function to HostBuilder
#B HostBuilder provides a hosting context and an instance of ConfigurationBuilder.
#C Clears the providers configured by default in CreateDefaultBuilder
#D Adds a JSON configuration provider, providing the filename of the configuration file

> **TIP** **In listing 11.5, I extracted the configuration to a static helper method,** AddAppConfiguration**, but you can also provide this inline as a lambda method.**

The HostBuilder creates an ConfigurationBuilder instance before invoking the ConfigureAppConfiguration method. All you need to do is add the configuration providers for your application.

In this example, you've added a single JSON configuration provider by calling the AddJsonFile extension method and providing a filename. You've also set the value of optional to true. This tells the configuration provider to skip over files it can't find at runtime, instead of throwing FileNotFoundException. Note that the extension method just registers the provider at this point, it doesn't try to load the file yet.

And that's it! The HostBuilder instance takes care of calling Build(), which generates IConfiguration, which represents your configuration object. This is then registered with the

DI container, so you can inject it into your classes. You'd commonly inject this into the constructor of your `Startup` class, so you can use it in the `Configure` and `ConfigureServices` methods:

```
public class Startup
{
    public Startup(IConfiguration config)
    {
        Configuration = config
    }
    public IConfiguration Configuration { get; }
}
```

> **NOTE The `ConfigurationBuilder` creates an `IConfigurationRoot` instance, which implements `IConfiguration`. This is registered, as an `IConfiguration` in the DI container, *not* an `IConfigurationRoot`. `IConfiguration` is one of the few things that you can inject into the `Startup` constructor.**

At this point, at the end of the `Startup` constructor, you have a fully loaded configuration object! But what can you do with it? The `IConfiguration` stores configuration as a set of key-value `string` pairs. You can access any value by its key, using standard dictionary syntax. For example, you could use

```
var zoomLevel = Configuration["MapSettings:DefaultZoomLevel"];
```

to retrieve the configured zoom level for your application. Note that I used a colon ":" to designate a separate section. Similarly, to retrieve the `latitude` key, you could use

```
Configuration["MapSettings:DefaultLocation:Latitude"];
```

> **NOTE If the requested configuration key does not exist, you will get a `null` value.**

You can also grab a whole section of the configuration using the `GetSection(section)` method, which returns an `IConfigurationSection`, which implements `IConfiguration`. This grabs a chunk of the configuration and resets the namespace. Another way of getting the latitude key would be

```
Configuration.GetSection("MapSettings")["DefaultLocation:Latitude"];
```

Accessing setting values like this is useful in the `ConfigureServices` and `Configure` methods of `Startup`, when you're defining your application. When setting up your application to connect to a database, for example, you'll often load a connection string from the `Configuration` object (you'll see a concrete example of this in the next chapter, when we look at Entity Framework Core).

If you need to access the configuration object like this from classes other than `Startup`, you can use DI to take it as a dependency in your service's constructor. But accessing configuration using `string` keys like this isn't particularly convenient; you should try to use strongly typed configuration instead, as you'll see in section 11.4.

So far, this is probably all feeling a bit convoluted and run-of-the-mill to load settings from a JSON file, and I'll grant you, it is. Where the ASP.NET Core configuration system shines is when you have multiple providers.

11.3.2 Using multiple providers to override configuration values

You've seen that ASP.NET Core uses the builder pattern to construct the configuration object, but so far, you've only configured a single provider. When you add providers, it's important to consider the order in which you add them, as that defines the order in which the configuration values are added to the underlying dictionary. Configuration values from later providers will overwrite values with the same key from earlier providers.

> **NOTE** This bears repeating: the order you add configuration providers to `ConfigurationBuilder` is important. Later configuration providers can overwrite the values of earlier providers.

Think of the configuration providers as adding "layers" of configuration values to a stack, where each layer may overlap with some or all of the layers below, as shown in figure 11.3. When you call `Build()`, `ConfigurationBuilder` collapses these layers down into one, to create the final set of configuration values stored in `IConfiguration`.

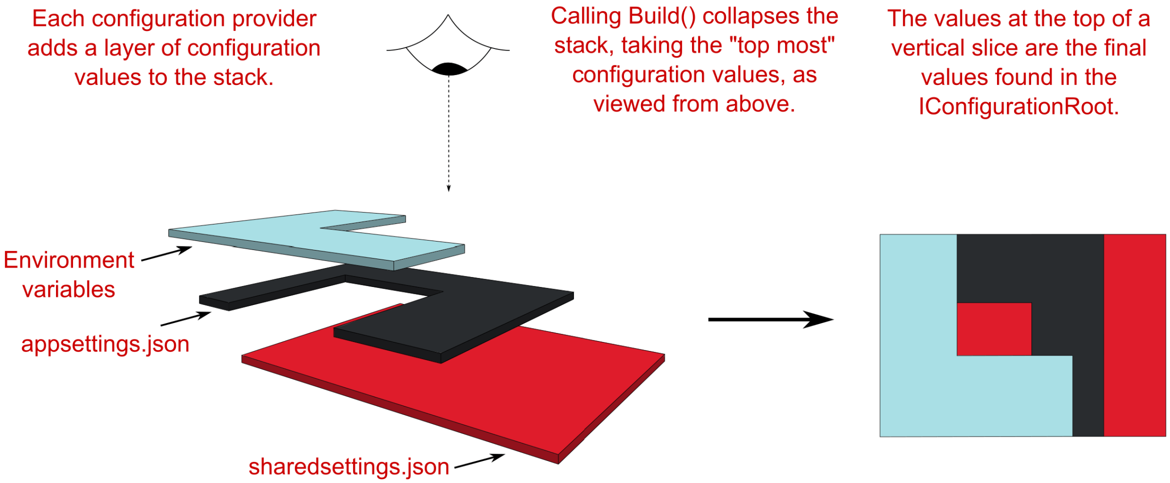

Each configuration provider adds a layer of configuration values to the stack.
Calling Build() collapses the stack, taking the "top most" configuration values, as viewed from above.
The values at the top of a vertical slice are the final values found in the IConfigurationRoot.
Environment variables
appsettings.json
sharedsettings.json

Figure 11.3 Each configuration provider adds a "layer" of values to `ConfigurationBuilder`. Calling `Build()` collapses that configuration. Later providers will overwrite configuration values with the same key as earlier providers.

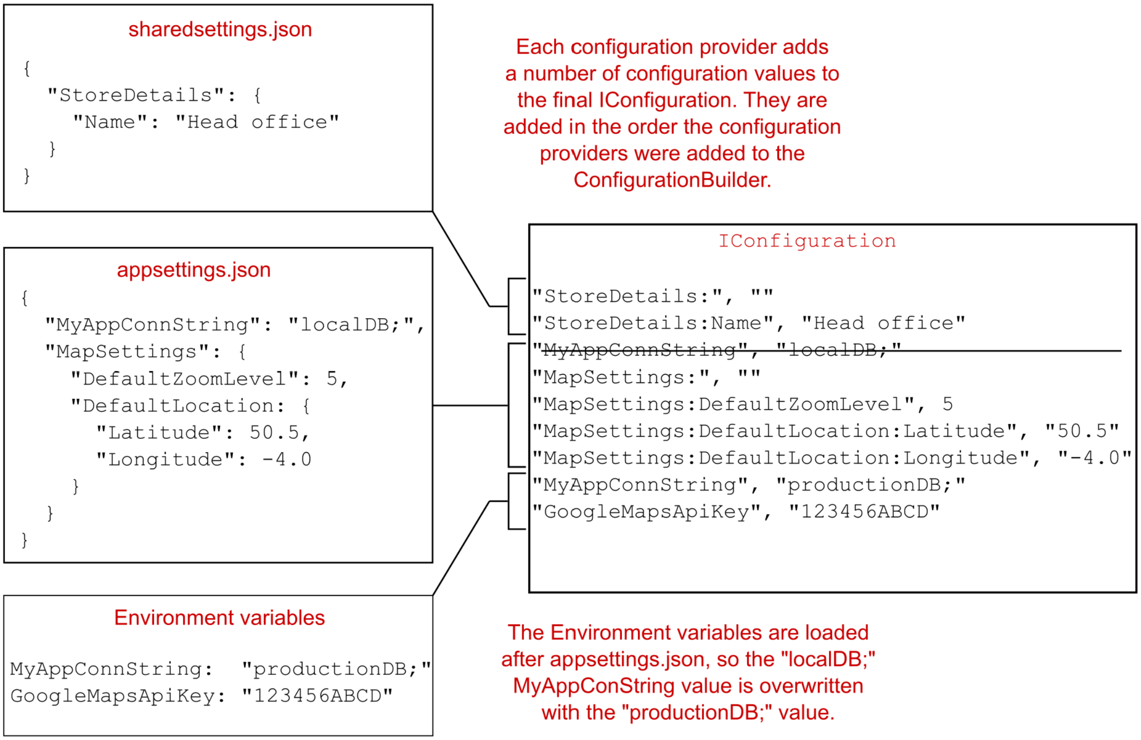
Update your code to load configuration from three different configuration providers—two JSON providers and an environment variable provider—by adding them to `ConfigurationBuilder`. I've only shown the `AddAppConfiguration` method in this listing for brevity.

Listing 11.6 Loading from multiple providers in Startup.cs

```
public class Program
{
    /* Additional Program configuration*/
    public static void AddAppConfiguration(
        HostBuilderContext hostingContext,
        IConfigurationBuilder config)
    {
        config.Sources.Clear();
        config
           .AddJsonFile("sharedSettings.json", optional: true)   #A
           .AddJsonFile("appsettings.json", optional: true)
           .AddEnvironmentVariables();                           #B
    }
}
```

#A Loads configuration from a different JSON configuration file before the appsettings.json file
#B Adds the machine’s environment variables as a configuration provider

This layered design can be useful for a number of things. Fundamentally, it allows you to aggregate configuration values from a number of different sources into a single, cohesive object. To cement this in place, consider the configuration values in figure 11.4.



```
{
  "StoreDetails": {
    "Name": "Head office"
  }
}
```

```
{
  "MyAppConnString": "localDB;",
  "MapSettings": {
    "DefaultZoomLevel": 5,
    "DefaultLocation: {
      "Latitude": 50.5,
      "Longitude": -4.0
    }
  }
}
```

```
MyAppConnString:  "productionDB;"
GoogleMapsApiKey: "123456ABCD"
```

```
"StoreDetails:", ""
"StoreDetails:Name", "Head office"
~~"MyAppConnString", "localDB;"~~
"MapSettings:", ""
"MapSettings:DefaultZoomLevel", 5
"MapSettings:DefaultLocation:Latitude", "50.5"
"MapSettings:DefaultLocation:Longitude", "-4.0"
"MyAppConnString", "productionDB;"
"GoogleMapsApiKey", "123456ABCD"
```

Each configuration provider adds a number of configuration values to the final IConfiguration. They are added in the order the configuration providers were added to the ConfigurationBuilder.

The Environment variables are loaded after appsettings.json, so the "localDB;" MyAppConString value is overwritten with the "productionDB;" value.

Figure 11.4 The final `IConfiguration` includes the values from each of the providers. Both appsettings.json and the environment variables include the `MyAppConnString` key. As the environment variables are added later, that configuration value is used.

Most of the settings in each provider are unique and added to the final `IConfiguration`. But the `"MyAppConnString"` key appears both in appsettings.json and as an environment variable. Because the environment variable provider is added *after* the JSON providers, the environment variable configuration value is used in `IConfiguration`.

The ability to collate configuration from multiple providers is a handy trait on its own, but this design is especially useful when it comes to handling sensitive configuration values, such as connection strings and passwords. The next section shows how to deal with this problem, both locally on your development machine and on production servers.

11.3.3 Storing configuration secrets safely

As soon as you build a nontrivial app, you'll find you have a need to store some sort of sensitive data as a setting somewhere. This could be a password, connection string, or an API key for a remote service, for example.

Storing these values in appsettings.json is generally a bad idea, as you should never commit secrets to source control; the number of secret API keys people have committed to GitHub is scary! Instead, it's much better to store these values outside of your project folder, where they won't get accidentally committed.

You can do this in a few ways, but the easiest and most commonly used approaches are to use environment variables for secrets on your production server and User Secrets locally.

Neither approach is truly secure, in that they don't store values in an encrypted format. If your machine is compromised, attackers will be able to read the stored values as they're stored in plaintext. They're intended to help you avoid committing secrets to source control.

> **TIP** Azure Key Vault[50] is a secure alternative, in that it stores the values encrypted in Azure. But you will still need to use the following approach for storing the Azure Key Value connection details!

Whichever approach you choose to store your application secrets, make sure you aren't storing them in source control, if possible. Even private repositories may not stay private forever, so it's best to err on the side of caution!

STORING SECRETS IN ENVIRONMENT VARIABLES IN PRODUCTION

You can add the environment variable configuration provider using the `AddEnvironmentVariables` extension method, as you've already seen in listing 11.6. This adds all of the environment variables on your machine as key-value pairs in the configuration object.

> **REMINDER** The environment variable provider is added by default in `CreateDefaultBuilder` as you saw in section 11.2.

You can create the same hierarchical sections in environment variables that you typically see in JSON files by using a colon, `:`, or a double underscore, `__`, to demarcate a section, for example: `MapSettings:MaxNumberOfPoints` or `MapSettings__MaxNumberOfPoints`.

> **TIP** Some environments, such as Linux, don't allow ":" in environment variables. You must use the double underscore approach in these environments instead. You should always use ":" when *retrieving* values from an `IConfiguration` in your app.

The environment variable approach is particularly useful when you're publishing your app to a self-contained environment, such as a dedicated server, Azure, or a Docker container. You can set environment variables on your production machine, or on your Docker container, and the

[50] The Azure Key Vault configuration provider is available as a Microsoft.Extensions.Configuration.AzureKeyVault NuGet package. For details on using it in your application, see the documentation at https://docs.microsoft.com/en-us/aspnet/core/security/key-vault-configuration.

provider will read them at runtime, overriding the defaults specified in your appsettings.json files.[51]

For a development machine, environment variables are less useful, as all your apps would be using the same values. For example, if you set the `ConnectionStrings__DefaultConnection` environment variable, then that would be added for *every* app you run locally. That sounds like more of a hassle than a benefit!

For development scenarios, you can use the User Secrets Manager. This effectively adds per-app environment variables, so you can have different settings for each app, but store them in a different location from the app itself.

STORING SECRETS WITH THE USER SECRETS MANAGER IN DEVELOPMENT

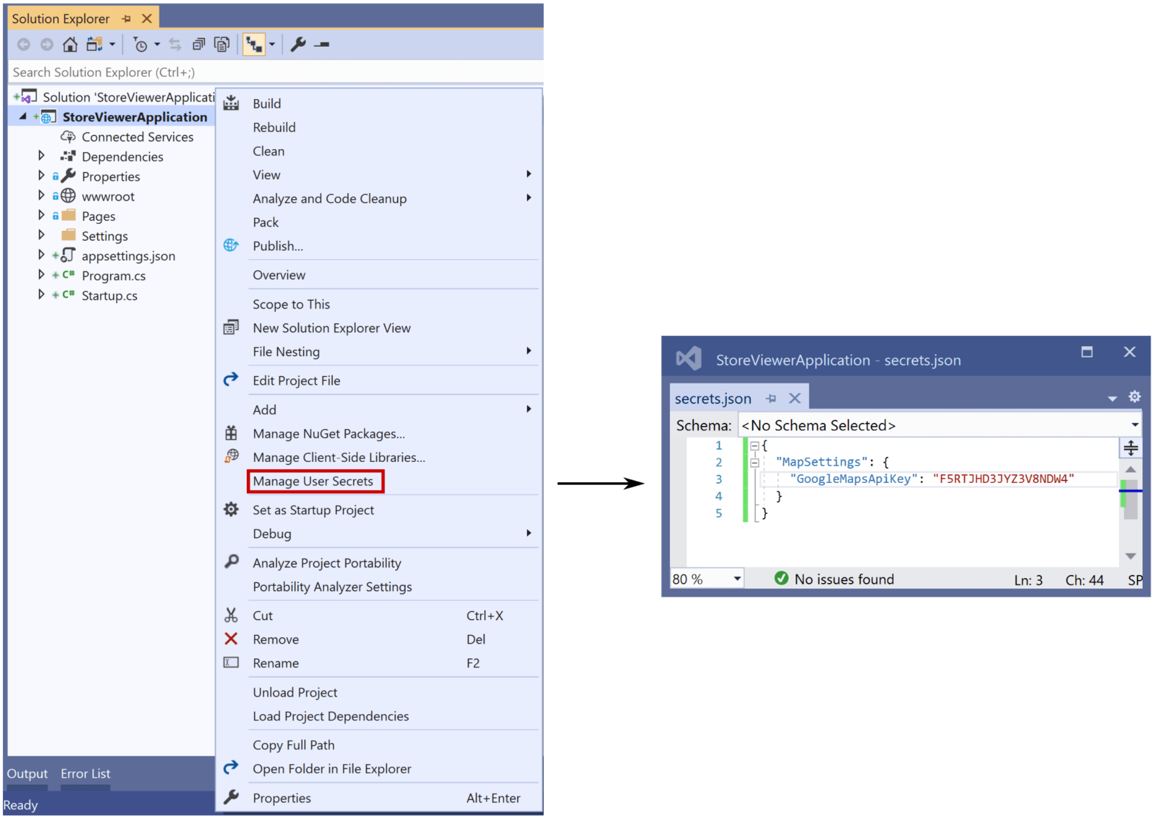
The idea behind User Secrets is to simplify storing per-app secrets outside of your app's project tree. This is similar to environment variables, but you use a unique key per-app to keep the secrets segregated.

> **WARNING** The secrets aren't encrypted, so shouldn't be considered secure. Nevertheless, it's an improvement on storing them in your project folder.

Setting up User Secrets takes a bit more effort than using environment variables, as you need to configure a tool to read and write them, add the User Secrets configuration provider, and define a unique key for your application:

1. ASP.NET Core includes the User Secrets provider by default. The .NET Core SDK also includes a global tool for working with secrets from the command line.
2. If you're using Visual Studio, right-click your project and choose Manage User Secrets. This opens an editor for a secrets.json file in which you can store your key-value pairs, as if it were an appsettings.json file, as shown in figure 11.5.

[51] For instructions on how to set environment variables for your operating system, see the documentation at https://docs.microsoft.com/en-us/aspnet/core/fundamentals/environments.



```
{
  "MapSettings": {
    "GoogleMapsApiKey": "F5RTJHD3JYZ3V8NDW4"
  }
}
```

Figure 11.5 Click Manage User Secrets to open an editor for the User Secrets app. You can use this file to store secrets when developing your app locally. These are stored outside your project folder, so won't be committed to source control accidentally.

3. Add a unique identifier to your csproj file. Visual Studio does this automatically when you click Manage User Secrets, but if you're using the command line, you'll need to add it yourself. Typically, you'd use a unique ID, like a GUID:

```
<PropertyGroup>
  <UserSecretsId>96eb2a39-1ef9-4d8e-8b20-8e8bd14038aa</UserSecretsId>
</PropertyGroup>
```

4. If you aren't using Visual Studio, you can add User Secrets using the command line:

```
dotnet user-secrets set "MapSettings:GoogleMapsApiKey" F5RJT9GFHKR7
```

or you can edit the secret.json file directly using your favorite editor. The exact location of this file depends on your operating system and may vary. Check the documentation[52] for details.

Phew, that's a lot of setup, and if you're customizing the `HostBuilder`, you're not done yet! You need to update your app to load the User Secrets at runtime using the `AddUserSecrets` extension method in your ConfigureAppConfiguration method:

```
if(env.IsDevelopment())
{
    configBuilder.AddUserSecrets<Startup>();
}
```

NOTE **You should only use the User Secrets provider in development, *not* in production, so in the snippet above you conditionally add the provider to `ConfigurationBuilder`. In production, you should use environment variables or Azure Key Vault, as discussed earlier. This is all configured correctly by default if you use `Host.CreateDefaultBuilder()`.**

This method has a number of overloads, but the simplest is a generic method that you can call passing your application's `Startup` class as a generic argument. The User Secrets provider needs to read the `UserSecretsId` property that you (or Visual Studio) added to the csproj file. The `Startup` class acts as a simple marker to indicate which assembly contains this property.

NOTE **If you're interested, the User Secrets package uses the `UserSecretsId` property in your csproj file to generate an assembly-level `UserSecretsIdAttribute`. The provider then reads this attribute at runtime to determine the `UserSecretsId` of the app, and hence generates the path to the secrets.json file.**

And there you have it, safe storage of your secrets outside your project folder during development. This might seem like overkill, but if you have anything that you consider remotely sensitive that you need to load into configuration, then I strongly urge you to use environment variables or User Secrets.

It's almost time to leave configuration providers behind, but before we do, I'd like to show you the ASP.NET Core configuration system's party trick: reloading files on the fly.

11.3.4 Reloading configuration values when they change

Besides security, not having to recompile your application every time you want to tweak a value is one of the advantages of using configuration and settings. In the previous version of ASP.NET, changing a setting by editing web.config would cause your app to have to restart.

[52] The Secret Manager Tool .stores the secrets.json file in the user profile. You can read more about the this tool specifically here https://docs.microsoft.com/en-gb/aspnet/core/security/app-secrets and about .NET core tools in general here: https://docs.microsoft.com/en-us/dotnet/core/tools/global-tools.

This beat having to recompile, but waiting for the app to start up before it could serve requests was a bit of a drag.

In ASP.NET Core, you finally get the ability to edit a file and have the configuration of your application automatically update, without having to recompile or restart.

An often cited scenario where you might find this useful is when you're trying to debug an app you have in production. You typically configure logging to one of a number of levels, for example:

- Error
- Warning
- Information
- Debug

Each of these settings is more verbose than the last, but also provides more context. By default, you might configure your app to only log warning and error-level logs in production, so you don't generate too many superfluous log entries. Conversely, if you're trying to debug a problem, you want as much information as possible, so you might want to use the debug log level.

Being able to change configuration at runtime means you can easily switch on extra logs when you encounter an issue and switch them back afterwards by editing your appsettings.json file.

> **NOTE** Reloading is generally only available for file-based configuration providers, as opposed to the environment variable or User Secrets provider.

You can enable the reloading of configuration files when you add any of the file-based providers to your `ConfigurationBuilder`. The `Add*File` extension methods include an overload with a `reloadOnChange` parameter. If this is set to true, the app will monitor the filesystem for changes to the file and will trigger a complete rebuild of the `IConfiguration`, if needs be. This listing shows how to add configuration reloading to the appsettings.json file loaded inside the `AddAppConfiguration` method.

Listing 11.7 Reloading appsettings.json when the file changes

```
public class Program
{
    /* Additional Program configuration*/

    public static void AddAppConfiguration(
        HostBuilderContext hostingContext,
        IConfigurationBuilder config)
    {
        config.AddJsonFile(
            "appsettings.json",
            optional: true
            reloadOnChange: true);        #A
    }
}
```

#A IConfiguration will be rebuilt if the appsettings.json file changes.

With that in place, any changes you make to the file will be mirrored in the `IConfiguration`. But as I said at the start of this chapter, `IConfiguration` isn't the preferred way to pass settings around in your application. Instead, as you'll see in the next section, you should favor strongly typed POCO objects.

11.4 Using strongly typed settings with the options pattern

In this section you'll learn about strongly typed configuration and the Options pattern. This is the preferred way of accessing configuration in ASP.NET Core. By using strongly typed configuration, you can avoid issues with typos when accessing configuration. It also makes classes easier to test, as you can use simple POCO objects for configuration, instead of relying on the `IConfiguration` abstraction.

Most of the examples I've shown so far have been about how to get values *into* `IConfiguration`, as opposed to how to *use* them. You've seen that you can access a key using the `Configuration["key"]` dictionary syntax, but using `string` keys like this feels messy and prone to typos.

Instead, ASP.NET Core promotes the use of strongly typed settings. These are POCO objects that you define and create and represent a small collection of settings, scoped to a single feature in your app.

The following listing shows both the settings for your store locator component and display settings to customize the homepage of the app. They're separated into two different objects with `"MapSettings"` and `"AppDisplaySettings"` keys corresponding to the different areas of the app they impact.

Listing 11.8 Separating settings into different objects in appsettings.json

```
{
  "MapSettings": {             #A
    "DefaultZoomLevel": 6,     #A
    "DefaultLocation": {       #A
      "latitude": 50.500,      #A
      "longitude": -4.000      #A
    }
  },
  "AppDisplaySettings": {            #B
    "Title":  "Acme Store Locator",  #B
    "ShowCopyright": true            #B
  }
}
```

#A Settings related to the store locator section of the app
#B General settings related to displaying the app

The simplest approach to making the homepage settings available in the Index.cshtml Razor Page would be to inject `IConfiguration` into the `PageModel` and access the values using the dictionary syntax; for example:

```
public class IndexModel : PageModel
{
    public IndexModel(IConfiguration config)
    {
        var title = config["HomePageSettings:Title"];
        var showCopyright = bool.Parse(
            config["HomePageSettings:ShowCopyright"]);
    }
}
```

But you don’t want to do this; too many strings for my liking! And that `bool.Parse`? Yuk! Instead, you can use custom strongly typed objects, with all the type safety and IntelliSense goodness that brings.

Listing 11. 9 Injecting strongly typed options into a `PageModel` using `IOptions<T>`

```
public class IndexModel: PageModel
{
    public IndexModel(IOptions<AppDisplaySettings> options)    #A
    {
        AppDisplaySettings settings = options.Value;              #B
        var title = settings.Title;                               #C
        var showCopyright = settings.ShowCopyright;               #D
    }
}
```

#A You can inject a strongly typed options class using the IOptions<> wrapper interface.
#B The Value property exposes the POCO settings object.
#C The settings object contains properties that are bound to configuration values at runtime.
#D The binder can also convert string values directly to primitive types.

The ASP.NET Core configuration system includes a *binder*, which can take a collection of configuration values and *bind* them to a strongly typed object, called an *options class*. This is similar to the concept of model binding from chapter 6, where request values were bound to your POCO binding model classes.

This section shows how to set up the binding of configuration values to a POCO options class and how to make sure it reloads when the underlying configuration values change. We’ll also have a look at the different sorts of objects you can bind.

11.4.1 Introducing the IOptions interface

ASP.NET Core introduced strongly typed settings as a way of letting configuration code adhere to the single responsibility principle and to allow injecting configuration classes as explicit dependencies. They also make testing easier; instead of having to create an instance of `IConfiguration` to test a service, you can create an instance of the POCO options class.

For example, the AppDisplaySettings class shown in the previous example could be simple, exposing just the values related to the homepage:

```
public class AppDisplaySettings
{
    public string Title { get; set; }
    public bool ShowCopyright { get; set; }
}
```

Your options classes need to be non-abstract and have a public parameterless constructor to be eligible for binding. The binder will set any public properties that match configuration values, as you'll see shortly.

> **TIP** You don't just have to primitive types like string and bool, you can use nested complex types too. The options system will bind sections to complex properties. See the associated source code for examples.

To help facilitate the binding of configuration values to your custom POCO options classes, ASP.NET Core introduces the IOptions<T> interface. This is a simple interface with a single property, Value, which contains your configured POCO options class at runtime. Options classes are set up in the ConfigureServices section of Startup, as shown here.

Listing 11. 10 Configuring the options classes using Configure<T> in Startup.cs

```
public IConfiguration Configuration { get; }
public void ConfigureServices(IServiceCollection services)
{
    services.Configure<MapSettings>(          #A
        Configuration.GetSection("MapSettings"));     #A

    services.Configure<AppDisplaySettings>(                #B
        Configuration.GetSection("AppDisplaySettings"));   #B
}
```

#A Binds the MapSettings section to the POCO options class MapSettings
#B Binds the AppDisplaySettings section to the POCO options class AppDisplaySettings

> **TIP** You don't have to use the same name for both the section and class as I do in listing 11.10, it's just a convention I like to follow. With this convention you can use the nameof() operator to further reduce the chance of typos, by calling GetSection(nameof(MappSettings)) for example.

Each call to Configure<T> sets up the following series of actions internally:

- Creates an instance of ConfigureOptions<T>, which indicates that IOptions<T> should be configured based on configuration.

  If Configure<T> is called multiple times, then multiple ConfigureOptions<T> objects will be used, all of which can be applied to create the final object, in much the same way as the IConfiguration is built from multiple layers.

- Each ConfigureOptions<T> instance binds a section of IConfiguration to an instance of the T POCO class. This sets any public properties on the options class based on the keys in the provided ConfigurationSection.

  Remember that the section name ("MapSettings" in listing 11.10) can have any value; it doesn't have to match the name of your options class.

- Registers the IOptions<T> interface in the DI container as a singleton, with the final bound POCO object in the Value property.

This last step lets you inject your options classes into controllers and services by injecting IOptions<T>, as you've seen. This gives you encapsulated, strongly typed access to your configuration values. No more magic strings, woo-hoo!

> **WARNING** **If you forget to call Configure<T> and inject IOptions<T> into your services, you won't see any errors, but the T options class won't be bound to anything and will only have default values in its properties.**

The binding of the T options class to ConfigurationSection happens when you first request IOptions<T>. The object is registered in the DI container as a singleton, so it's only bound once.

There's one catch with this setup: you can't use the reloadOnChange parameter I described in section 11.3.4 to reload your strongly typed options classes when using IOptions<T>. IConfiguration will still be reloaded if you edit your appsettings.json files, but it won't propagate to your options class.

If that seems like a step backwards, or even a deal-breaker, then don't worry. IOptions<T> has a cousin, IOptionsSnapshot<T>, for such an occasion.

11.4.2 Reloading strongly typed options with IOptionsSnapshot

In the previous section, you used IOptions<T> to provide strongly typed access to configuration. This provided a nice encapsulation of the settings for a particular service, but with a specific drawback: the options class never changes, even if you modify the underlying configuration file from which it was loaded, for example appsettings.json.

This is often not a problem (you shouldn't really be modifying files on live production servers anyway!), but if you need this functionality, you can use the IOptionsSnapshot<T> interface.

Conceptually, IOptionsSnaphot<T> is identical to IOptions<T> in that it's a strongly typed representation of a section of configuration. The difference is when, and how often, the POCO options objects are created when each of these are used.

- IOptions<T>—The instance is created once, when first needed. It always contains the configuration when the object instance was first created.
- IOptionsSnapshot<T>—A new instance is created when needed, if the underlying configuration has changed since the last instance was created.

IOptionsSnaphot<T> is automatically set up for your options classes at the same time as IOptions<T>, so you can use it in your services in exactly the same way! This listing shows how you could update your IndexModel home page so that you always get the latest configuration values in your strongly typed AppDisplaySettings options class.

Listing 11.11 Injecting reloadable options using IOptionsSnapshot<T>

```
public class IndexModel: PageModel
{
    public IndexModel(
        IOptionsSnapshot<AppDisplaySettings> options)    #A
    {                                                  #B
        AppDisplaySettings settings = options.Value;    #C
        var title = settings.Title;
    }
}
```

#A IOptionsSnapshot<T> will update if the underlying configuration values change.
#B The Value property exposes the POCO settings object, the same as for IOptions<T>.
#C The settings object will match the configuration values at some point, instead of at first run.

Whenever you edit the settings file and cause IConfiguration to be reloaded, IOptionsSnapshot<AppDisplaySettings> will be rebuilt. A new AppDisplaySettings object is created with the new configuration values and will be used for all future dependency injection. Until you edit the file again, of course! It's as simple as that; update your code to use IOptionsSnapshot<T> instead of IOptions<T> wherever you need it.

The final thing I want to touch on in this section is the design of your POCO options classes themselves. These are typically simple collections of properties, but there are a few things to bear in mind so that you don't get stuck debugging why the binding seemingly hasn't worked!

11.4.3 Designing your options classes for automatic binding

I've touched on some of the requirements for your POCO classes for the IOptions<T> binder to be able to populate them, but there are a few rules to bear in mind.

The first key point is that the binder will be creating instances of your options classes using reflection, so your POCO options classes need to:

- Be non-abstract
- Have a default (public parameterless) constructor

If your classes satisfy these two points, the binder will loop through all the properties on your class and bind any it can. In the broadest sense, the binder can bind any property which

- Is public
- Has a getter—the binder won't write set-only properties
- Has a setter or, for complex types, a non-null value
- Is not an indexer

This listing shows an extensive options class, with a whole host of different types of properties, some of which are valid to bind, and some of which aren't.

Listing 11.12 An options class containing binding and nonbinding properties

```
public class TestOptions
{
    public string String { get; set; }                        #A
    public int Integer { get; set; }                          #A
    public SubClass Object { get; set; }                      #A
    public SubClass ReadOnly { get; } = new SubClass();       #A
    public Dictionary<string, SubClass> Dictionary { get; set; }       #B
    public List<SubClass> List { get; set; }                           #B
    public IDictionary<string, SubClass> IDictionary { get; set; }     #B
    public IEnumerable<SubClass> IEnumerable { get; set; }             #B
    public ICollection<SubClass> IEnumerable { get; }                  #B
        = new List<SubClass>();                                        #B

    internal string NotPublic { get; set; }                             #C
    public SubClass SetOnly { set => _setOnly = value; }                #C
    public SubClass NullReadOnly { get; } = null;                       #C
    public SubClass NullPrivateSetter { get; private set; } = null;     #C
    public SubClass this[int i] {                                       #C
        get => _indexerList[i];                                         #C
        set => _indexerList[i] = value;                                 #C
    }
    public List<SubClass> NullList { get; }                             #D
    public Dictionary<int, SubClass> IntegerKeys { get; set; }          #D
    public IEnumerable<SubClass> ReadOnlyEnumerable { get; }            #D
        = new List<SubClass>();                                         #D
    public SubClass _setOnly = null;                    #E
    private readonly List<SubClass> _indexerList        #E
        = new List<SubClass>();                         #E
    public class SubClass
    {
        public string Value { get; set; }
    }
}
```

#A The binder can bind simple and complex object types, and read-only properties with a default.
#B The binder will also bind collections, including interfaces; dictionaries must have string keys.
#C The binder can't bind nonpublic, set-only, null-read-only, or indexer properties.
#D These collection properties can't be bound.
#E The backing fields for SetOnly and Indexer properties

As shown in the listing, the binder generally supports collections—both implementations and interfaces. If the collection property is already initialized, it will use that, but the binder can also create backing fields for them. If your property implements any of the following classes, the binder will create a `List<>` of the appropriate type as the backing object:

- `IReadOnlyList<>`
- `IReadOnlyCollection<>`
- `ICollection<>`

- `IEnumerable<>`

> **WARNING** **You can't bind to an** `IEnumerable<>` **property that has already been initialized, as the underlying type doesn't expose an** `Add` **function! You *can* bind to an** `IEnumerable<>` **if you leave its initial value as** `null`**.**

Similarly, the binder will create a `Dictionary<,>` as the backing field for properties with dictionary interfaces, as long as they use `string` keys:

- `IDictionary<string,>`
- `IReadOnlyDictionary<string,>`

> **WARNING** **You can't bind dictionaries with non-string values, such as** `int`**. For examples of binding collection types, see the associated source code for this book.**

Clearly there are quite a few nuances here, but if you stick to the simple cases from the preceding example, you'll be fine. Be sure to check for typos in your JSON files!

> **TIP** **The options pattern is most commonly used to bind POCO classes to configuration, but you can also configure your strongly typed settings classes in code, by providing a lambda to the** `Configure` **function, for example** `services.Configure<TestOptions>(opt => opt.Value=true)`.

That brings us to the end of this section on strongly typed settings. In the next section, we'll look at how you can dynamically change your settings at runtime, based on the environment in which your app is running.

11.5 Configuring an application for multiple environments

In this section you'll learn about hosting environments in ASP.NET Core. You'll learn how to set and determine which environment an application is running in, and how to change which configuration values are used based on the environment. This lets you easily switch between different sets of configuration values in production compared to development, for example.

Any application that makes it to production will likely have to run in multiple environments. For example, if you're building an application with database access, you'll probably have a small database running on your machine that you use for development. In production, you'll have a completely different database running on a server somewhere else.

Another common requirement is to have different amounts of logging depending on where your app is running. In development, it's great to generate lots of logs as it helps debugging, but once you get to production, too much logging can be overwhelming. You'll want to log warnings and errors, maybe information-level logs, but definitely not debug-level logs!

To handle these requirements, you need to make sure your app loads different configuration values depending on the environment it's running in; load the production database connection string when in production and so on. You need to consider three aspects:

- How does your app identify which environment it's running in?
- How do you load different configuration values based on the current environment?
- How can you change the environment for a particular machine?

This section tackles each of these questions in turn, so you can easily tell your development machine apart from your production servers and act accordingly.

11.5.1 Identifying the hosting environment

As you saw in section 11.2, the `ConfigureHostingConfiguration` method on `HostBuilder` is where you define how your application calculates the hosting environment. By default, `CreateDefaultBuilder` uses, perhaps unsurprisingly, an environment variable to identify the current environment! The `HostBuilder` looks for a magic environment variable called `ASPNETCORE_ENVIRONMENT` and uses it to create an `IHostEnvironment` object.

> **NOTE You can use either the `DOTNET_ENVIRONMENT` or `ASPNETCORE_ENVIRONMENT` environment variables. The `ASPNETCORE_` value overrides the `DOTNET_` value if both are set. I use the `ASPNETCORE_` version throughout this book.**

The `IHostEnvironment` interface exposes a number of useful properties about the running context of your app. Some of these you've already seen, such as `ContentRootPath`, which points to the folder containing your application's content files; for example, the appsettings.json files. The property you're interested in here is `EnvironmentName`.

The `IHostEnvironment.EnvironmentName` property is set to the value of the `ASPNETCORE_ENVIRONMENT` environment variable, so it can be anything, but you should stick to three commonly used values in most cases:

- `"Development"`
- `"Staging"`
- `"Production"`

ASP.NET Core includes several helper methods for working with these three values, so you'll have an easier time if you stick to them. In particular, whenever you're testing whether your app is running in a particular environment, you should use one of the following extension methods:

- `IHostEnvironment.IsDevelopment()`
- `IHostEnvironment.IsStaging()`
- `IHostEnvironment.IsProduction()`
- `IHostEnvironment.IsEnvironment(string environmentName)`

These methods all make sure they do case-insensitive checks of the environment variable, so you don't get any wonky errors at runtime if you don't capitalize the environment variable value.

TIP Where possible, use the IHostEnvironment extension methods over direct string comparison with EnvironmentValue, as they provide case-insensitive matching.

IHostEnvironment doesn't do anything other than expose the details of your current environment, but you can use it in a number of different ways. In chapter 8, you saw the Environment Tag Helper, which you used to show and hide HTML based on the current environment. Now you know where it was getting its information—IHostEnvironment.

You can use a similar approach to customize which configuration values you load at runtime by loading different files when running in development versus production. This is common and is included out of the box in most ASP.NET Core templates, as well as in the CreateDefaultBuilder helper method.

11.5.2 Loading environment-specific configuration files

The EnvironmentName value is determined early in the process of bootstrapping your application, before the ConfigurationBuilder passed to ConfigureAppConfiguration is created. This means you can dynamically change which configuration providers are added to the builder, and hence which configuration values are loaded when the IConfiguration is built.

A common pattern is to have an optional, environment-specific appsettings.ENVIRONMENT.json file that's loaded after the default appsettings.json file. This listing shows how you could achieve this if you're customizing the ConfigureAppConfiguration method in Program.cs.

Listing 11.13 Adding environment-specific appsettings.json files

```
public class Program
{
    public static void AddAppConfiguration(
        HostBuilderContext hostingContext,
        IConfigurationBuilder config)
    {
        var env = hostingContext.HostingEnvironment;     #A
        config

            .AddJsonFile(
                "appsettings.json",
                optional: false)                         #B
            .AddJsonFile                                     #C
                $"appsettings.{env.EnvironmentName}.json",   #C
                optional: true);                          #C
    }
}
```

#A The current IHostEnvironment is available on HostBuilderContext.
#B It's common to make the base appsettings.json compulsory.
#C Adds an optional environment-specific JSON file where the filename varies with the environment

With this pattern, a global appsettings.json file contains settings applicable to most environments. Additional, optional, JSON files called appsettings.Development.json, appsettings.Staging.json, and appsettings.Production.json are subsequently added to ConfigurationBuilder, depending on the current EnvironmentName.

Any settings in these files will overwrite values from the global appsettings.json, if they have the same key, as you've seen previously. This lets you do things like set the logging to be verbose in the development environment only and switch to more selective logs in production.

Another common pattern is to completely add or remove configuration providers depending on the environment. For example, you might use the User Secrets provider when developing locally, but Azure Key Vault in production. This listing shows how you can use IHostEnvironment to conditionally include the User Secrets provider in development only.

Listing 11.14 Conditionally including the User Secrets configuration provider

```
public class Program
{
    /* Additional Program configuration*/
    public static void AddAppConfiguration(
        HostBuilderContext hostingContext,
        IConfigurationBuilder config)
    {
        var env = hostingContext.HostingEnvironment
        config
            .AddJsonFile(
                "appsettings.json",
                optional: false)
            .AddJsonFile(
                $"appsettings.{env.EnvironmentName}.json",
                optional: true);
         if(env.IsDevelopment())                   #A
         {
             builder.AddUserSecrets<Startup>();    #B
        }
    }
}
```

#A Extension methods make checking the environment simple and explicit.
#B In Staging and Production, the User Secrets provider wouldn't be used.

Another common place to customize your application based on the environment is when setting up your middleware pipeline. In chapter 3, you learned about DeveloperExceptionPageMiddleware and how you should use it when developing locally. The following listing shows how you can use IHostEnvironment to control your pipeline in this way, so that when you're in Staging or Production, your app uses ExceptionHandlerMiddleware instead.

Listing 11.15 Using the hosting environment to customize your middleware pipeline

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    if (env.IsDevelopment())                  #A
    {                                         #A
        app.UseDeveloperExceptionPage();      #A
    }                                         #A
    else                                          #B
    {                                             #B
        app.UseExceptionHandler("/Error");        #B
    }                                             #B

    app.UseHttpsRedirection();
    app.UseStaticFiles();

    app.UseRouting();
    app.UseAuthorization();
    app.UseEndpoints(endpoints =>
    {
        endpoints.MapRazorPages();
    });

}
```

#A In Development, DeveloperExceptionPageMiddleware is added to the pipeline.
#B In Staging or Production, the pipeline uses ExceptionHandlerMiddleware instead.

> **NOTE** **In listing 11.15 we injected** `IWebHostEnvironment` **instead of** `IHostEnvironment`**. This interface extends** `IHostEnvironment` **by adding the** `WebRootPath` **property—the path to the wwwroot folder in your application. You'll learn more about the difference between these interfaces in chapter 20.**

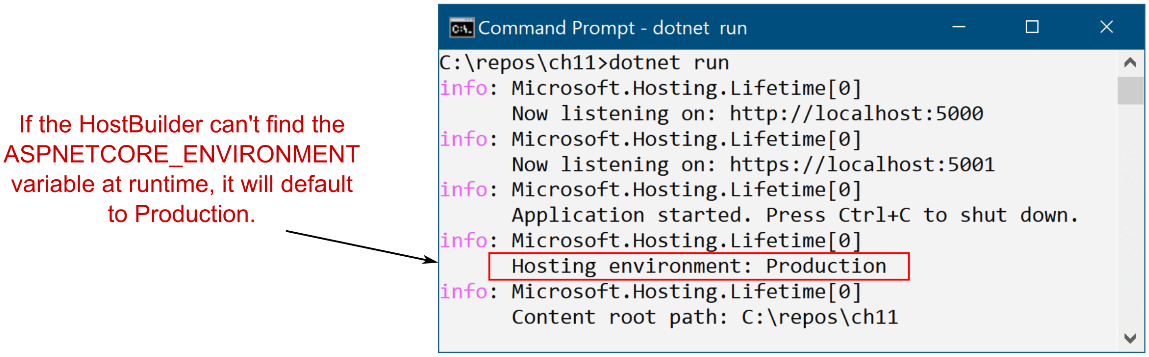
You can inject `IHostEnvironment` anywhere in your app, but I'd advise against using it in your own services, outside of `Startup` and `Program`. It's far better to use the configuration providers to customize strongly typed settings based on the current hosting environment, and inject these settings into your application instead.

As useful as it is, setting `IHostEnvironment` with an environment variable can be a little cumbersome if you want to switch back and forth between different environments during testing. Personally, I'm always forgetting how to set environment variables on the various operating systems I use. The final skill I'd like to teach you is how to set the hosting environment when you're developing locally.

11.5.3 Setting the hosting environment

In this section, I'll show you a couple of ways to set the hosting environment when you're developing. These makes it easy to test a specific app's behavior in different environments, without having to change the environment for all the apps on your machine.

If your ASP.NET Core application can't find an `ASPNETCORE_ENVIRONMENT` environment variable when it starts up, it defaults to a production environment, as shown in figure 11.6. This means that when you deploy to production, you'll be using the correct environment by default.



```
C:\repos\ch11>dotnet run
info: Microsoft.Hosting.Lifetime[0]
      Now listening on: http://localhost:5000
info: Microsoft.Hosting.Lifetime[0]
      Now listening on: https://localhost:5001
info: Microsoft.Hosting.Lifetime[0]
      Application started. Press Ctrl+C to shut down.
info: Microsoft.Hosting.Lifetime[0]
      Hosting environment: Production
info: Microsoft.Hosting.Lifetime[0]
      Content root path: C:\repos\ch11
```

If the HostBuilder can't find the ASPNETCORE_ENVIRONMENT variable at runtime, it will default to Production.

Figure 11.6 By default, ASP.NET Core applications run in the Production hosting environment. You can override this by setting the `ASPNETCORE_ENVIRONMENT` variable.

> **TIP** By default, the current hosting environment is logged to the console at startup, which can be useful for quickly checking that the environment variable has been picked up correctly.

Another option is to use a launchSettings.json file to control the environment. All the default ASP.NET Core applications include this file in the Properties folder. LaunchSettings.json defines "profiles" for running your application.

> **TIP** Profiles can be used to run your application with different environment variables. You can also use profiles to emulate running on Windows behind IIS by using the IIS Express profile. Personally, I rarely use this profile, even on Windows, and always choose the "project" profile.

A typical launchSettings.json file is shown in the following listing, which defines two profiles: "IIS Express", and "StoreViewerApplication". The latter profile is equivalent to using `dotnet run` to run the project, and is conventionally named the same as the project containing the launchSettings.json file.

Listing 11.16 A typical launchSettings.json file defining two profiles

```
{
  "iisSettings": {                                         #A
    "windowsAuthentication": false,                        #A
    "anonymousAuthentication": true,                       #A
    "iisExpress": {                                        #A
      "applicationUrl": "http://localhost:53846",          #A
      "sslPort": 44399                                     #A
    }
  },
  "profiles": {
    "IIS Express": {                                       #B
      "commandName": "IISExpress",                         #B
      "launchBrowser": true,                               #C
      "environmentVariables": {                            #D
```

```
        "ASPNETCORE_ENVIRONMENT": "Development"          #D
      }                                                   #D
    },
    "StoreViewerApplication": {                           #E
      "commandName": "Project",                           #E
      "launchBrowser": true,                         #C
      "environmentVariables": {                      #F
        "ASPNETCORE_ENVIRONMENT": "Development"      #F
      },                                             #F
      "applicationUrl":
          "https://localhost:5001;http://localhost:5000"     #G
    }
  }
}
```

#A Defines settings for when running behind IIS or using the IIS Express profile
#B The IIS Express profile is used by default in Visual Studio on Windows
#C If true, launches the browser when you run the application
#D Defines custom environment variables for the profile. Sets the environment to Development
#E The “project” profile, equivalent to calling dotnet run on the project
#F Each profile can have different environment variables
#G Defines the URLs the application will listen on in this profile

The advantage of using the launchSettings.json file locally is it allows you to set “local” environment variables for a project. For example, in listing 11.16, the environment is set to the Development environment. This lets you use different environment variables for each project, and even for each profile, and store them in source control.

You can choose a profile to use in Visual Studio by selecting from the dropdown list next to the Debug button on the toolbar, as shown in figure 11.7. You can choose a profile to run from the command line using `dotnet run --launch-profile <Profile Name>`. If you don’t specify a profile, the first “Project” type profile is used. If you don’t want to use *any* profile, you must explicitly ignore the launchSettings.json file, by using `dotnet run --no-launch-profile`.

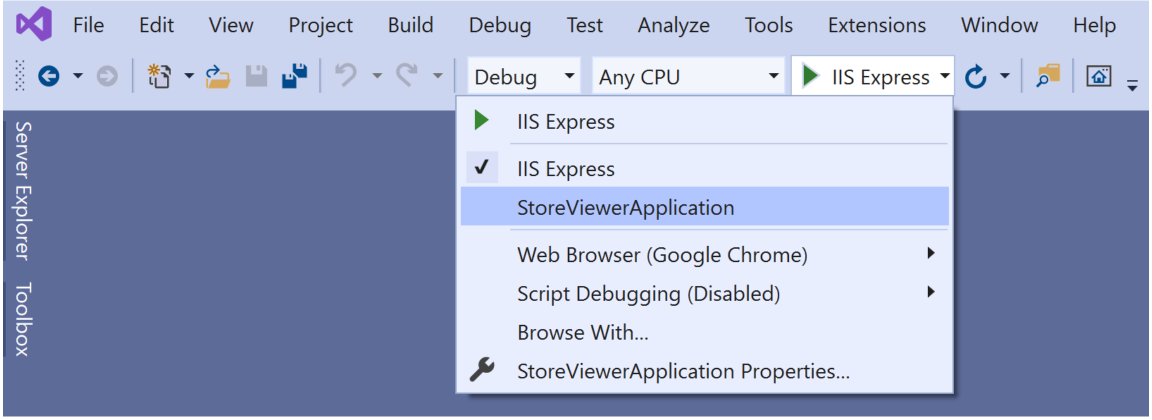
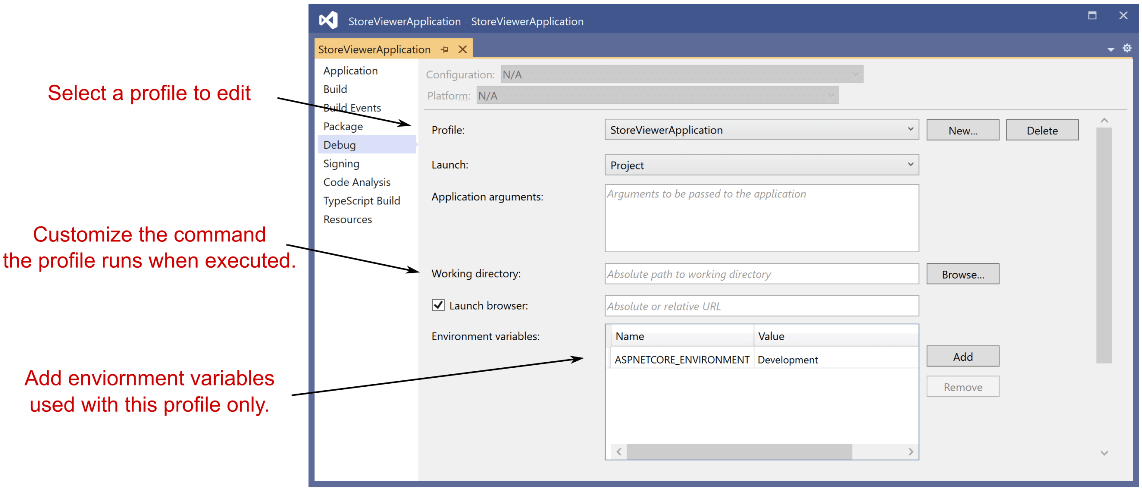


Figure 11.7 You can choose the profile to use from Visual Studio by selecting from the Debug dropdown. Visual Studio defaults to using the IIS Express profile. The default profile running with `dotnet run` is the first "project" profile—StoreViewerApplication in this case.

If you're using Visual Studio, you can also edit the launchSettings.json file visually: double-click the Properties node and choose the Debug tab. You can see in figure 11.8 that the `ASPNETCORE_ENVIRONMENT` is set to Development: any changes made in this tab are mirrored in launchSettings.json.



Configuration: N/A
Platform: N/A
Profile: StoreViewerApplication
Launch: Project
Application arguments: Arguments to be passed to the application
Working directory: Absolute path to working directory
☑ Launch browser: Absolute or relative URL
Environment variables:

Name	Value
ASPNETCORE_ENVIRONMENT	Development

Select a profile to edit

Customize the command the profile runs when executed.

Add enviornment variables used with this profile only.

Figure 11.8 You can use Visual Studio to edit the launchSettings.json file if you prefer. Changes will be mirrored between the launchSettings.json file and the Properties dialog.

The launchSettings.json file is intended for local development only; by default the file isn't deployed to production servers. While you *can* deploy and use the file in production, it's generally not worth the hassle. Environment variables are a better fit.

One final trick I've used to set the environment in production is to use command line arguments. For example, you could set the environment to Staging using the following

```
dotnet run --no-launch-profile --environment Staging
```

Note that you also have to pass `--no-launch-profile` if there's a launchSettings.json file, otherwise the values in the file take precedence.

That brings us to the end of this chapter on configuration. Configuration isn't glamorous, but it's an essential part of all apps. The ASP.NET Core configuration provider model handles a wide range of scenarios, letting you store settings and secrets in a variety of locations.

Simple settings can be stored in appsettings.json, where they're easy to tweak and modify during development, and can be overwritten by using environment-specific JSON files. Meanwhile, your secrets and sensitive settings can be stored outside the project file, in the User Secrets manager, or as environment variables. This gives you both flexibility and safety—as long as you don't go writing your secrets to appsettings.json!

In the next chapter, we'll take a brief look at the new object relational mapper that fits well with ASP.NET Core: Entity Framework Core. We'll only be getting a taste of it in this book, but you'll learn how to load and save data, build a database from your code, and migrate the database as your code evolves.

11.6 Summary

- Anything that could be considered a setting or a secret is normally stored as a configuration value.
- ASP.NET Core uses configuration providers to load key-value pairs from a variety of sources. Applications can use many different configuration providers.
- `ConfigurationBuilder` describes how to construct the final configuration representation for your app and `IConfiguration` holds the configuration values themselves.
- You create a configuration object by adding configuration providers to an instance of `ConfigurationBuilder` using extension methods such as `AddJsonFile()`. `HostBuilder` creates the `ConfigurationBuilder` instance for you and calls `Build()` to create an instance of `IConfiguration`.
- ASP.NET Core includes built-in providers for JSON files, XML files, environment files, and command-line arguments, among others. NuGet packages exist for many other providers, such as YAML files and Azure KeyVault.
- The order in which you add providers to `ConfigurationBuilder` is important; subsequent providers replace the values of settings defined in earlier providers.
- Configuration keys aren't case-sensitive.

- You can retrieve settings from `IConfiguration` directly using the indexer syntax, for example `Configuration["MySettings:Value"]`.
- The `CreateDefaultBuilder` method configures JSON, environment variables, command-line arguments, and User Secret providers for you. You can customize the configuration providers used in your app by calling `ConfigureAppConfiguration`.
- In production, store secrets in environment variables. These can be loaded after your file-based settings in the configuration builder.
- On development machines, the User Secrets Manager is a more convenient tool than using environment variables. It stores secrets in your OS user's profile, outside the project folder.
- Be aware that neither environment variables nor the User Secrets Manager tool encrypt secrets, they merely store them in locations that are less likely to be made public, as they're outside your project folder.
- File-based providers, such as the JSON provider, can automatically reload configuration values when the file changes. This allows you to update configuration values in real time, without having to restart your app.
- Use strongly typed POCO options classes to access configuration in your app.
- Use the `Configure<T>()` extension method in `ConfigureServices` to bind your POCO options objects to `ConfigurationSection`.
- You can inject the `IOptions<T>` interface into your services using DI. You can access the strongly typed options object on the `Value` property.
- You can configure `IOptions<T>` objects in code instead of using configuration values by passing a lambda to the `Configure()` method.
- If you want to reload your POCO options objects when your configuration changes, use the `IOptionsSnapshot<T>` interface instead.
- Applications running in different environments, Development versus Production for example, often require different configuration values.
- ASP.NET Core determines the current hosting environment using the `ASPNETCORE_ENVIRONMENT` environment variable. If this variable isn't set, the environment is assumed to be Production.
- You can set the hosting environment locally by using the launchSettings.json. This allows you to scope environment variables to a specific project.
- The current hosting environment is exposed as an `IHostEnvironment` interface. You can check for specific environments using `IsDevelopment()`, `IsStaging()`, and `IsProduction()`.
- You can use the `IHostEnvironment` object to load files specific to the current environment, such as appsettings.Production.json.

12
Saving data with Entity Framework Core

This chapter includes

- **What Entity Framework Core is and why you should use it**
- **Adding Entity Framework Core to an ASP.NET Core application**
- **Building a data model and using it to create a database**
- **Querying, creating, and updating data using Entity Framework Core**

Most applications that you'll build with ASP.NET Core will require storing and loading some kind of data. Even the examples so far in this book have assumed you have some sort of data store—storing exchange rates, user shopping carts, or the locations of physical main street stores. I've glossed over this for the most part but, typically, you'll store this data in a database.

Working with databases can often be a rather cumbersome process. You have to manage connections to the database, translate data from your application to a format the database can understand, as well as handle a plethora of other subtle issues.

You can manage this complexity in a variety of ways, but I'm going to focus on using a library built primarily for .NET Core: Entity Framework Core (EF Core). EF Core is a library that lets you quickly and easily build database access code for your ASP.NET Core applications. It's modeled on the popular Entity Framework 6.x library, but has significant changes that mean it stands alone in its own right and is more than an upgrade.

The aim of this chapter is to provide a quick overview of EF Core and how you can use it in your applications to quickly query and save to a database. You'll have enough knowledge to connect your app to a database, and to manage schema changes to the database, but I won't be going into great depth on any topics.

NOTE For an in-depth look at EF Core I recommend, *Entity Framework Core in Action, Second Edition* by Jon P Smith (Manning, 2021). Alternatively, you can read about EF Core and its cousin, Entity Framework, on the Microsoft documentation website at https://docs.microsoft.com/ef/core/.

Section 12.1 introduces EF Core and explains why you might want to use it in your applications. You'll learn how the design of EF Core helps you to quickly iterate on your database structure and reduce the friction of interacting with a database.

In section 12.2, you'll learn how to add EF Core to an ASP.NET Core app and configure it using the ASP.NET Core configuration system. You'll see how to build a model for your app that represents the data you'll store in the database and how to hook it into the ASP.NET Core DI container.

NOTE For this chapter, and the rest of the book, I'm going to be using SQL Server Express' LocalDB feature. This is installed as part of Visual Studio 2019 (when you choose the ASP.NET and Web Development workload) and provides a lightweight SQL Server engine.[53] Very little of the code is specific to SQL Server, so you should be able to follow along with a different database if you prefer. The code sample for the book includes a version using SQLite, for example.

No matter how carefully you design your original data model, the time will come when you need to change it. In section 12.3, I show how you can easily update your model and apply these changes to the database itself, using EF Core for all the heavy lifting.

Once you have EF Core configured and a database created, section 12.4 shows how to use EF Core in your application code. You'll see how to create, read, update, and delete (CRUD) records, as well as some of the patterns to use when designing your data access.

In section 12.5, I highlight a few of the issues you'll want to take into consideration when using EF Core in a production app. A single chapter on EF Core can only offer a brief introduction to all of the related concepts though, so if you choose to use EF Core in your own applications—especially if this is your first time using such a data access library—I strongly recommend reading more once you have the basics from this chapter.

Before we get into any code, let's look at what EF Core is, what problems it solves, and when you might want to use it.

12.1 Introducing Entity Framework Core

Database access code is ubiquitous across web applications. Whether you're building an e-commerce app, a blog, or the Next Big Thing™, chances are you'll need to interact with a database.

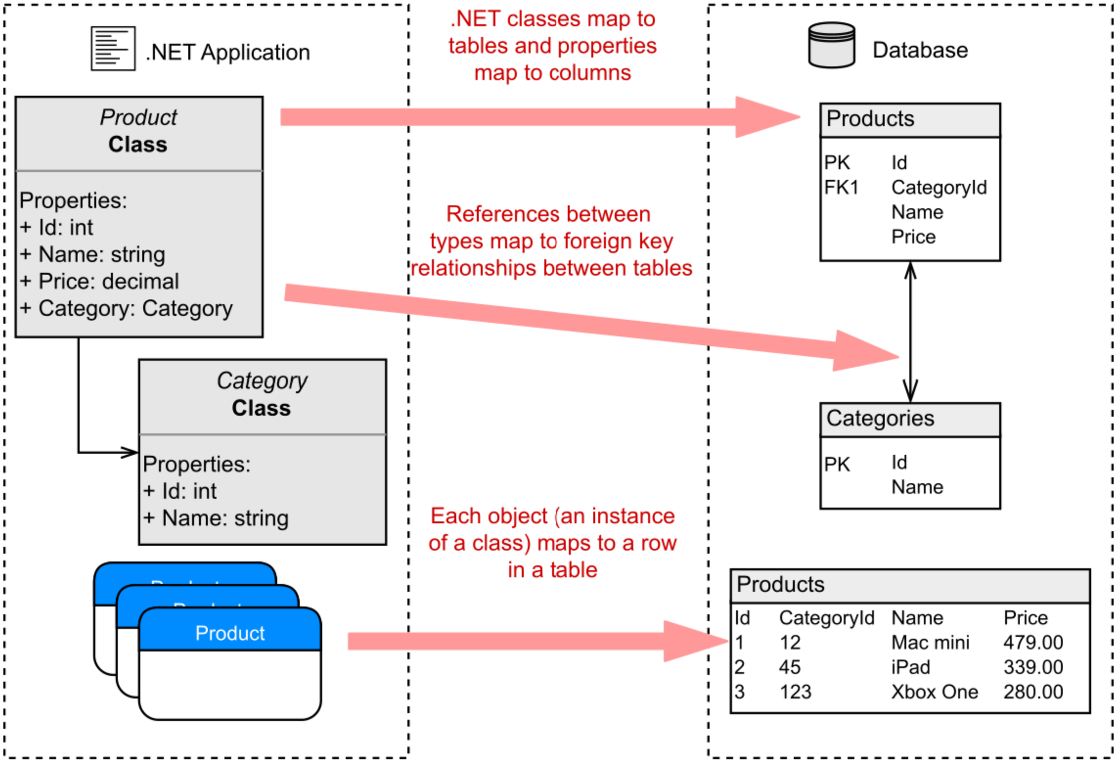
[53] You can read more about LocalDB at https://docs.microsoft.com/en-us/sql/database-engine/configure-windows/sql-server-express-localdb.

Unfortunately, interacting with databases from app code is often a messy affair and there are many different approaches you can take. For example, something as simple as reading data from a database requires handling network connections, writing SQL statements, and handling variable result data. The .NET ecosystem has a whole array of libraries you can use for this, ranging from the low-level ADO.NET libraries, to higher-level abstractions like EF Core.

In this section, I describe what EF Core is and the problem it's designed to solve. I cover the motivation behind using an abstraction such as EF Core, and how it helps to bridge the gap between your app code and your database. As part of that, I present some of the trade-offs you'll make by using it in your apps, which should help you decide if it's right for your purposes. Finally, we'll take a look at an example EF Core mapping, from app code to database, to get a feel for EF Core's main concepts.

12.1.1 What is EF Core?

EF Core is a library that provides an object-oriented way to access databases. It acts as an *object-relational mapper* (ORM), communicating with the database for you and mapping database responses to .NET classes and objects, as shown in figure 12.1.



Products

Id	CategoryId	Name	Price
1	12	Mac mini	479.00
2	45	iPad	339.00
3	123	Xbox One	280.00

Figure 12.1 EF Core maps .NET classes and objects to database concepts such as tables and rows.

DEFINITION With an *object-relational mapper* (ORM), you can manipulate a database using object-oriented concepts such as classes and objects by mapping them to database concepts such as tables and columns.

EF Core is based on, but is distinct from, the existing Entity Framework libraries (currently, up to version 6.x). It was built as part of the .NET Core push to work cross-platform, but with additional goals in mind. In particular, the EF Core team wanted to make a highly performant library that could be used with a wide range of databases.

There are many different types of databases, but probably the most commonly used family is *relational* databases, accessed using Structured Query Language (SQL). This is the bread and butter of EF Core; it can map Microsoft SQL Server, MySQL, Postgres, and many other relational databases. It even has a cool in-memory feature you can use when testing to create a temporary database. EF Core uses a provider model, so that support for other relational databases can be plugged in later, as they become available.

NOTE As of .NET Core 3.0, EF Core now also works with nonrelational, *NoSQL*, or *document* databases like Cosmos DB too. I'm only going to consider mapping to relational databases in this book however, as that's the most common requirement in my experience. Historically, most data access, especially in the .NET ecosystem, has been using relational databases, so it generally remains the most popular approach.

That covers what EF Core is, but it doesn't dig into why you'd want to use it. Why not access the database directly using the traditional ADO.NET libraries? Most of the arguments for using EF Core can be applied to ORMs in general, so what are the advantages of an ORM?

12.1.2 Why use an object-relational mapper?

One of the biggest advantages an ORM brings is the speed with which you can develop an application. You can stay in the familiar territory of object-oriented .NET, in many cases without ever needing to directly manipulate a database or write custom SQL.

Imagine you have an e-commerce site and you want to load the details of a product from the database. Using low-level database access code, you'd have to open a connection to the database, write the necessary SQL using the correct table and column names, read the data over the connection, create a POCO to hold the data, and manually set the properties on the object, converting the data to the correct format as you go. Sounds painful, right?

An ORM, such as EF Core, takes care of most of this for you. It handles the connection to the database, generating the SQL, and mapping data back to your POCO objects. All you need to provide is a LINQ query describing the data you want to retrieve.

ORMs serve as high-level abstractions over databases, so they can significantly reduce the amount of plumbing code you need to write to interact with a database. At the most basic level, they take care of mapping SQL statements to objects and vice versa, but most ORMs take this a step further and provide additional features.

ORMs like EF Core keep track of which properties have changed on any objects they rehydrate from the database. This lets you load an object from the database by mapping it from a database table, modify it in .NET code, and then ask the ORM to update the associated record in the database. The ORM will work out which properties have changed and issue update statements for the appropriate columns, saving you a bunch of work.

As is so often the case in software development, using an ORM has its drawbacks. One of the biggest advantages of ORMs is also their Achilles heel—they hide you from the database. Sometimes, this high level of abstraction can lead to problematic database query patterns in your apps. A classic example is the *N+1* problem, where what should be a single database request turns into separate requests for every single row in a database table.

Another commonly cited drawback is performance. ORMs are abstractions over a number of concepts, and so inherently do more work than if you were to hand craft every piece of data access in your app. Most ORMs, EF Core included, trade off some degree of performance for ease of development.

That said, if you're aware of the pitfalls of ORMs, you can often drastically simplify the code required to interact with a database. As with anything, if the abstraction works for you, use it, otherwise, don’t. If you only have minimal database access requirements, or you need the best performance you can get, then an ORM such as EF Core may not be the right fit.

An alternative is to get the best of both worlds: use an ORM for the quick development of the bulk of your application, and then fall back to lower level APIs such as ADO.NET for those few areas that prove to be the bottlenecks in your application. That way, you can get good-enough performance with EF Core, trading off performance for development time, and only optimize those areas that need it.

Even if you do decide to use an ORM in your app, there are many different ORMs available for .NET, of which EF Core is one. Whether EF Core is right for you will depend on the features you need and the trade-offs you’re willing to make to get them. The next section compares EF Core to Microsoft’s other offering, Entity Framework, but there many other alternatives you could consider, such as Dapper and NHibernate, each with their own set of trade-offs.

12.1.3 When should you choose EF Core?

Microsoft designed EF Core as a reimagining of the mature Entity Framework 6.x (EF 6.x) ORM, which it released in 2008. With ten years of development behind it, EF 6.x is a stable and feature-rich ORM.

In contrast, EF Core, is a comparatively new project. The APIs of EF Core are designed to be close to that of EF 6.x—though they aren’t identical—but the core components have been completely rewritten. You should consider EF Core as distinct from EF 6.x; upgrading directly from EF 6.x to EF Core is nontrivial.

Microsoft supports both EF Core and EF 6.x, and both will see ongoing improvements, so which should you choose? You need to consider a number of things:

- *Cross platform*—EF Core targets .NET Standard, so it can be used in cross-platform apps that target .NET Core. Since version 6.3, EF 6.x is *also* cross platform, with some limitations when running on .NET Core, such as no designer support.
- *Database providers*—Both EF 6.x and EF Core let you connect to various database types by using pluggable providers. EF Core has a growing number of providers, but there aren’t as many for EF 6.x, especially if you want to run EF 6.x on .NET Core. If there isn’t a provider for the database you’re using, that’s a bit of a deal breaker!
- *Performance*—The performance of EF 6.x has been a bit of a black mark on its record, so EF Core aims to rectify that. EF Core is designed to be fast and lightweight, significantly outperforming EF 6.x. But it’s unlikely to ever reach the performance of a more lightweight ORM, such as Dapper, or handcrafted SQL statements.
- *Features*—Features are where you’ll find the biggest disparity between EF 6.x and EF Core. EF Core has some features that EF 6.x doesn’t have (batching statements, client-side key generation, in-memory database for testing), but EF 6.x is much more feature-rich than EF Core.

  At the time of writing, EF Core has excellent feature parity, with missing features including stored procedure mapping, and many-to-many relationships without a join entity. On top of that, EF Core is under active development, so new features will no doubt appear soon.[54] In contrast, EF 6.x will likely only see incremental improvements and bug fixes, rather than major feature additions.

Whether these trade-offs and limitations are a problem for you will depend a lot on your specific app. It's a lot easier to start a new application bearing these limitations in mind than trying to work around them later.

> **TIP** EF Core isn't recommended for everyone, but it's recommended over EF 6.x for new applications. Be sure you understand the trade-offs involved, and keep an eye on the guidance from the EF team here: https://docs.microsoft.com/en-us/ef/efcore-and-ef6/choosing.

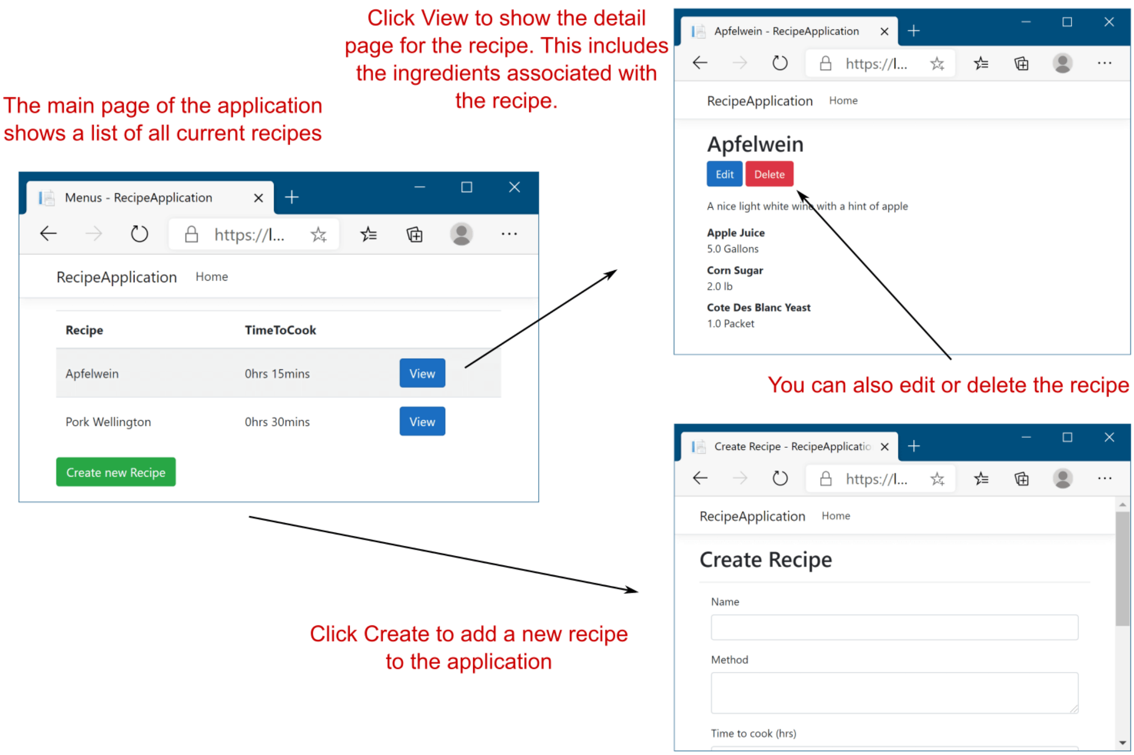
If you're working on a new ASP.NET Core application, you want to use an ORM for rapid development, and you don't require any of the unavailable features, then EF Core is a great contender. It's also supported out of the box by various other subsystems of ASP.NET Core. For instance, in chapter 14 you'll see how to use EF Core with the ASP.NET Core Identity authentication system for managing users in your apps.

Before we get into the nitty-gritty of using EF Core in your app, I'll describe the application we're going to be using as the case study for this chapter. We'll go over the application and database details and how to use EF Core to communicate between the two.

12.1.4 Mapping a database to your application code

EF Core focuses on the communication between an application and a database, so to show it off, we need an application! This chapter uses the example of a simple cooking app that lists recipes, and lets you view a recipe's ingredients, as shown in figure 12.2. Users can browse for recipes, add new ones, edit recipes, and delete old ones.

[54] For a detailed list of feature differences between EF 6.x and EF Core, see the documentation at https://docs.microsoft.com/en-us/ef/efcore-and-ef6/features.



The main page of the application shows a list of all current recipes

Click View to show the detail page for the recipe. This includes the ingredients associated with the recipe.

You can also edit or delete the recipe

Click Create to add a new recipe to the application

Recipe	TimeToCook	
Apfelwein	0hrs 15mins	View
Pork Wellington	0hrs 30mins	View

Apfelwein

A nice light white wine with a hint of apple

Apple Juice
5.0 Gallons

Corn Sugar
2.0 lb

Cote Des Blanc Yeast
1.0 Packet

Create Recipe

Name

Method

Time to cook (hrs)

Figure 12.2 The cookery app lists recipes. You can view, update, and delete recipes, or create new ones.

This is obviously a simple application, but it contains all the database interactions you need with its two *entities*: `Recipe` and `Ingredient`.

DEFINITION An *entity* is a .NET class that's mapped by EF Core to the database. These are classes you define, typically as POCO classes, that can be saved and loaded by mapping to database tables using EF Core.

When you interact with EF Core, you'll be primarily using POCO entities and a *database context* that inherits from the `DbContext` EF Core class. The entity classes are the object-oriented representations of the tables in your database; they represent the data you want to store in the database. You use the `DbContext` in your application to both configure EF Core and to access the database at runtime.

NOTE You can potentially have multiple `DbContext`s in your application and can even configure them to integrate with different databases.

When your application first uses EF Core, EF Core creates an internal representation of the database, based on the `DbSet<T>` properties on your application's `DbContext` and the entity classes themselves, as shown in figure 12.3.

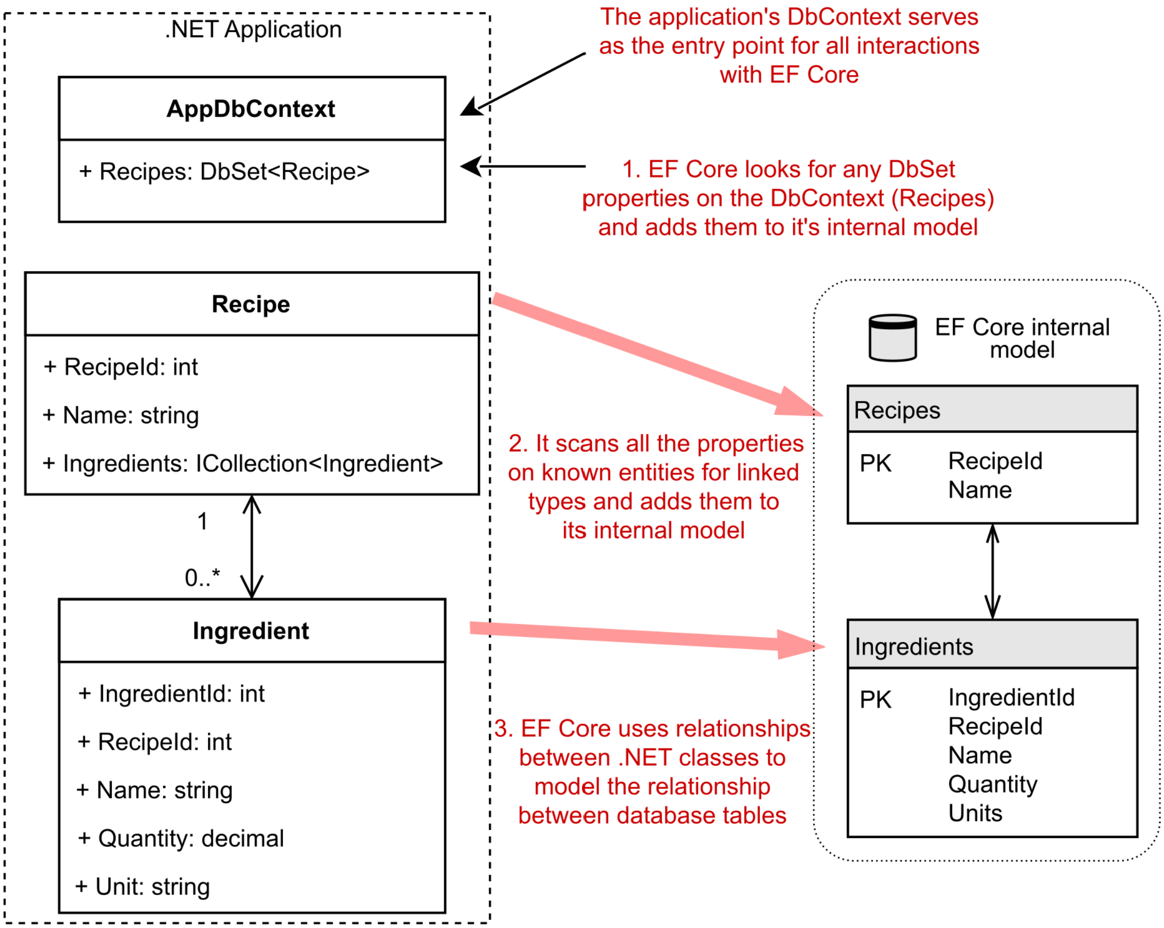

.NET Application
AppDbContext
+ Recipes: DbSet<Recipe>
Recipe
+ RecipeId: int
+ Name: string
+ Ingredients: ICollection<Ingredient>
1
0..*
Ingredient
+ IngredientId: int
+ RecipeId: int
+ Name: string
+ Quantity: decimal
+ Unit: string
The application's DbContext serves as the entry point for all interactions with EF Core
1. EF Core looks for any DbSet properties on the DbContext (Recipes) and adds them to it's internal model
2. It scans all the properties on known entities for linked types and adds them to its internal model
3. EF Core uses relationships between .NET classes to model the relationship between database tables
EF Core internal model
Recipes
PK
RecipeId
Name
Ingredients
PK
IngredientId
RecipeId
Name
Quantity
Units

Figure 12.3 EF Core creates an internal model of your application's data model by exploring the types in your code. It adds all of the types referenced in the `DbSet<>` properties on your app's `DbContext`, and any linked types.

For your recipe app, EF Core will build a model of the `Recipe` class because it's exposed on the `AppDbContext` as a `DbSet<Recipe>`. Furthermore, EF Core will loop through all the properties on `Recipe`, looking for types it doesn't know about, and add them to its internal model. In your app, the `Ingredients` collection on `Recipe` exposes the `Ingredient` entity as an `ICollection<Ingredient>`, so EF Core models the entity appropriately.

Each entity is mapped to a table in the database, but EF Core also maps the relationships between the entities. Each recipe can have *many* ingredients, but each ingredient (which has a name, quantity, and unit) belongs to *one* recipe, so this is a many-to-one relationship. EF Core uses that knowledge to correctly model the equivalent many-to-one database structure.

> **NOTE** Two different recipes, say fish pie and lemon chicken, may use an ingredient that has both the same name and quantity, for example the juice of one lemon, but they're fundamentally two different instances. If you update the lemon chicken recipe to use two lemons, you wouldn't want this change to automatically update the fish pie to use two lemons too!

EF Core uses the internal model it builds when interacting with the database. This ensures it builds the correct SQL to create, read, update, and delete entities.

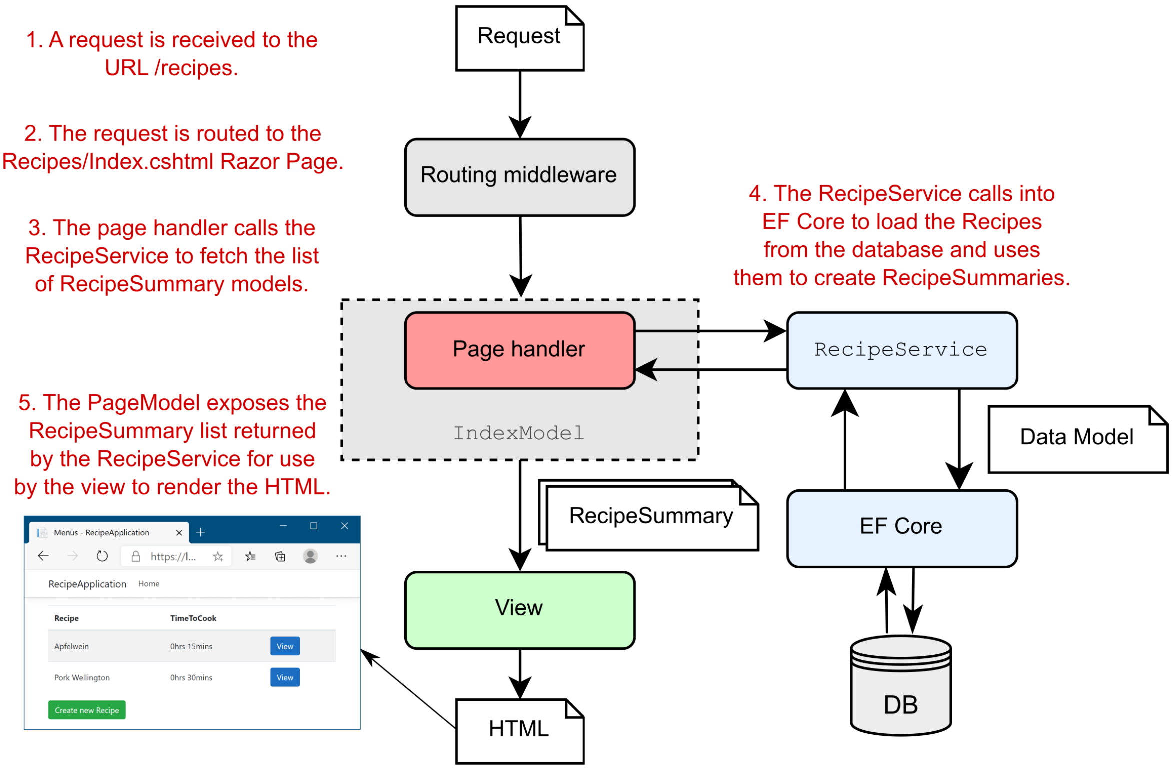
Right, it's about time for some code! In the next section, you'll start building the recipe app. You'll see how to add EF Core to an ASP.NET Core application, configure a database provider, and design your application's data model.

12.2 Adding EF Core to an application

In this section, we focus on getting EF Core installed and configured in your ASP.NET Core recipe app. You'll learn how to install the required NuGet packages and how to build the data model for your application. As we're talking about EF Core in this chapter, I'm not going to go into how to create the application in general—I created a simple Razor Pages app as the basis, nothing fancy.

> **TIP** The sample code for this chapter shows the state of the application at three points in this chapter: the end of section 12.2, at the end of section 12.3, and at the end of the chapter. It also includes examples using both Local DB and SQLite providers.

Interaction with EF Core in the example app occurs in a service layer that encapsulates all the data access outside of the Razor Pages framework, as shown in figure 12.4. This keeps your concerns separated and makes your services testable.


1. A request is received to the URL /recipes.
2. The request is routed to the Recipes/Index.cshtml Razor Page.
3. The page handler calls the RecipeService to fetch the list of RecipeSummary models.
4. The RecipeService calls into EF Core to load the Recipes from the database and uses them to create RecipeSummaries.
5. The PageModel exposes the RecipeSummary list returned by the RecipeService for use by the view to render the HTML.
Request
Routing middleware
Page handler
IndexModel
RecipeService
Data Model
EF Core
DB
RecipeSummary
View
HTML
Menus - RecipeApplication
https://l...
RecipeApplication
Home
View
Create new Recipe

Recipe	TimeToCook	
Apfelwein	0hrs 15mins	View
Pork Wellington	0hrs 30mins	View

Figure 12.4 Handling a request by loading data from a database using EF Core. Interaction with EF Core is restricted to `RecipeService` only—the Razor Page doesn't access EF Core directly.

Adding EF Core to an application is a multistep process:

1. Choose a database provider; for example, Postgres, SQLite, or MS SQL Server.
2. Install the EF Core NuGet packages.
3. Design your app's `DbContext` and entities that make up your data model.
4. Register your app's `DbContext` with the ASP.NET Core DI container.
5. Use EF Core to generate a *migration* describing your data model.
6. Apply the migration to the database to update the database's schema.

This might seem a little daunting already, but we'll walk through steps 1–4 in this section, and steps 5–6 in section 12.3, so it won't take long. Given the space constraints of this chapter, I'm going to be sticking to the default conventions of EF Core in the code I show. EF Core is far more customizable than it may initially appear, but I encourage you to stick to the defaults wherever possible. It will make your life easier in the long run!

The first step in setting up EF Core is to decide which database you'd like to interact with. It's likely that a client or your company's policy will dictate this to you, but it's still worth giving the choice some thought.

12.2.1 Choosing a database provider and installing EF Core

EF Core supports a range of databases by using a provider model. The modular nature of EF Core means you can use the same high-level API to program against different underlying databases, and EF Core knows how to generate the necessary implementation-specific code and SQL statements.

You probably already have a database in mind when you start your application, and you'll be pleased to know that EF Core has got most of the popular ones covered. Adding support for a given database involves adding the correct NuGet package to your csproj file. For example:

- *PostgreSQL*—Npgsql.EntityFrameworkCore.PostgreSQL
- *Microsoft SQL Server*—Microsoft.EntityFrameworkCore.SqlServer
- *MySQL*—MySql.Data.EntityFrameworkCore
- *SQLite*—Microsoft.EntityFrameworkCore.SQLite

Some of the database provider packages are maintained by Microsoft, some are maintained by the open source community, and some may require a paid license (for example, the Oracle provider), so be sure to check your requirements. You can find a list of providers at https://docs.microsoft.com/ef/core/providers/.

You install a database provider into your application in the same way as any other library: by adding a NuGet package to your project's csproj file and running `dotnet restore` from the command line (or letting Visual Studio automatically restore for you).

EF Core is inherently modular, so you'll want to install two packages. I'm using the SQL Server database provider with LocalDB for the recipe app, so I'll be using the SQL Server packages.

- *Microsoft.EntityFrameworkCore.SqlServer*—This is the main database provider package for using EF Core at runtime. It also contains a reference to the main EF Core NuGet package.
- *Microsoft.EntityFrameworkCore.Design*—This contains shared design-time components for EF Core.

> **TIP** You'll also want to install tooling to help you create and update your database. I show how to install these in section 12.3.1.

Listing 12.1 shows the recipe app's csproj file after adding the EF Core packages. Remember, you add NuGet packages as `PackageReference` elements.

Listing 12.1 Installing EF Core into an ASP.NET Core application

```
<Project Sdk="Microsoft.NET.Sdk.Web">
```

```
  <PropertyGroup>
    <TargetFramework>netcoreapp3.1</TargetFramework>                #A
  </PropertyGroup>

  <ItemGroup>
    <PackageReference                                            #B
        Include="Microsoft.EntityFrameworkCore.SqlServer"        #B
        Version="3.1.3" />                                       #B
    <PackageReference                                            #C
        Include="Microsoft.EntityFrameworkCore.Design"           #C
        Version="3.1.3" />                                       #C
  </ItemGroup>
</Project>
```

#A The app targets .NET Core 3.1.
#B Install the appropriate NuGet package for your selected DB
#C Contains shared design-time components for EF Core

With these packages installed and restored, you have everything you need to start building the data model for your application. In the next section, we'll create the entity classes and the `DbContext` for your recipe app.

12.2.2 Building a data model

In section 12.1.4, I showed an overview of how EF Core builds up its internal model of your database from the `DbContext` and entity models. Apart from this discovery mechanism, EF Core is pretty flexible in letting you define your entities the way *you* want to, as POCO classes.

Some ORMs require your entities to inherit from a specific base class or decorate your models with attributes to describe how to map them. EF Core heavily favors a convention over configuration approach, as you can see in this listing, which shows the `Recipe` and `Ingredient` entity classes for your app.

Listing 12.2 Defining the EF Core entity classes

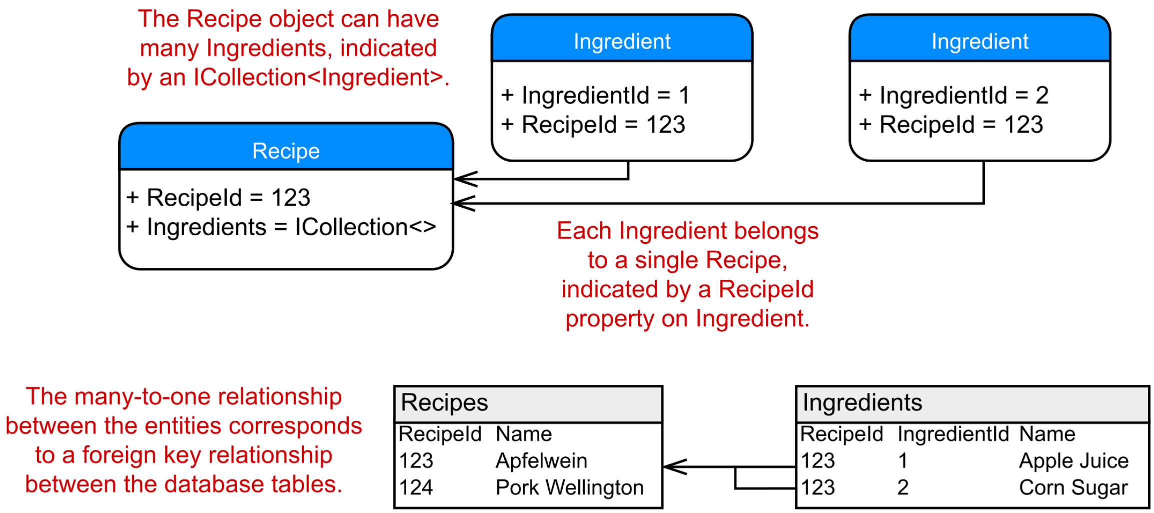
```
public class Recipe
{
    public int RecipeId { get; set; }
    public string Name { get; set; }
    public TimeSpan TimeToCook { get; set; }
    public bool IsDeleted { get; set; }
    public string Method { get; set; }
    public ICollection<Ingredient> Ingredients { get; set; }     #A
}
public class Ingredient
{
    public int IngredientId { get; set; }
    public int RecipeId { get; set; }
    public string Name { get; set; }
    public decimal Quantity { get; set; }
    public string Unit { get; set; }
}
```

#A A Recipe can have many Ingredients, represented by ICollection.

These classes conform to certain default conventions that EF Core uses to build up a picture of the database it's mapping. For example, the `Recipe` class has a `RecipeId` property and the `Ingredient` class has an `IngredientId` property. EF Core identifies this pattern of `TId` as indicating the *primary key* of the table.

> **DEFINITION** The *primary key* of a table is a value that uniquely identifies the row among all the others in the table. It's often an `int` or a `Guid`.

Another convention visible here is the `RecipeId` property on the `Ingredient` class. EF Core interprets this to be a *foreign key* pointing to the `Recipe` class. When considered with `ICollection<Ingredient>` on the `Recipe` class, this represents a many-to-one relationship, where each recipe has many ingredients, but each ingredient only belongs to a single recipe, as shown in figure 12.5.



The Recipe object can have many Ingredients, indicated by an ICollection<Ingredient>.

Each Ingredient belongs to a single Recipe, indicated by a RecipeId property on Ingredient.

The many-to-one relationship between the entities corresponds to a foreign key relationship between the database tables.

Recipes

RecipeId	Name
123	Apfelwein
124	Pork Wellington

Ingredients

RecipeId	IngredientId	Name
123	1	Apple Juice
123	2	Corn Sugar

Figure 12.5 Many-to-one relationships in code are translated to foreign key relationships between tables.

> **DEFINITION** A *foreign key* on a table points to the primary key of a different table, forming a link between the two rows.

Many other conventions are at play here, such as the names EF Core will assume for the database tables and columns, or the database column types it will use for each property, but I'm not going to discuss them here. The EF Core documentation contains details about all of the conventions, as well as how to customize them for your application: https://docs.microsoft.com/ef/core/modeling/.

TIP You can also use `DataAnnotations` attributes to decorate your entity classes, controlling things like column naming or `string` length. EF Core will use these attributes to override the default conventions.

As well as the entities, you also define the `DbContext` for your application. This is the heart of EF Core in your application, used for all your database calls. Create a custom `DbContext`, in this case called `AppDbContext`, and derive from the `DbContext` base class, as shown next. This exposes the `DbSet<Recipe>` so EF Core can discover and map the `Recipe` entity. You can expose multiple instances of `DbSet<>` in this way, for each of the "top-level" entities in your application.

Listing 12.3 Defining the application `DbContext`

```
public class AppDbContext : DbContext
{
    public AppDbContext(DbContextOptions<AppDbContext> options)     #A
        : base(options) { }                                         #A
    public DbSet<Recipe> Recipes { get; set; }                      #B
}
```

#A The constructor options object, containing details such as the connection string
#B You'll use the Recipes property to query the database.

The `AppDbContext` for your app is simple, containing a list of your root entities, but you can do a lot more with it in a more complex application. If you wanted, you could completely customize how EF Core maps entities to the database, but for this app you're going to use the defaults.

NOTE You didn't list `Ingredient` on `AppDbContext`, but it will be modeled by EF Core as it's exposed on the `Recipe`. You can still access the `Ingredient` objects in the database, but you have to go *via* the `Recipe` entity's `Ingredients` property to do so, as you'll see in section 12.4.

For this simple example, your data model consists of these three classes: `AppDbContext`, `Recipe`, and `Ingredient`. The two entities will be mapped to tables and their columns to properties, and you'll use the `AppDbContext` to access them.

NOTE This *code first* approach is typical, but if you have an existing database, you can automatically generate the EF entities and `DbContext` instead. (More information can be found at https://docs.microsoft.com/ef/core/managing-schemas/scaffolding.)

The data model is complete, but you're not quite ready to use it yet. Your ASP.NET Core app doesn't know how to create your `AppDbContext`, and your `AppDbContext` needs a connection string so that it can talk to the database. In the next section, we'll tackle both of these issues, and will finish setting up EF Core in your ASP.NET Core app.

12.2.3 Registering a data context

Like any other service in ASP.Net Core, you should register your `AppDbContext` with the DI container. When registering your context, you also configure the database provider and set the connection string, so EF Core knows how to talk with the database.

You register the `AppDbContext` in the `ConfigureServices` method of Startup.cs. EF Core provides a generic `AddDbContext<T>` extension method for this purpose, which takes a configuration function for a `DbContextOptionsBuilder` instance. This builder can be used to set a host of internal properties of EF Core and lets you completely replace the internal services of EF Core if you want.

The configuration for your app is, again, nice and simple, as you can see in the following listing. You set the database provider with the `UseSqlServer` extension method, made available by the Microsoft.EntityFrameworkCore.SqlServer package, and pass it a connection string.

Listing 12.4 Registering a `DbContext` with the DI container

```
public void ConfigureServices(IServiceCollection services)
{
    var connString = Configuration                          #A
        .GetConnectionString("DefaultConnection");          #A

    services.AddDbContext<AppDbContext>(                    #B
        options => options.UseSqlServer(connString));       #C

    // Add other services.
}
```

#A The connection string is taken from configuration, from the ConnectionStrings section.
#B Register your app's DbContext by using it as the generic parameter.
#C Specify the database provider in the customization options for the DbContext.

> **NOTE** **If you're using a different database provider, for example a provider for SQLite, you will need to call the appropriate** `Use*` **method on the** `options` **object when registering your** `AppDbContext`.

The connection string is a typical secret as I discussed in the previous chapter, so loading it from configuration makes sense. At runtime, the correct configuration string for your current environment will be used, so you can use different databases when developing locally and in production.

> **TIP** **You can configure your** `AppDbContext` **in other ways and provide the connection string, such as with the** `OnConfiguring` **method, but I recommend the method shown here for ASP.NET Core websites.**

You now have a `DbContext`, `AppDbContext`, registered with the DI container, and a data model corresponding to your database. Code-wise, you're ready to start using EF Core, but the one thing you *don't* have is a database! In the next section, you'll see how you can easily use the .NET CLI to ensure your database stays up to date with your EF Core data model.

12.3 Managing changes with migrations

In this section, you'll learn how to generate SQL statements to keep your database's schema in sync with your application's data model, using migrations. You'll learn how to create an initial migration and use it to create the database. You'll then update your data model, create a second migration, and use it to update the database schema.

Managing *schema* changes for databases, such as when you need to add a new table or a new column, is notoriously difficult. Your application code is explicitly tied to a particular *version* of a database, and you need to make sure the two are always in sync.

> **DEFINITION** *Schema* refers to how the data is organized in a database, including, among others things, the tables, columns, and the relationships between them.

When you deploy an app, you can normally delete the old code/executable and replace it with the new code—job done. If you need to roll back a change, delete that new code and deploy an old version of the app.

The difficulty with databases is that they contain data! That means that blowing it away and creating a new database with every deployment isn't possible.

A common best practice is to explicitly version a database's schema along with your application's code. You can do this in a number of ways but, typically, you need to store a diff between the previous schema of the database and the new schema, often as a SQL script. You can then use libraries such as DbUp and FluentMigrator[55] to keep track of which scripts have been applied and ensure your database schema is up to date. Alternatively, you can use external tools that manage this for you.

EF Core provides its own version of schema management called *migrations*. Migrations provide a way to manage changes to a database schema when your EF Core data model changes. A migration is a C# code file in your application that defines how the data model changed—which columns were added, new entities, and so on. Migrations provide a record over time of how your database schema evolved as part of your application, so the schema is always in sync with your app's data model.

You can use command-line tools to create a new database from the migrations, or to update an existing database by *applying* new migrations to it. You can even rollback a migration, which will update a database to a previous schema.

> **WARNING** Applying migrations modifies the database, so you always have to be aware of data loss. If you remove a table from the database using a migration and then rollback the migration, the table will be recreated, but the data it previously contained will be gone forever!

[55] DbUp and FluentMigrator are open source projects, available at https://github.com/fluentmigrator/fluentmigrator and https://github.com/DbUp/DbUp respectively.

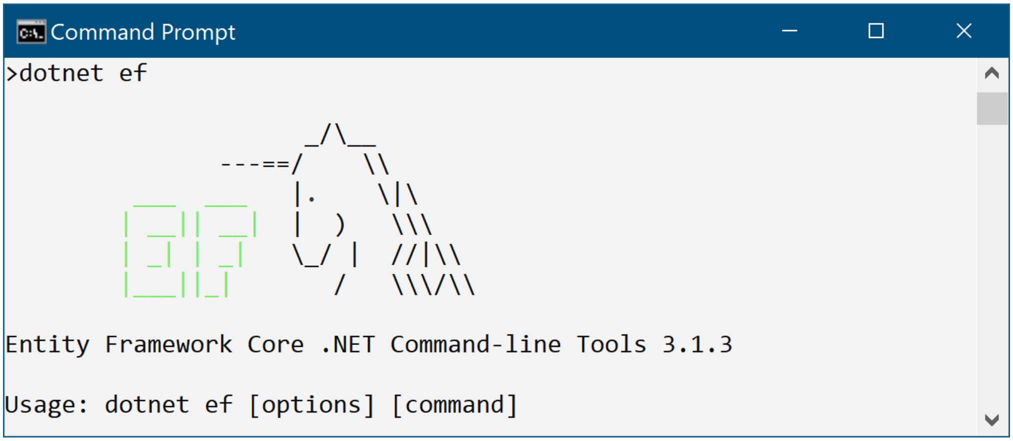
In this section, you'll see how to create your first migration and use it to create a database. You'll then update your data model, create a second migration, and use it to update the database schema.

12.3.1 Creating your first migration

Before you can create migrations, you'll need to install the necessary tooling. There are two primary ways to do this:

- *Package manager console*—Provides a number of PowerShell cmdlets for use inside Visual Studio's Package Manager Console (PMC). You can install them directly from the PMC or by adding the Microsoft.EntityFrameworkCore.Tools package to your project.
- *.NET Core tool*—Cross-platform tooling that you can run from the command line which extends the .NET SDK. You can install these tools globally for your machine by running `dotnet tool install --global dotnet-ef`.[56]

In this book, I'll be using the cross-platform .NET Core tools, but if you're familiar with EF 6.X or prefer to use the Visual Studio PMC, then there are equivalent commands for all of the steps you're going to take.[57] You can check the .NET Core tool installed correctly by running `dotnet ef`. This should produce a help screen like the one shown in figure 12.6.



```
>dotnet ef

                     _/\__
               ---==/    \\
         ___  ___   |.    \|\
        | __|| __|  |  )   \\\
        | _| | _|   \_/ |  //|\\
        |___||_|       /   \\\/\\

Entity Framework Core .NET Command-line Tools 3.1.3

Usage: dotnet ef [options] [command]
```

Figure 12.6 Running the `dotnet ef` command to check the .NET Core EF Core tools are installed correctly.

[56] Alternatively, you can install the tools *locally*, using a *tool manifest file*. To see how to use this approach, see https://andrewlock.net/new-in-net-core-3-local-tools/.

[57] Documentation for PowerShell cmdlets can be found at https://docs.microsoft.com/ef/core/miscellaneous/cli/powershell.

TIP **If you get the *No executable found matching command "dotnet-ef"* message when running the preceding command, make sure you have installed the global tool using** `dotnet tool install --global dotnet-ef`**. In general, you need to run the** `dotnet ef` **tools from the *project* folder in which you have registered your** `AppDbContext` **(not at the solution-folder level).**

With the tools installed and your database context configured, you can create your first migration by running the following command from inside your web project folder and providing a name for the migration—in this case, "`InitialSchema`":

```
dotnet ef migrations add InitialSchema
```

This command creates three files in the Migrations folder in your project:

- *Migration file*—A file with the Timestamp_MigrationName.cs format. This describes the actions to take on the database, such as Create table or Add column. Note the commands generated here are *database provider specific*, based on the database provider configured in your project.
- *Migration designer.cs file*—This file describes EF Core's internal model of your data model at the point in time the migration was generated.
- *AppDbContextModelSnapshot.cs*—This describes EF Core's *current* internal model. This will be updated when you add another migration, so it should always be the same as the current, latest migration.

  EF Core can use AppDbContextModelSnapshot.cs to determine a database's previous state when creating a new migration, without interacting with the database directly.

These three files encapsulate the migration process but adding a migration doesn't update anything in the database itself. For that, you must run a different command to apply the migration to the database.

TIP **You can, and should, look inside the migration file EF Core generates to check what it will do to your database before running the following commands. Better safe than sorry!**

You can apply migrations in one of three ways:

- Using the .NET Core tool
- Using the Visual Studio PowerShell cmdlets
- In code, by obtaining an instance of your `AppDbContext` from the DI container and calling `context.Database.Migrate()`.

Which is best for you is a matter of how you've designed your application, how you'll update your production database, and your personal preference. I'll use the .NET Core tool for now, but I discuss some of these considerations in section 12.5.

You can apply migrations to a database by running

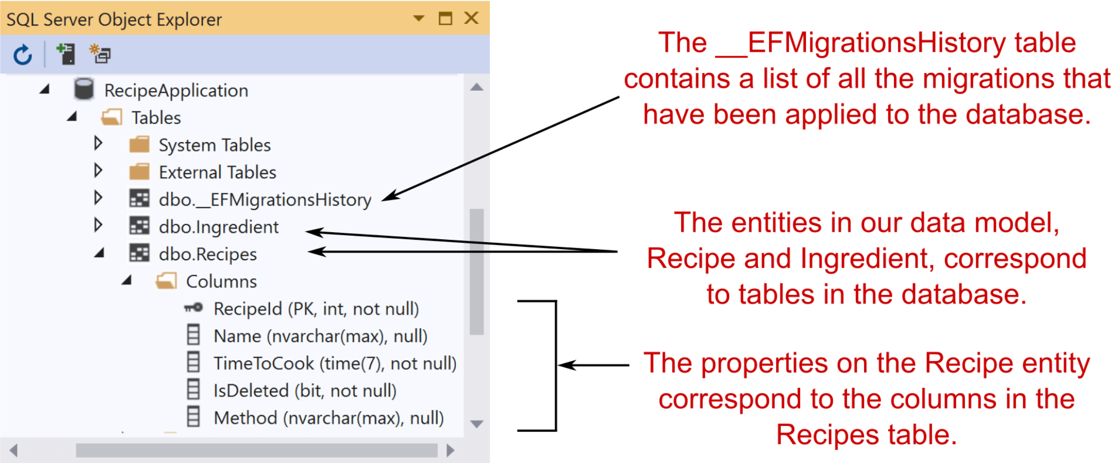
```
dotnet ef database update
```

from the project folder of your application. I won't go into the details of how this works, but this command performs four steps:

1. Builds your application.
2. Loads the services configured in your app's `Startup` class, including `AppDbContext`.
3. Checks whether the database in the `AppDbContext` connection string exists. If not, creates it.
4. Updates the database by applying any unapplied migrations.

If everything is configured correctly, as I showed in section 12.2, then running this command will set you up with a shiny new database, such as the one shown in figure 12.7!

> **REMINDER** If you get an error message "No project was found" when running these commands, check that you're running them in your application's *project* folder, not the top-level solution folder.


SQL Server Object Explorer
RecipeApplication
Tables
System Tables
External Tables
dbo.__EFMigrationsHistory
dbo.Ingredient
dbo.Recipes
Columns
RecipeId (PK, int, not null)
Name (nvarchar(max), null)
TimeToCook (time(7), not null)
IsDeleted (bit, not null)
Method (nvarchar(max), null)

The __EFMigrationsHistory table contains a list of all the migrations that have been applied to the database.

The entities in our data model, Recipe and Ingredient, correspond to tables in the database.

The properties on the Recipe entity correspond to the columns in the Recipes table.

Figure 12.7 Applying migrations to a database will create the database if it doesn't exist and update the database to match EF Core's internal data model. The list of applied migrations is stored in the __EFMigrationsHistory table.

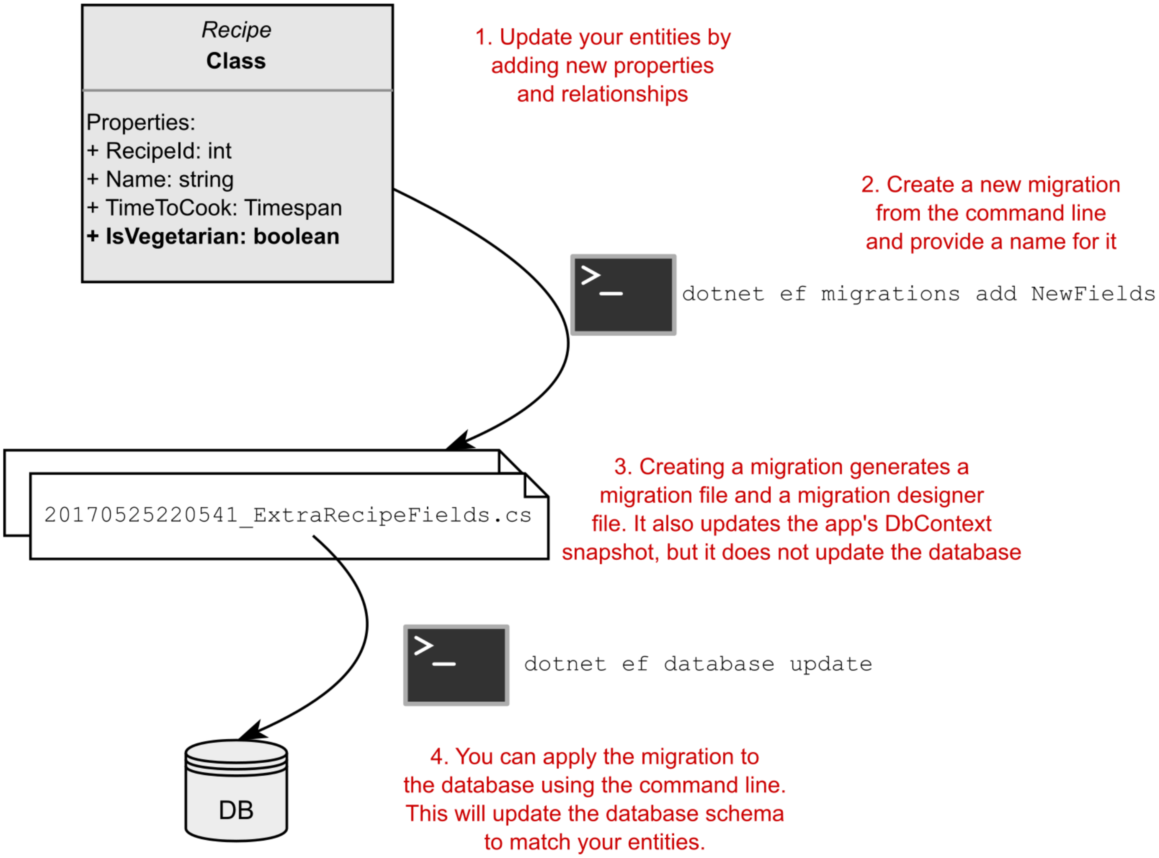
When you apply the migrations to the database, EF Core creates the necessary tables in the database and adds the appropriate columns and keys. You may have also noticed the __EFMigrationsHistory table. EF Core uses this to store the names of migrations that it's applied to the database. Next time you run `dotnet ef database update`, EF Core can compare this table to the list of migrations in your app and will apply only the new ones to your database.

In the next section, we'll look at how this makes it easy to change your data model, and update the database schema, without having to recreate the database from scratch.

12.3.2 Adding a second migration

Most applications inevitably evolve, whether due to increased scope or simple maintenance. Adding properties to your entities, adding new entities entirely, and removing obsolete classes—all are likely.

EF Core migrations make this simple. Change your entities to your desired state, generate a migration, and apply it to the database, as shown in figure 12.8. Imagine you decide that you'd like to highlight vegetarian and vegan dishes in your recipe app by exposing `IsVegetarian` and `IsVegan` properties on the `Recipe` entity.



Recipe
Class
Properties:
+ RecipeId: int
+ Name: string
+ TimeToCook: Timespan
+ IsVegetarian: boolean
1. Update your entities by adding new properties and relationships
2. Create a new migration from the command line and provide a name for it
>_
dotnet ef migrations add NewFields
20170525220541_ExtraRecipeFields.cs
3. Creating a migration generates a migration file and a migration designer file. It also updates the app's DbContext snapshot, but it does not update the database
>_
dotnet ef database update
DB
4. You can apply the migration to the database using the command line. This will update the database schema to match your entities.

Figure 12.8 Creating a second migration and applying it to the database using the command-line tools.

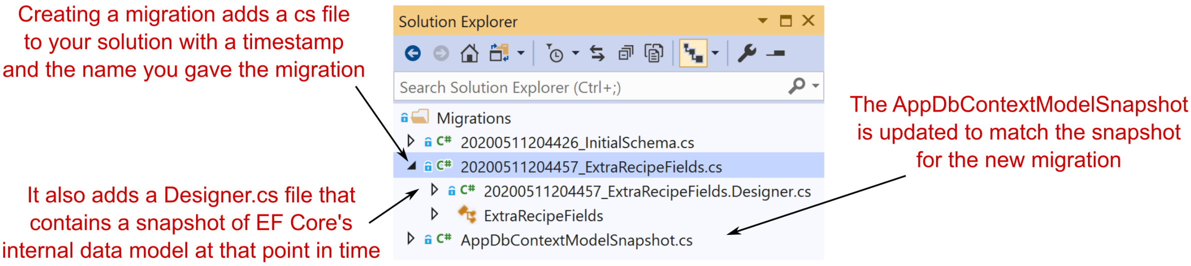
Listing 12.5 Adding properties to the `Recipe` entity

```
public class Recipe
{
    public int RecipeId { get; set; }
    public string Name { get; set; }
    public TimeSpan TimeToCook { get; set; }
    public bool IsDeleted { get; set; }
    public string Method { get; set; }
    public bool IsVegetarian { get; set; }
    public bool IsVegan { get; set; }
    public ICollection<Ingredient> Ingredients { get; set; }
}
```

After changing your entities, you need to update EF Core’s internal representation of your data model. You do this in the exact same way as for the first migration, by calling `dotnet ef migrations add` and providing a name for the migration:

```
dotnet ef migrations add ExtraRecipeFields
```

This creates a second migration in your project by adding the migration file and its .designer.cs snapshot file and updating AppDbContextModelSnapshot.cs, as shown in figure 12.9.


Solution Explorer
Search Solution Explorer (Ctrl+;)
Migrations
20200511204426_InitialSchema.cs
20200511204457_ExtraRecipeFields.cs
20200511204457_ExtraRecipeFields.Designer.cs
ExtraRecipeFields
AppDbContextModelSnapshot.cs

Creating a migration adds a cs file to your solution with a timestamp and the name you gave the migration

It also adds a Designer.cs file that contains a snapshot of EF Core's internal data model at that point in time

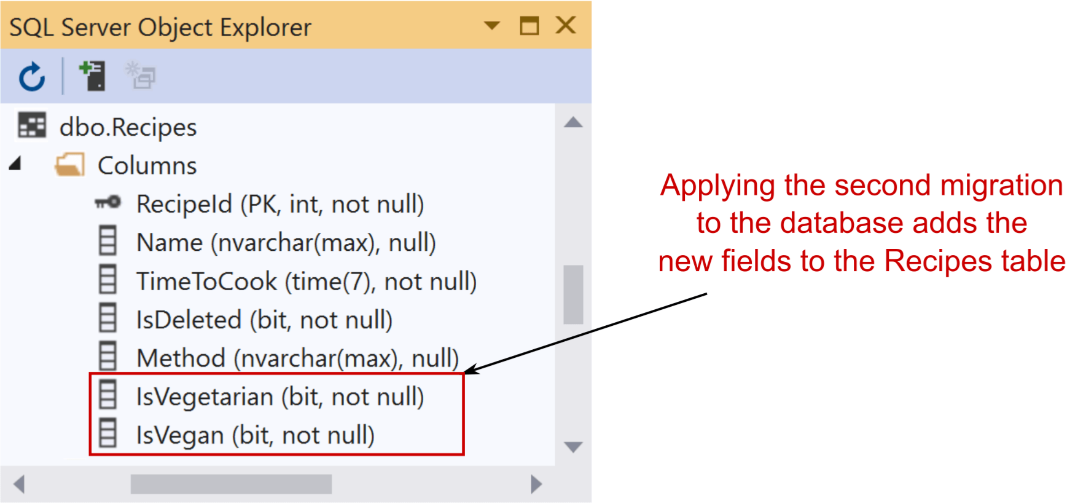
The AppDbContextModelSnapshot is updated to match the snapshot for the new migration

Figure 12.9 Adding a second migration adds a new migration file and a migration Designer.cs file. It also updates AppDbContextModelSnapshot to match the new migration’s Designer.cs file.

As before, this creates the migration’s files, but it doesn’t modify the database. You can apply the migration, and update the database, by running

```
dotnet ef database update
```

This compares the migrations in your application to the __EFMigrationsHistory table on your database to see which migrations are outstanding and then runs them. EF Core will run the 20200511204457_ExtraRecipeFields migration, adding the `IsVegetarian` and `IsVegan` fields to the database, as shown in figure 12.10.



SQL Server Object Explorer

dbo.Recipes

Columns

RecipeId (PK, int, not null)

Name (nvarchar(max), null)

TimeToCook (time(7), not null)

IsDeleted (bit, not null)

Method (nvarchar(max), null)

IsVegetarian (bit, not null)

IsVegan (bit, not null)

Applying the second migration to the database adds the new fields to the Recipes table

Figure 12.10 Applying the ExtraRecipeFields migration to the database adds the `IsVegetarian` and `IsVegan` fields to the Recipes table.

Using migrations is a great way to ensure your database is versioned along with your app code in source control. You can easily check out your app’s source code for a historical point in time and recreate the database schema that your application used at that point.

Migrations are easy to use when you’re working alone, or when you’re deploying to a single web server, but even in these cases, there are important things to consider when deciding how to manage your databases. For apps with multiple web servers using a shared database, or for containerized applications, you have even more things to think about.

This book is about ASP.NET Core, not EF Core, so I don’t want to dwell on database management too much, but section 12.5 points out some of the things you need to bear in mind when using migrations in production.

In the next section, we’ll get back to the meaty stuff—defining our business logic and performing CRUD operations on the database.

12.4 Querying data from and saving data to the database

Let’s review where you are in creating the recipe application:

- You created a simple data model for the application, consisting of recipes and ingredients.
- You generated migrations for the data model, to update EF Core’s internal model of your entities.
- You applied the migrations to the database, so its schema matches EF Core’s model.

In this section, you'll build the business logic for your application by creating a `RecipeService`. This handles querying the database for recipes, creating new recipes, and modifying existing ones. As this app only has a simple domain, I'll be using `RecipeService` to handle all the requirements, but in your own apps you may have multiple services that cooperate to provide the business logic.

> **NOTE** For simple apps, you may be tempted to move this logic into your Razor Pages. I'd encourage you to resist this urge; extracting your business logic to other services decouples the HTTP-centric nature of Razor Pages and Web APIs from the underlying business logic. This will often make your business logic easier to test and more reusable.

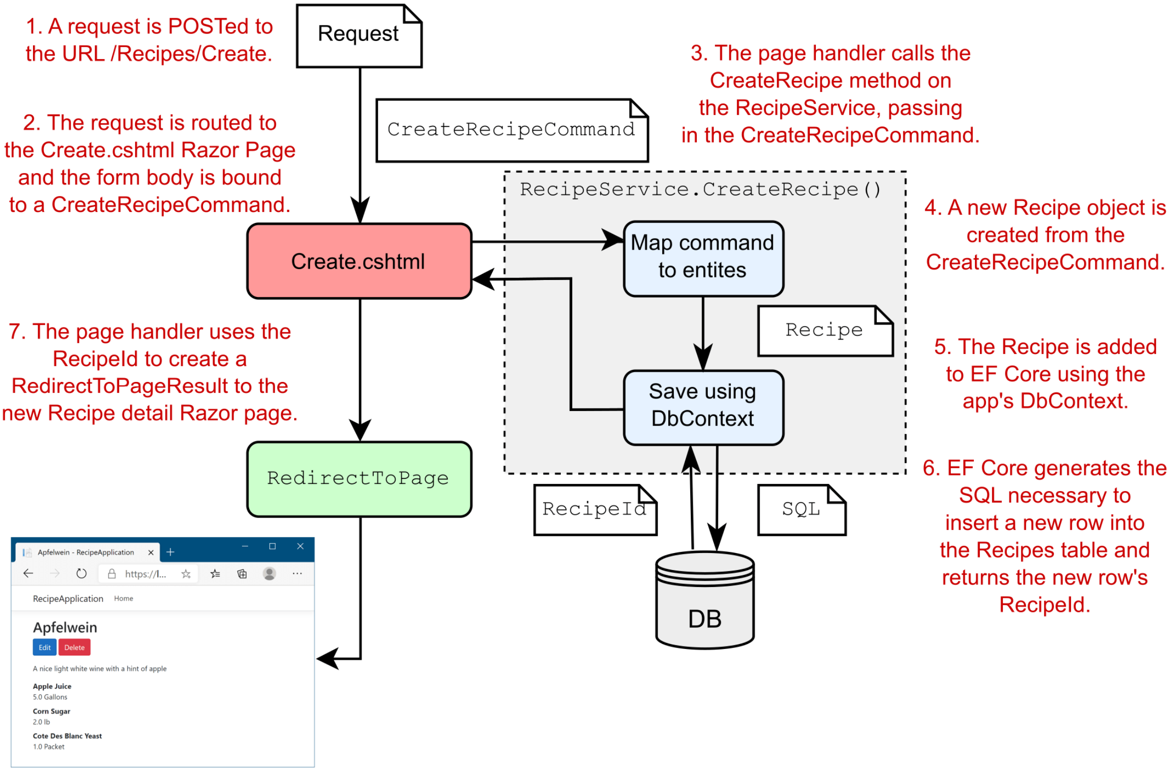
Our database doesn't have any data in it yet, so we'd better start by letting you create a recipe!

12.4.1 Creating a record

In this section, you're going to build the functionality to let users create a recipe in the app. This will primarily consist of a form that the user can use to enter all the details of the recipe using Razor Tag Helpers, which you learned about in chapters 7 and 8. This form is posted to the Create.cshtml Razor Page, which uses model binding and validation attributes to confirm the request is valid, as you saw in chapter 6.

If the request is valid, the page handler calls `RecipeService` to create the new `Recipe` object in the database. As EF Core is the topic of this chapter, I'm going to focus on this service alone, but you can always check out the source code for this book if you want to see how everything fits together.

The business logic for creating a recipe in this application is simple—there *is* no logic! Map the *command* binding model provided in the Create.cshtml Razor Page to a `Recipe` entity and its `Ingredients`, add the `Recipe` object to `AppDbContext`, and save that in the database, as shown in figure 12.11.


1. A request is POSTed to the URL /Recipes/Create.
Request
2. The request is routed to the Create.cshtml Razor Page and the form body is bound to a CreateRecipeCommand.
CreateRecipeCommand
3. The page handler calls the CreateRecipe method on the RecipeService, passing in the CreateRecipeCommand.
RecipeService.CreateRecipe()
Create.cshtml
Map command to entites
4. A new Recipe object is created from the CreateRecipeCommand.
Recipe
5. The Recipe is added to EF Core using the app's DbContext.
Save using DbContext
7. The page handler uses the RecipeId to create a RedirectToPageResult to the new Recipe detail Razor page.
RedirectToPage
RecipeId
SQL
6. EF Core generates the SQL necessary to insert a new row into the Recipes table and returns the new row's RecipeId.
DB
Apfelwein - RecipeApplication
https://l...
RecipeApplication
Home
Edit
Delete

Apfelwein

A nice light white wine with a hint of apple

Apple Juice
5.0 Gallons

Corn Sugar
2.0 lb

Cote Des Blanc Yeast
1.0 Packet

Figure 12.11 Calling the Create.cshtml Razor Page and creating a new entity. A `Recipe` is created from the `CreateRecipeCommand` binding model and is added to the `DbContext`. EF Core generates the SQL to add a new row to the Recipes table in the database.

> **WARNING** Many simple, equivalent, sample applications using EF or EF Core allow you to bind *directly* to the `Recipe` entity as the view model for your MVC actions. Unfortunately, this exposes a security vulnerability known as overposting and is a bad practice. If you want to avoid the boilerplate mapping code in your applications, consider using a library such as AutoMapper (http://automapper.org/). For more details on overposting, see https://andrewlock.net/preventing-mass-assignment-or-over-posting-with-razor-pages-in-asp-net-core/.

Creating an entity in EF Core involves adding a new row to the mapped table. For your application, whenever you create a new `Recipe`, you also add the linked `Ingredient` entities. EF Core takes care of linking these all correctly by creating the correct `RecipeId` for each `Ingredient` in the database.

The bulk of the code required for this example involves translating from `CreateRecipeCommand` to the `Recipe` entity—the interaction with the `AppDbContext` consists of only two methods: `Add()` and `SaveChangesAsync()`.

Listing 12.6 Creating a `Recipe` entity in the database

```
readonly AppDbContext _context;                       #A
public async Task<int> CreateRecipe(CreateRecipeCommand cmd)     #B
{
    var recipe = new Recipe                               #C
    {                                                     #C
        Name = cmd.Name,                                  #C
        TimeToCook = new TimeSpan(                        #C
            cmd.TimeToCookHrs, cmd.TimeToCookMins, 0),    #C
        Method = cmd.Method,                              #C
        IsVegetarian = cmd.IsVegetarian,                  #C
        IsVegan = cmd.IsVegan,                            #C
        Ingredients = cmd.Ingredients?.Select(i =>        #C
        new Ingredient                       #D
        {                                    #D
            Name = i.Name,                   #D
            Quantity = i.Quantity,           #D
            Unit = i.Unit,                   #D
        }).ToList()                          #D
    };
    _context.Add(recipe);         #E
    await _context.SaveChangesAsync();       #F
    return recipe.RecipeId;       #G
}
```

#A An instance of the AppDbContext is injected in the class constructor using DI.
#B CreateRecipeCommand is passed in from the Razor Page handler.
#C Create a Recipe by mapping from the command object to the Recipe entity.
#D Map each CreateIngredientCommand onto an Ingredient entity.
#E Tell EF Core to track the new entities.
#F Tell EF Core to write the entities to the database. This uses the async version of the command.
#G EF Core populates the RecipeId field on your new Recipe when it's saved.

All interactions with EF Core and the database start with an instance of `AppDbContext`, which is typically DI injected via the constructor. Creating a new entity requires three steps:

1. Create the `Recipe` and `Ingredient` entities.
2. Add the entities to EF Core's list of tracked entities using `_context.Add(entity)`.
3. Execute the SQL `INSERT` statements against the database, adding the necessary rows to the `Recipe` and `Ingredient` tables, by calling `_context.SaveChangesAsync()`.

> **TIP** **There are *sync* and *async* versions of most of the EF Core commands that involve interacting with the database, such as `SaveChanges()` and `SaveChangesAsync()`. In general, the async versions will allow your app to handle more concurrent connections, so I tend to favor them whenever I can use them.**

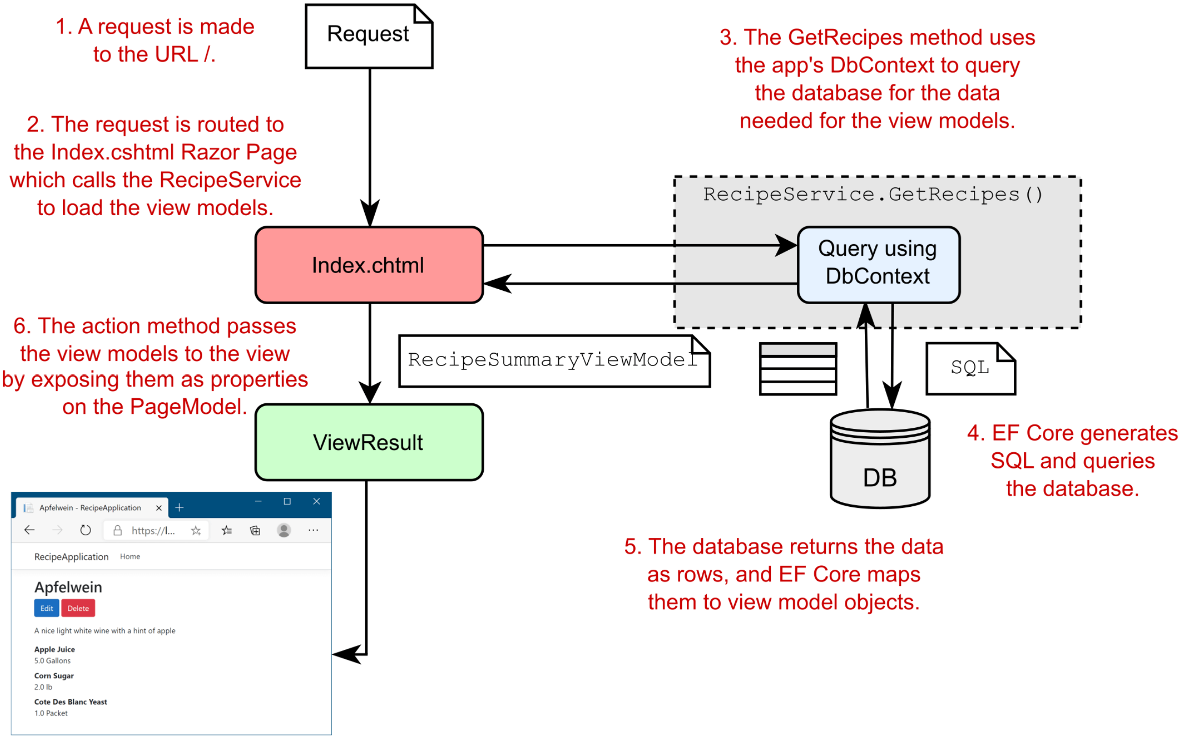
If there's a problem when EF Core tries to interact with your database—you haven't run the migrations to update the database schema, for example—it will throw an exception. I haven't shown it here, but it's important to handle these in your application, so you don't present users with an ugly error page when things go wrong.

Assuming all goes well, EF Core updates all the auto-generated IDs of your entities (`RecipeId` on `Recipe`, and both `RecipeId` and `IngredientId` on `Ingredient`). Return the recipe ID to the Razor Page so it can use it, for example, to redirect to the View Recipe page.

And there you have it—you've created your first entity using EF Core. In the next section, we'll look at loading these entities from the database so you can view them in a list.

12.4.2 Loading a list of records

Now that you can create recipes, you need to write the code to view them. Luckily, loading data is simple in EF Core, relying heavily on LINQ methods to control which fields you need. For your app, you'll create a method on `RecipeService` that returns a summary view of a recipe, consisting of the `RecipeId`, `Name`, and `TimeToCook` as a `RecipeSummaryViewModel`, as shown in figure 12.12.



1. A request is made to the URL /.

2. The request is routed to the Index.cshtml Razor Page which calls the RecipeService to load the view models.

3. The GetRecipes method uses the app's DbContext to query the database for the data needed for the view models.

4. EF Core generates SQL and queries the database.

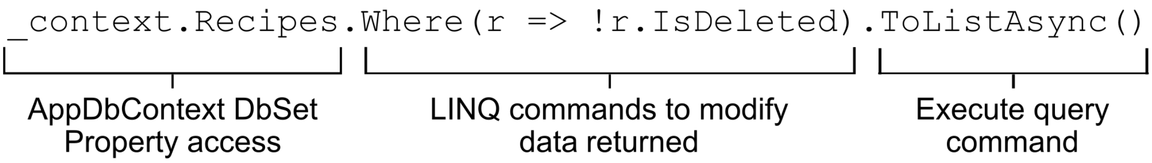
5. The database returns the data as rows, and EF Core maps them to view model objects.

6. The action method passes the view models to the view by exposing them as properties on the PageModel.

Figure 12.12 Calling the Index.cshtml Razor Page and querying the database to retrieve a list of `RecipeSummaryViewModels`. EF Core generates the SQL to retrieve the necessary fields from the database and maps them to view model objects.

NOTE Creating a view model is technically a UI concern rather than a business logic concern. I'm returning them directly from `RecipeService` here mostly to hammer home that you shouldn't be using EF Core entities directly in your Razor Pages.

The `GetRecipes` method in `RecipeService` is conceptually simple and follows a common pattern for querying an EF Core database, as shown in figure 12.13.



```
_context.Recipes.Where(r => !r.IsDeleted).ToListAsync()
```

Figure 12.13 The three parts of an EF Core database query.

EF Core uses a fluent chain of LINQ commands to define the query to return on the database. The `DbSet<Recipe>` property on `AppDataContext` is an `IQueryable`, so you can use all the usual `Select()` and `Where()` clauses that you would with other `IQueryable` providers. EF Core will convert these into a SQL statement to query the database with when you call an *execute* function such as `ToListAsync()`, `ToArrayAsync()`, or `SingleAsync()`, or their non-async brethren.

You can also use the `Select()` extension method to map to objects other than your entities as part of the SQL query. You can use this to efficiently query the database by only fetching the columns you need.

Listing 12.7 shows the code to fetch a list of `RecipeSummaryViewModel`s, following the same basic pattern as in figure 12.12. It uses a `Where` LINQ expression to filter out recipes marked as deleted, and a `Select` clause to map to the view models. The `ToListAsync()` command instructs EF Core to generate the SQL query, execute it on the database, and build `RecipeSummaryViewModel` from the data returned.

Listing 12.7 Loading a list of items using EF Core

```
public async Task<ICollection<RecipeSummaryViewModel>> GetRecipes()
{
    return await _context.Recipes                       #A
        .Where(r => !r.IsDeleted)
        .Select(r => new RecipeSummaryViewModel                #B
        {                                                      #B
            Id = r.RecipeId,                                   #B
            Name = r.Name,                                     #B
            TimeToCook = "{r.TimeToCook.TotalMinutes}mins"     #B
        })
        .ToListAsync();              #C
}
```

#A A query starts from a DbSet property
#B EF Core will only query the Recipe columns it needs to map the view model correctly

#C This executes the SQL query and creates the final view models.

Notice that in the Select method, you convert the TimeToCook property from a TimeSpan to a string using string interpolation:

```
TimeToCook = $"{x.TimeToCook.TotalMinutes}mins"
```

I said before that EF Core converts the series of LINQ expressions into SQL, but that's only a half-truth; EF Core can't or doesn't know how to convert some expressions to SQL. For those cases, such as in this example, EF Core finds the fields from the DB that it needs in order to run the expression on the client side, selects those from the database, and then runs the expression in C# afterwards. This lets you combine the power and performance of database-side evaluation without compromising the functionality of C#.

> **WARNING** **Client-side evaluation is both powerful and useful but has the potential to cause issues. In general, recent versions of EF Core will throw an exception if a query requires dangerous client-side evaluation. For examples, including how to avoid these issues, see the documentation at https://docs.microsoft.com/ef/core/querying/client-eval.**

At this point, you have a list of records, displaying a summary of the recipe's data, so the obvious next step is to load the detail for a single record.

12.4.3 Loading a single record

For most intents and purposes, loading a single record is the same as loading a list of records. They share the same common structure you saw in figure 12.13, but when loading a single record, you'll typically use a Where clause and execute a command that restricts the data to a single entity.

Listing 12.8 shows the code to fetch a recipe by ID following the same basic pattern as before (figure 12.12). It uses a Where() LINQ expression to restrict the query to a single recipe, where RecipeId == id, and a Select clause to map to RecipeDetailViewModel. The SingleOrDefaultAsync() clause will cause EF Core to generate the SQL query, execute it on the database, and build the view model.

> **NOTE** SingleOrDefaultAsync() **will throw an exception if the previous** Where **clause returns more than one record.**

Listing 12.8 Loading a single item using EF Core

```
public async Task<RecipeDetailViewModel> GetRecipeDetail(int id)      #A
{
    return await _context.Recipes                                    #B
        .Where(x => x.RecipeId == id)                          #C
        .Select(x => new RecipeDetailViewModel          #D
        {                                               #D
            Id = x.RecipeId,                            #D
            Name = x.Name,                              #D
            Method = x.Method,                          #D
            Ingredients = x.Ingredients                        #E
            .Select(item => new RecipeDetailViewModel.Item     #E
            {                                                  #E
                Name = item.Name,                              #E
                Quantity = $"{item.Quantity} {item.Unit}"      #E
            })                                                #E
        })
        .SingleOrDefaultAsync();       #F
}
```

#A The id of the recipe to load is passed as a parameter.
#B As before, a query starts from a DbSet property.
#C Limit the query to the recipe with the provided id.
#D Map the Recipe to a RecipeDetailViewModel.
#E Load and map linked Ingredients as part of the same query.
#F Execute the query and map the data to the view model.

Notice that, as well as mapping the `Recipe` to a `RecipeDetailViewModel`, you also map the related `Ingredient`s for a `Recipe`, as though you're working with the objects directly in memory. This is one of the advantages of using an ORM—you can easily map child objects and let EF Core decide how best to build the underlying queries to fetch the data.

> **NOTE** **EF Core logs all the SQL statements it runs as** `LogLevel.Information` **events by default, so you can easily see what queries are being run against the database.**

Our app is definitely shaping up; you can create new recipes, view them all in a list, and drill down to view individual recipes with their ingredients and method. Pretty soon though, someone's going to introduce a typo and want to change their data. To do this, you'll have to implement the *U* in CRUD: update.

12.4.4 Updating a model with changes

Updating entities when they have changed is generally the hardest part of CRUD operations, as there are so many variables. Figure 12.14 gives an overview of this process as it applies to your recipe app.

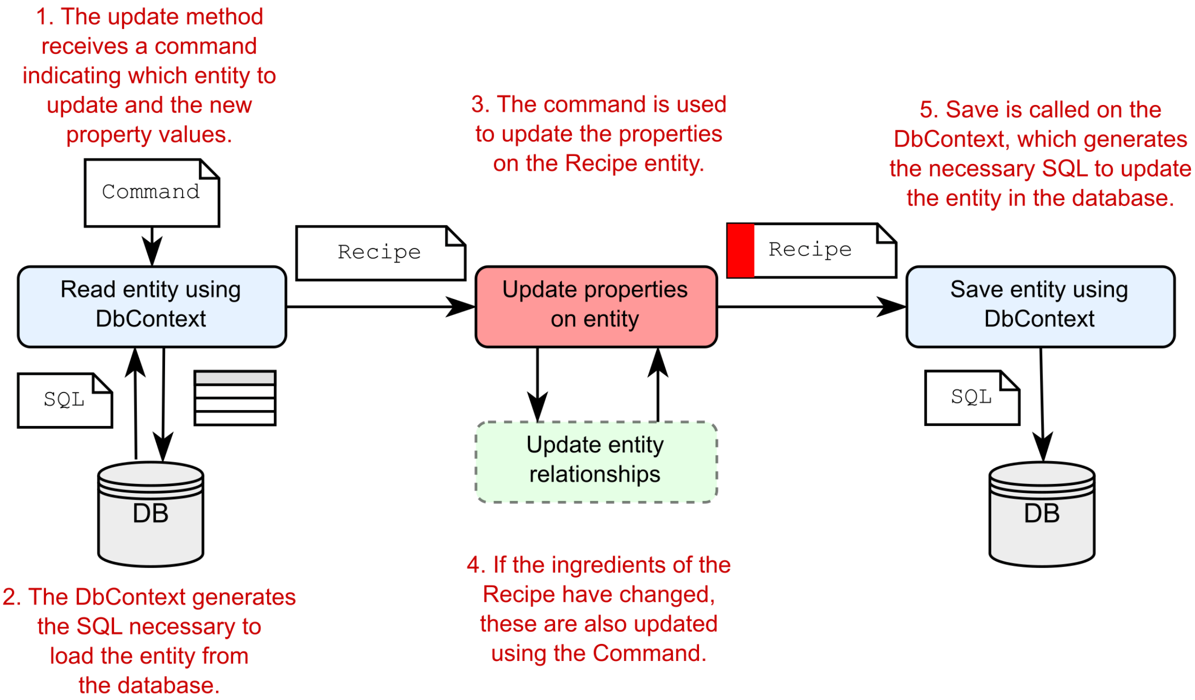

1. The update method receives a command indicating which entity to update and the new property values.
Command
Read entity using DbContext
SQL
DB
2. The DbContext generates the SQL necessary to load the entity from the database.
Recipe
3. The command is used to update the properties on the Recipe entity.
Update properties on entity
Update entity relationships
4. If the ingredients of the Recipe have changed, these are also updated using the Command.
Recipe
5. Save is called on the DbContext, which generates the necessary SQL to update the entity in the database.
Save entity using DbContext
SQL
DB

Figure 12.14 Updating an entity involves three steps: read the entity using EF Core, update the properties of the entity, and call `SaveChangesAsync()` on the `DbContext` to generate the SQL to update the correct rows in the database.

I'm not going to handle the relationship aspect in this book because that's generally a complex problem, and how you tackle it depends on the specifics of your data model. Instead, I'll focus on updating properties on the `Recipe` entity itself.[58]

For web applications, when you update an entity, you'll typically follow the steps outlined in Figure 12.14:

1. Read the entity from the database
2. Modify the entity's properties
3. Save the changes to the database

You'll encapsulate these three steps in a method on `RecipeService`, `UpdateRecipe`, which takes `UpdateRecipeCommand`, containing the changes to make to the `Recipe` entity.

[58] For a detailed discussion on handling relationship updates in EF Core, see *EF Core in Action* by Jon P Smith (Manning, 2018) https://livebook.manning.com#!/book/smith3/Chapter-3/109.

NOTE As with the `Create` command, you don't directly modify the entities in the Razor Page, ensuring you keep the UI concern separate from the business logic.

The following listing shows the `RecipeService.UpdateRecipe` method, which updates the `Recipe` entity. It's the three steps we defined previously to read, modify, and save the entity. I've extracted the code to update the recipe with the new values to a helper method.

Listing 12.9 Updating an existing entity with EF Core

```
public async Task UpdateRecipe(UpdateRecipeCommand cmd)
{
    var recipe = await _context.Recipes.FindAsync(cmd.Id);        #A
    if(recipe == null) {                                         #B
        throw new Exception("Unable to find the recipe");        #B
    }                                                            #B
    UpdateRecipe(recipe, cmd);                                   #C
    await _context.SaveChangesAsync();                            #D
}

static void UpdateRecipe(Recipe recipe, UpdateRecipeCommand cmd)    #E
{                                                                   #E
    recipe.Name = cmd.Name;                                         #E
    recipe.TimeToCook =                                             #E
        new TimeSpan(cmd.TimeToCookHrs, cmd.TimeToCookMins, 0);     #E
    recipe.Method = cmd.Method;                                     #E
    recipe.IsVegetarian = cmd.IsVegetarian;                         #E
    recipe.IsVegan = cmd.IsVegan;                                   #E
}                                                                   #E
```

#A Find is exposed directly by Recipes and simplifies reading an entity by id.
#B If an invalid id is provided, recipe will be null.
#C Set the new values on the Recipe entity.
#D Execute the SQL to save the changes to the database.
#E A helper method for setting the new properties on the Recipe entity

In this example, I read the `Recipe` entity using the `FindAsync(id)` method exposed by `DbSet`. This is a simple helper method for loading an entity by its ID, in this case `RecipeId`. I could've written a similar query using LINQ as

```
_context.Recipes.Where(r=>r.RecipeId == cmd.Id).FirstOrDefault();
```

Using `FindAsync()` or `Find()` is a little more declarative and concise.

TIP `Find` **is actually a bit more complicated.** `Find` **first checks to see if the entity is already being tracked in EF Core's** `DbContext`. **If it is (because the entity was previously loaded this request) then the entity is returned immediately without calling the DB. This can obviously be faster if the entity *is* tracked, but it can also be slower if you *know* the entity *isn't* being tracked yet.**

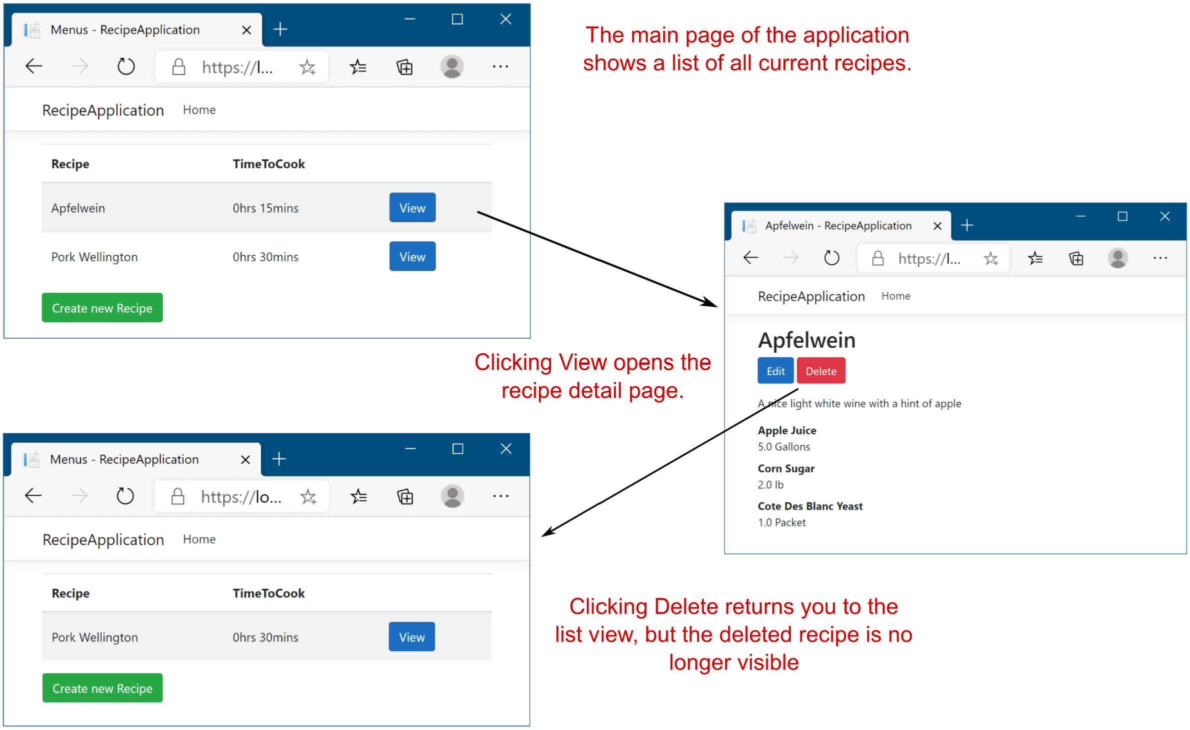
You may be wondering how EF Core knows which columns to update when you call `SaveChangesAsync()`. The simplest approach would be to update every column—if the field hasn't changed, then it doesn't matter if you write the same value again. But EF Core is a bit more clever than that.

EF Core internally tracks the *state* of any entities it loads from the database. It creates a snapshot of all the entity's property values, so it can track which ones have changed. When you call `SaveChanges()`, EF Core compares the state of any tracked entities (in this case, the `Recipe` entity) with the tracking snapshot. Any properties that have been changed are included in the `UPDATE` statement sent to the database, unchanged properties are ignored.

> **NOTE** EF Core provides other mechanisms to track changes, as well as options to disable change-tracking altogether. See the documentation or Jon P Smith's *EF Core in Action, Second Edition* (Manning, 2021) for details https://livebook.manning.com/book/entity-framework-core-in-action-second-edition/chapter-3.

With the ability to update recipes, you're almost done with your recipe app. "But wait," I hear you cry, "we haven't handled the *D* in CRUD—delete!" And that's true, but in reality, I've found few occasions when you *want* to delete data.

Let's consider the requirements for deleting a recipe from the application, as shown in figure 12.15. You need to add a (scary-looking) Delete button next to a recipe. After the user clicks Delete, the recipe is no longer visible in the list and can't be viewed.



Recipe	TimeToCook
Apfelwein	0hrs 15mins
Pork Wellington	0hrs 30mins

The main page of the application shows a list of all current recipes.

Apfelwein

A nice light white wine with a hint of apple

Apple Juice
5.0 Gallons

Corn Sugar
2.0 lb

Cote Des Blanc Yeast
1.0 Packet

Clicking View opens the recipe detail page.

Recipe	TimeToCook
Pork Wellington	0hrs 30mins

Clicking Delete returns you to the list view, but the deleted recipe is no longer visible

Figure 12.15 The desired behavior when deleting a recipe from the app. Clicking Delete should return you to the application's main list view, with the deleted recipe no longer visible.

Now, you *could* achieve this by deleting the recipe from the database, but the problem with data is once it's gone, it's gone! What if a user accidentally deletes a record? Also, deleting a row from a relational database typically has implications on other entities. For example, you can't delete a row from the Recipe table in your application without also deleting all the Ingredient rows that reference it, thanks to the foreign key constraint on `Ingredient.RecipeId`.

EF Core can easily handle these *true deletion* scenarios for you with the `DbContext.Remove(entity)` command but, typically, what you *mean* when you find a need to delete data is to "archive" it or hide it from the UI. A common approach to handling this scenario is to include some sort of "Is this entity deleted" flag on your entity, such as the `IsDeleted` flag I included on the `Recipe` entity:

```
public bool IsDeleted {get;set;}
```

If you take this approach then, suddenly, deleting data becomes simpler, as it's nothing more than an update to the entity. No more issues of lost data and no more referential integrity problems.

> **NOTE** The main exception I've found to this pattern is when you're storing your users' personally identifying information. In these cases, you may be duty-bound (and, potentially, legally bound) to scrub their information from your database on request.

With this approach, you can create a *delete* method on `RecipeService`, which updates the `IsDeleted` flag, as shown in the following listing. In addition, you should ensure you have `Where()` clauses in all the other methods in your `RecipeService`, to ensure you can't display a deleted `Recipe`, as you saw in listing 12.9, for the `GetRecipes()` method.

Listing 12.10 Marking entities as deleted in EF Core

```
public async Task DeleteRecipe(int recipeId)
{
    var recipe = await _context.Recipes.FindAsync(recipeId);       #A
    if(recipe is null) {                                     #B
        throw new Exception("Unable to find the recipe");    #B
    }                                                        #B
    recipe.IsDeleted = true;      #C
    await _context.SaveChangesAsync();       #D
}
```

#A Fetch the Recipe entity by id.
#B If an invalid id is provided, recipe will be null.
#C Mark the Recipe as deleted.
#D Execute the SQL to save the changes to the database.

This approach satisfies the requirements—it removes the recipe from the UI of the application—but it simplifies a number of things. This *soft delete* approach won't work for all scenarios, but I've found it to be a common pattern in projects I've worked on.

> **TIP** EF Core has a handy feature called ***global query filters***. These allow you to specify a `Where` clause at the model level, so you could, for example, ensure that EF Core ***never*** loads `Recipes` for which `IsDeleted` is `true`. This is also useful for segregating data in a multi-tenant environment. See the documentation for details: https://docs.microsoft.com/ef/core/querying/filters.

We're almost at the end of this chapter on EF Core. We've covered the basics of adding EF Core to your project and using it to simplify data access, but you'll likely need to read more into EF Core as your apps become more complex. In the final section of this chapter, I'd like to pinpoint a number of things you need to take into consideration before using EF Core in your own applications, so you're familiar with some of the issues you'll face as your apps grow.

12.5 Using EF Core in production applications

This book is about ASP.NET Core, not EF Core, so I didn't want to spend too much time exploring EF Core. This chapter should've given you enough to get up and running, but you'll definitely need to learn more before you even think about putting EF Core into production. As I've said several times, I recommend *EF Core in Action* by Jon P Smith (Manning, 2018) for details (https://livebook.manning.com/#!/book/smith3/Chapter-11/), or exploring the EF Core documentation site at https://docs.microsoft.com/ef/core/.

The following topics aren't essential to getting started with EF Core, but you'll quickly come up against them if you build a production-ready app. This section isn't a prescriptive guide to how to tackle each of these; it's more a set of things to consider before you dive into production!

- *Scaffolding of columns*—EF Core uses conservative values for things like `string` columns by allowing strings of large or unlimited length. In practice, you may want to restrict these and other data types to sensible values.
- *Validation*—You can decorate your entities with `DataAnnotations` validation attributes, but EF Core won't automatically validate the values before saving to the database. This differs from EF 6.x behavior, in which validation was automatic.
- *Handling concurrency*—EF Core provides a few ways to handle concurrency, where multiple users attempt to update an entity at the same time. One partial solution is by using `Timestamp` columns on your entities.
- *Synchronous vs. asynchronous*—EF Core provides both synchronous and asynchronous commands for interacting with the database. Often, async is better for web apps, but there are nuances to this argument that make it impossible to recommend one approach over the other in all situations.

EF Core is a great tool for being productive when writing data-access code, but there are some aspects of working with a database that are unavoidably awkward. The issue of database management is one of the thorniest issues to tackle. This book is about ASP.NET Core, not EF Core, so I don't want to dwell on database management too much. Having said that, most web applications use some sort of database, so the following issues are likely to impact you at some point.

- *Automatic migrations*—If you automatically deploy your app to production as part of some sort of DevOps pipeline, you'll inevitably need some way of applying migrations to a database automatically. You can tackle this in several ways, such as scripting the .NET Core tool, applying migrations in your app's startup code, or using a custom tool. Each approach has its pros and cons.
- *Multiple web hosts*—One specific consideration is whether you have multiple web servers hosting your app, all pointing to the same database. If so, then applying migrations in your app's startup code becomes harder, as you must ensure only one app can migrate the database at a time.
- *Making backward-compatible schema changes*—A corollary of the multiple-web host approach is that you'll often be in a situation where your app is accessing a database that has a *newer* schema than the app thinks. That means you should normally endeavor to make schema changes backward-compatible wherever possible.
- *Storing migrations in a different assembly*—In this chapter, I included all my logic in a single project, but in larger apps, data access is often in a different project to the web

app. For apps with this structure, you must use slightly different commands when using the .NET CLI or PowerShell cmdlets.

- *Seeding data*—When you first create a database, you often want it to have some initial *seed* data, such as a default user. EF 6.X had a mechanism for seeding data built in, whereas EF Core requires you to explicitly seed your database yourself.

How you choose to handle each of these issues will depend on the infrastructure and deployment approach you take with your application. None of them are particularly fun to tackle but they're an unfortunate necessity. Take heart though, they can all be solved one way or another!

That brings us to the end of this chapter on EF Core. In the next chapter, we'll look at one of the slightly more advanced topics of MVC and Razor Pages, the filter pipeline, and how you can use it to reduce duplication in your code.

12.6 Summary

- EF Core is an object-relational mapper (ORM) that lets you interact with a database by manipulating standard POCO classes, called entities, in your application. This can reduce the amount of SQL and database knowledge you need to have to be productive.
- EF Core maps entity classes to tables, properties on the entity to columns in the tables, and instances of entity objects to rows in these tables. Even if you use EF Core to avoid working with a database directly, you need to keep this mapping in mind.
- EF Core uses a database-provider model that lets you change the underlying database without changing any of your object manipulation code. EF Core has database providers for Microsoft SQL Server, SQLite, PostgreSQL, MySQL, and many others.
- EF Core is cross-platform and has good performance for an ORM, but has a different feature set to EF 6.x. Nevertheless, EF Core is recommended for all new applications over EF 6.x.
- EF Core stores an internal representation of the entities in your application and how they map to the database, based on the `DbSet<T>` properties on your application's `DbContext`. EF Core builds a model based on the entity classes themselves and any other entities they reference.
- You add EF Core to your app by adding a NuGet database provider package. You should also install the Design packages for EF Core. This works in conjunction with the .NET Core tools to generate and apply migrations to a database.
- EF Core includes many conventions for how entities are defined, such as primary keys and foreign keys. You can customize how entities are defined either declaratively, using `DataAnotations`, or using a fluent API.
- Your application uses a `DbContext` to interact with EF Core and the database. You register it with a DI container using `AddDbContext<T>`, defining the database provider and providing a connection string. This makes your `DbContext` available in the DI container throughout your app.

- EF Core uses migrations to track changes to your entity definitions. They're used to ensure your entity definitions, EF Core's internal model, and the database schema all match.
- After changing an entity, you can create a migration either using the .NET Core tool or using Visual Studio PowerShell cmdlets.
- To create a new migration with the .NET CLI, run `dotnet ef migrations add NAME` in your project folder, where `NAME` is the name you want to give the migration. This compares your current `DbContext` snapshot to the previous version and generates the necessary SQL statements to update your database.
- You can apply the migration to the database using `dotnet ef database update`. This will create the database if it doesn't already exist and apply any outstanding migrations.
- EF Core doesn't interact with the database when it creates migrations, only when you explicitly update the database, so you can still create migrations when you're offline.
- You can add entities to an EF Core database by creating a new entity, `e`, calling `_context.Add(e)` on an instance of your application's data context, `_context`, and calling `_context.SaveChangesAsync()`. This generates the necessary SQL `INSERT` statements to add the new rows to the database.
- You can load records from a database using the `DbSet<T>` properties on your app's `DbContext`. These expose the `IQueryable` interface, so you can use LINQ statements to filter and transform the data in the database before it's returned.
- Updating an entity consists of three steps: read the entity from the database, modify the entity, and save the changes to the database. EF Core will keep track of which properties have changed so that it can optimize the SQL it generates.
- You can delete entities in EF Core using the `Remove` method, but you should consider carefully whether you need this functionality. Often a *soft delete* technique using an `IsDeleted` flag on entities is safer and easier to implement.
- This chapter only covers a subset of the issues you must consider when using EF Core in your application. Before using it in a production app, you should consider, among other things: the data types generated for fields, validation, how to handle concurrency, the seeding of initial data, handling migrations on a running application, and handling migrations in a web-farm scenario.

13

The MVC and Razor Pages filter pipeline

This chapter covers

- **The filter pipeline and how it differs from middleware**
- **Creating custom filters to refactor complex action methods**
- **Using authorization filters to protect your action methods and Razor Pages**
- **Short-circuiting the filter pipeline to bypass action and page handler execution**
- **Injecting dependencies into filters**

In part 1, I covered the MVC and Razor Pages frameworks of ASP.NET Core in some detail. You learned how routing is used to select an action method or Razor Page to execute. You also saw model binding, validation, and how to generate a response by returning an `IActionResult` from your actions and page handlers. In this chapter, I'm going to head deeper into the MVC/Razor Pages frameworks and look at the *filter pipeline*, sometimes called the *action invocation pipeline*.

MVC and Razor Pages use several built-in filters to handle crosscutting concerns, such as authorization (controlling which users can access which action methods and pages in your application). Any application that has the concept of users will use authorization filters as a minimum, but filters are much more powerful than this single use case.

This chapter describes the filter pipeline primarily in the context of an API controller request. You'll learn how to create custom filters that you can use in your own apps, and how you can use them to reduce duplicate code in your action methods. You'll learn how to customize your application's behavior for specific actions, as well as how to apply filters globally to modify all of the actions in your app.

You'll also learn how the filter pipeline applies to Razor Pages. The Razor Pages filter pipeline is almost identical to the MVC/API controller filter pipeline, so we'll focus on where it differs. You'll see how to use page filters in your Razor Pages and learn how they differ from action filters.

Think of the filter pipeline as a mini middleware pipeline running inside the MVC and Razor Pages frameworks. Like the middleware pipeline in ASP.NET Core, the filter pipeline consists of a series of components connected as a pipe, so the output of one filter feeds into the input of the next.

This chapter starts by looking at the similarities and differences between filters and middleware, and when you should choose one over the other. You'll learn about all the different types of filters and how they combine to create the filter pipeline for a request that reaches the MVC or Razor Pages framework.

In section 13.2, I'll take you through each filter type in detail, how they fit into the MVC pipeline, and what to use them for. For each one, I'll provide example implementations that you might use in your own application.

A key feature of filters is the ability to short-circuit a request by generating a response and halting progression through the filter pipeline. This is similar to the way short-circuiting works in middleware, but there are subtle differences. On top of that, the exact behavior is slightly different for each filter, which I cover in section 13.3.

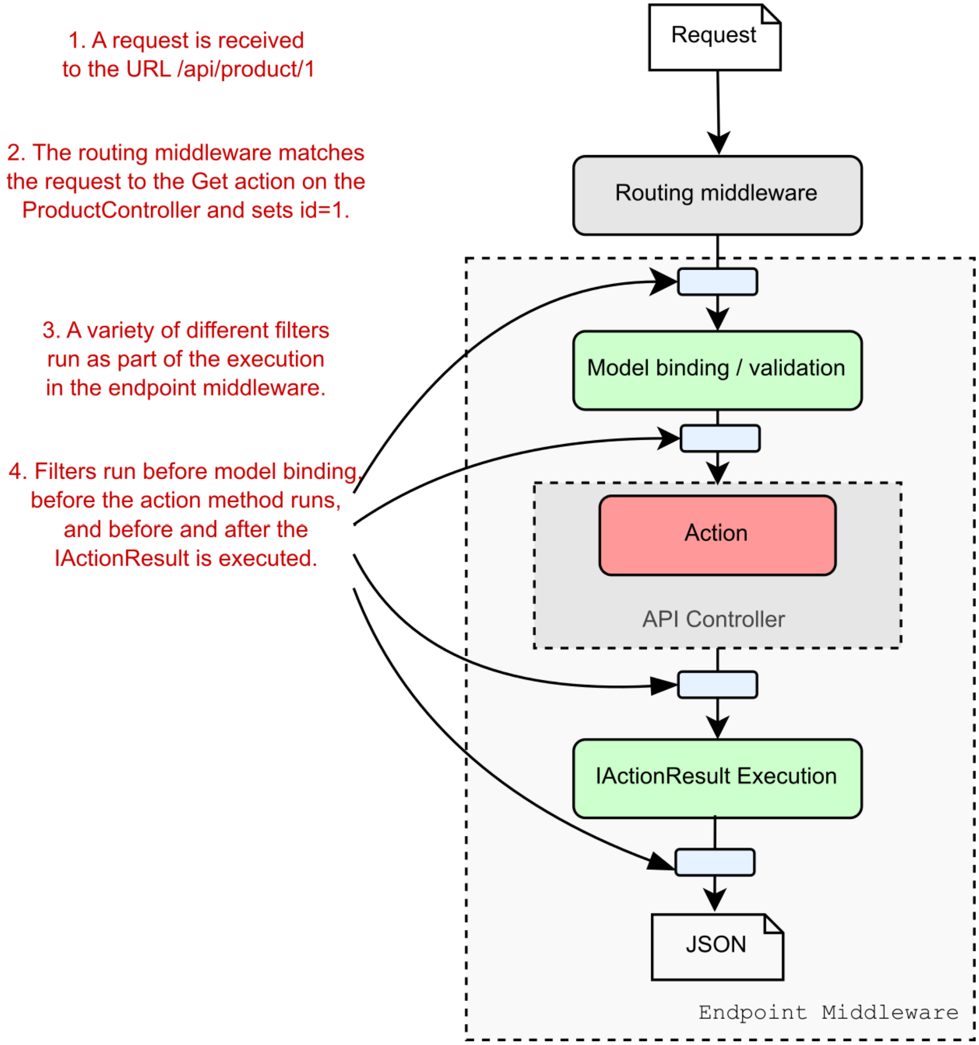
You typically add filters to the pipeline by implementing them as attributes added to your controller classes, action methods, and Razor Pages. Unfortunately, you can't easily use DI with attributes due to the limitations of C#. In section 13.4, I'll show you how to use the `ServiceFilterAttribute` and `TypeFilterAttribute` base classes to enable dependency injection in your filters.

Before we can start writing code, we should get to grips with the basics of the filter pipeline. The first section of this chapter explains what the pipeline is, why you might want to use it, and how it differs from the middleware pipeline.

13.1 Understanding filters and when to use them

In this section you'll learn all about the filter pipeline. You'll see where it fits in the lifecycle of a typical request, how it differs between MVC and Razor Pages, and how filters differ from middleware. You'll learn about the six types of filter, how you can add them to your own apps, and how to control the order in which they execute when handling a request.

The filter pipeline is a relatively simple concept, in that it provides *hooks* into the normal MVC request, as shown in figure 13.1. For example, say you wanted to ensure that users can create or edit products on an e-commerce app *only* if they're logged in. The app would redirect anonymous users to a login page instead of executing the action.



1. A request is received to the URL /api/product/1

2. The routing middleware matches the request to the Get action on the ProductController and sets id=1.

3. A variety of different filters run as part of the execution in the endpoint middleware.

4. Filters run before model binding, before the action method runs, and before and after the IActionResult is executed.

Figure 13.1 Filters run at multiple points in the `EndpointMiddleware` as part of the normal handling of an MVC request. A similar pipeline exists for Razor Page requests.

Without filters, you'd need to include the same code to check for a logged-in user at the start of each specific action method. With this approach the MVC framework would still execute the model binding and validation, even if the user were not logged in.

With filters, you can use the *hooks* in the MVC request to run common code across all, or a subset of, requests. This way, you can do a wide range of things, such as

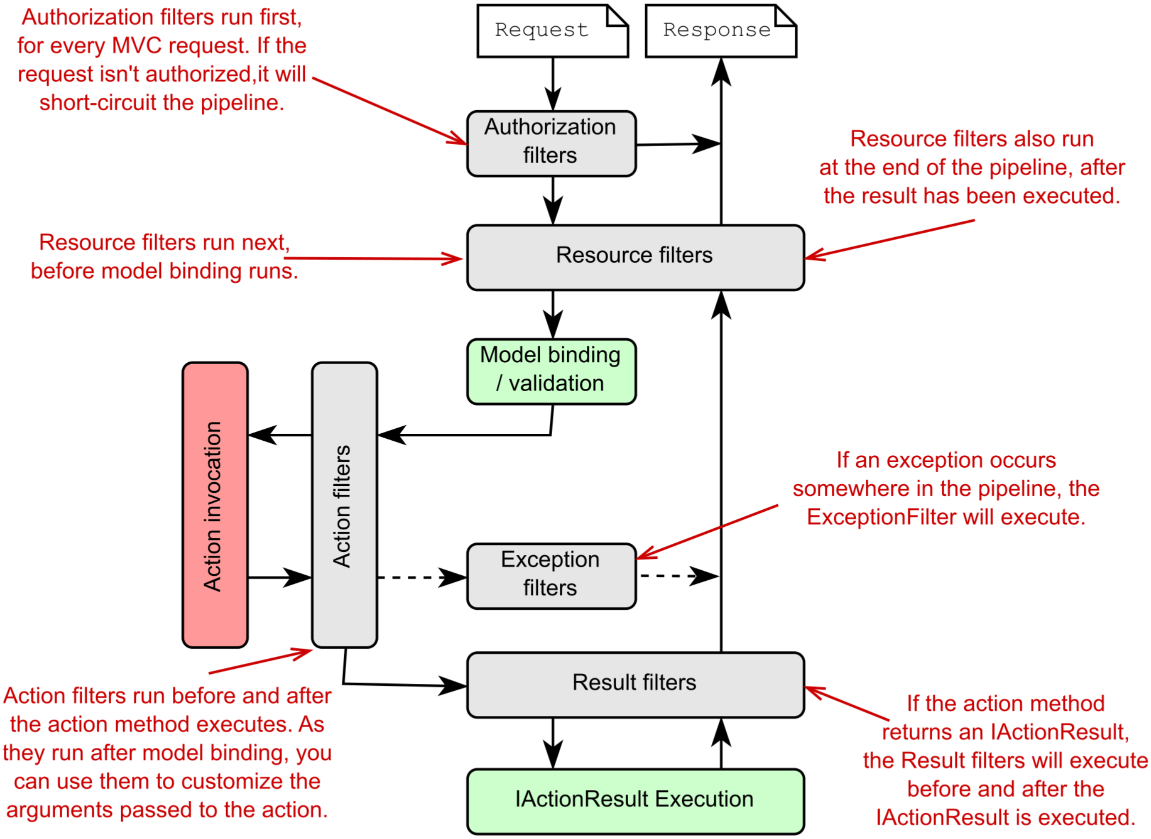
- Ensuring a user is logged in before an action method, model binding, or validation runs

- Customizing the output format of particular action methods
- Handling model validation failures before an action method is invoked
- Catching exceptions from an action method and handling them in a special way

In many ways, the filter pipeline is like a middleware pipeline, but restricted to MVC and Razor Pages requests only. Like middleware, filters are good for handling crosscutting concerns for your application and are a useful tool for reducing code duplication in many cases.

13.1.1 The MVC filter pipeline

As you saw in figure 13.1, filters run at a number of different points in an MVC request. This linear view of an MVC request and the filter pipeline that I've used so far doesn't *quite* match up with how these filters execute. There are five types of filter that apply to MVC requests, each of which runs at a different *stage* in the MVC framework, as shown in figure 13.2.



Authorization filters run first, for every MVC request. If the request isn't authorized,it will short-circuit the pipeline.

Resource filters also run at the end of the pipeline, after the result has been executed.

Resource filters run next, before model binding runs.

If an exception occurs somewhere in the pipeline, the ExceptionFilter will execute.

Action filters run before and after the action method executes. As they run after model binding, you can use them to customize the arguments passed to the action.

If the action method returns an IActionResult, the Result filters will execute before and after the IActionResult is executed.

Figure 13.2 The MVC filter pipeline, including the five different filter stages. Some filter stages (resource, action, and result) run twice, before and after the remainder of the pipeline.

Each filter stage lends itself to a particular use case, thanks to its specific location in the pipeline, with respect to model binding, action execution, and result execution.

- *Authorization filters*—These run first in the pipeline, so are useful for protecting your APIs and action methods. If an authorization filter deems the request unauthorized, it will short-circuit the request, preventing the rest of the filter pipeline (or action) from running.
- *Resource filters*—After authorization, resource filters are the next filters to run in the pipeline. They can also execute at the *end* of the pipeline, in much the same way that middleware components can handle both the incoming request and the outgoing response. Alternatively, resource filters can completely short-circuit the request pipeline and return a response directly.

  Thanks to their early position in the pipeline, resource filters can have a variety of uses. You could add metrics to an action method, prevent an action method from executing if an unsupported content type is requested, or, as they run before model binding, control the way model binding works for that request.
- *Action filters*—Action filters run just before and after an action method is executed. As model binding has already happened, action filters let you manipulate the arguments to the method—before it executes—or they can short-circuit the action completely and return a different `IActionResult`. Because they also run after the action executes, they can optionally customize an `IActionResult` returned by the action before the action result is executed.
- *Exception filters*—Exception filters can catch exceptions that occur in the filter pipeline and handle them appropriately. You can use exception filters to write custom MVC-specific error-handling code, which can be useful in some situations. For example, you could catch exceptions in API actions and format them differently from exceptions in your Razor Pages.
- *Result filters*—Result filters run before and after an action method's `IActionResult` is executed. You can use result filters to control the execution of the result, or even to short-circuit the execution of the result.

Exactly which filter you pick to implement will depend on the functionality you're trying to introduce. Want to short-circuit a request as early as possible? Resource filters are a good fit. Need access to the action method parameters? Use an action filter.

Think of the filter pipeline as a small middleware pipeline that lives by itself in the MVC framework. Alternatively, you could think of filters as *hooks* into the MVC action invocation process, which let you run code at a particular point in a request's lifecycle.

The example above describes how the filter pipeline works for MVC controllers, such as you would use to create APIs, but Razor Pages uses an almost identical filter pipeline.

13.1.2 The Razor Pages Filter pipeline

The Razor Pages framework uses the same underlying architecture as API controllers, so it’s perhaps not surprising that the filter pipeline is virtually identical. The only difference between the pipelines is that Razor Pages do not use action filters. Instead, they use page filters, as shown in figure 13.3.

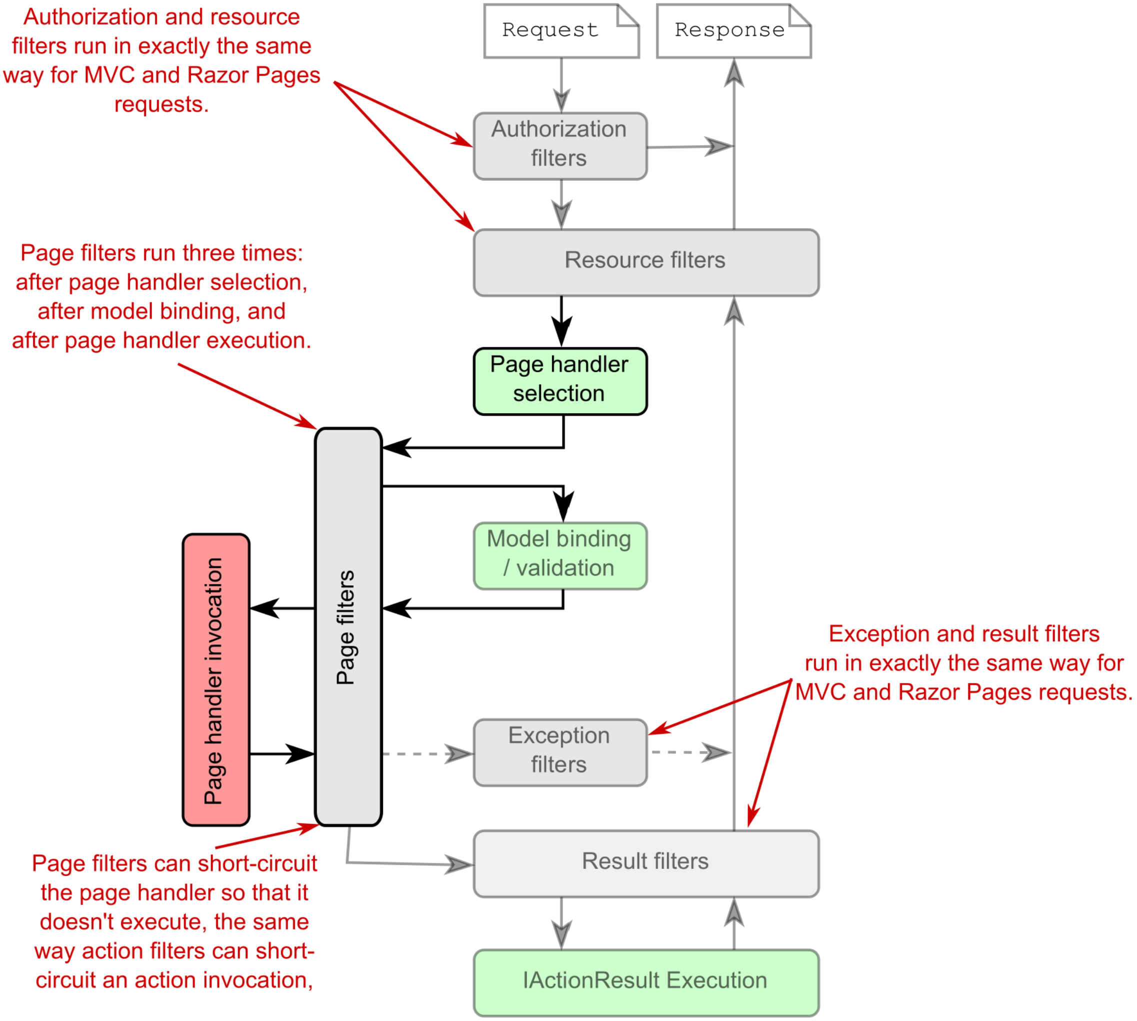

Authorization and resource filters run in exactly the same way for MVC and Razor Pages requests.
Request
Response
Authorization filters
Resource filters
Page filters run three times: after page handler selection, after model binding, and after page handler execution.
Page handler selection
Model binding / validation
Page filters
Page handler invocation
Exception and result filters run in exactly the same way for MVC and Razor Pages requests.
Exception filters
Result filters
Page filters can short-circuit the page handler so that it doesn't execute, the same way action filters can short-circuit an action invocation,
IActionResult Execution

Figure 13.3 The Razor Pages filter pipeline, including the five different filter stages. Authorization, resource, exception, and result filters execute in exactly the same way as for the MVC pipeline. Page filters are specific to Razor Pages and execute in three places: after page hander selection, after model binding and validation, and after page handler execution.

The authorization, resource, exception, and result filters are exactly the same filters as you saw for the MVC pipeline. They execute in the same way, serve the same purposes, and can be short-circuited in the same way.

> **NOTE** These filters are literally the same classes shared between the Razor Pages and MVC frameworks. For example, if you create an exception filter and register it globally, the filter will apply to all your API controllers and all your Razor Pages equally.

The difference with the Razor Pages filter pipeline is that it uses *page filters* instead of action filters. In contrast to other filter types, page filters run three times in the filter pipeline:

- *After page handler selection*—After the resource filters have executed, a page handler is selected, based on the request's HTTP verb and the `{handler}` route value, as you learned in chapter 5. After page handler selection, a page filter method executes for the first time. You can't short-circuit the pipeline at this stage, and model binding and validation has not yet executed.
- *After model binding*—After the first page filter execution, the request is model bound to the Razor Page's binding models and is validated. This execution is highly analogous to the action filter execution for API controllers. At this point you could manipulate the model-bound data or short-circuit the page handler execution completely by returning a different `IActionResult`.
- *After page handler execution*—If you don't short circuit the page handler execution, the page filter runs a third and final time after the page handler has executed. At this point you could customize the `IActionResult` returned by the page handler before the result is executed.

The triple-execution of page filters makes it a bit harder to visualize the pipeline, but you can generally just think of them as beefed-up action filters. Everything you can do with an action filter you can do with a page filter. Plus, you can hook-in after page handler selection if necessary.

> **TIP** Each execution of a filter executes a different method of the appropriate interface, so it's easy to know where you are in the pipeline, and to only execute a filter in one of its possible locations if you wish.

One of the main questions I hear when people learn about filters in ASP.NET Core is "Why do we need them?" If the filter pipeline is like a mini middleware pipeline, why not use a middleware component directly, instead of introducing the filter concept? That's an excellent point, which I'll tackle in the next section.

13.1.3 Filters or middleware: which should you choose?

The filter pipeline is similar to the middleware pipeline in many ways, but there are several subtle differences that you should consider when deciding which approach to use. When considering the similarities, they have three main parallels:

- *Requests pass through a middleware component on the way "in" and responses pass through again on the way "out."* Resource, action, and result filters are also two-way, though authorization and exception filters run only once for a request, and page filters run three times!
- *Middleware can short-circuit a request by returning a response, instead of passing it on to later middleware.* Filters can also short-circuit the filter pipeline by returning a response.
- *Middleware is often used for crosscutting application concerns, such as logging, performance profiling, and exception handling.* Filters also lend themselves to crosscutting concerns.

In contrast, there are three main differences between middleware and filters:

- Middleware can run for all requests; filters will only run for requests that reach the `EndpointMiddleware` and execute an API controller action or Razor Page.
- Filters have access to MVC constructs such as `ModelState` and `IActionResults`. Middleware, in general, is independent from MVC and Razor Pages, so can't use these concepts.
- Filters can be easily applied to a subset of requests; for example, all actions on a single controller, or a single Razor Page. Middleware doesn't have this concept as a first-class idea (though you could achieve something similar with custom middleware components).

That's all well and good, but how should we interpret these differences? When should we choose one over the other?

I like to think of middleware versus filters as a question of specificity. Middleware is the more general concept, so has the wider reach. If the functionality you need has no MVC-specific requirements, then you should use a middleware component. Exception handling is a great example of this; exceptions could happen anywhere in your application, and you need to handle them, so using exception-handling middleware makes sense.

On the other hand, if you *do* need access to MVC constructs, or you want to behave differently for some MVC actions, then you should consider using a filter. Ironically, this can also be applied to exception handling. You don't want exceptions in your Web API controllers to automatically generate HTML error pages when the client is expecting JSON. Instead, you could use an exception filter on your Web API actions to render the exception to JSON, while letting the exception-handling middleware catch errors from Razor Pages in your app.

> **TIP** **Where possible, consider using middleware for crosscutting concerns. Use filters when you need different behavior for different action methods, or where the functionality relies on MVC concepts like** `ModelState` **validation.**

The middleware versus filters argument is a subtle one, and it doesn't matter which you choose as long as it works for you. You can even use middleware components *inside* the filter pipeline as filters, but that's outside the scope of this book.

> **TIP** The middleware as filters feature was introduced in ASP.NET Core 1.1 and is also available in later versions. The canonical use case is for localizing requests to multiple languages. I have a blog series on how to use the feature here: https://andrewlock.net/series/adding-a-url-culture-provider-using-middleware-as-filters/.

Filters can be a little abstract in isolation, so in the next section, we'll look at some code and learn how to write a custom filter in ASP.NET Core.

13.1.4 Creating a simple filter

In this section, I show how to create your first filters; in section 13.1.5, you'll see how to apply them to MVC controllers and actions. We'll start small, creating filters that just write to the console, but in section 13.2, we'll look at some more practical examples and discuss some of their nuances.

You implement a filter for a given stage by implementing one of a pair of interfaces—one synchronous (sync), one asynchronous (async):

- *Authorization filters*—`IAuthorizationFilter` or `IAsyncAuthorizationFilter`
- *Resource filters*—`IResourceFilter` or `IAsyncResourceFilter`
- *Action filters*—`IActionFilter` or `IAsyncActionFilter`
- *Page filters*—`IPageFilter` or `IAsyncPageFilter`
- *Exception filters*—`IExceptionFilter` or `IAsyncExceptionFilter`
- *Result filters*—`IResultFilter` or `IAsyncResultFilter`

You can use any POCO class to implement a filter, but you'll typically implement them as C# attributes, which you can use to decorate your controllers, actions, and Razor Pages, as you'll see in section 13.1.5. You can achieve the same results with either the sync or async interface, so which you choose should depend on whether any services you call in the filter require async support.

> **NOTE** You should implement *either* the sync interface *or* the async interface, *not both*. If you implement both, then only the async interface will be used.

Listing 13.1 shows a resource filter that implements `IResourceFilter` and writes to the console when it executes. The `OnResourceExecuting` method is called when a request first reaches the resource filter stage of the filter pipeline. In contrast, the `OnResourceExecuted` method is called after the rest of the pipeline has executed; after model binding, action execution, result execution, and all intermediate filters have run.

Listing 13.1 Example resource filter implementing `IResourceFilter`

```
public class LogResourceFilter : Attribute, IResourceFilter
```

```
{
    public void OnResourceExecuting(         #A
        ResourceExecutingContext context)    #B
    {
        Console.WriteLine("Executing!");
    }

    public void OnResourceExecuted(          #C
        ResourceExecutedContext context)     #D
    {
        Console.WriteLine("Executed”");
    }
}
```

#A Executed at the start of the pipeline, after authorization filters.
#B The context contains the HttpContext, routing details, and information about the current action.
#C Executed after model binding, action execution, and result execution.
#D Contains additional context information, such as the IActionResult returned by the action.

The interface methods are simple and are similar for each stage in the filter pipeline, passing a context object as a method parameter. Each of the two-method sync filters has an `*Executing` and an `*Executed` method. The type of the argument is different for each filter, but it contains all the details for the filter pipeline.

For example, the `ResourceExecutingContext` passed to the resource filter contains the `HttpContext` object itself, details about the route that selected this action, details about the action itself, and so on. Contexts for later filters will contain additional details, such as the action method arguments for an action filter and the `ModelState`.

The context object for the `ResourceExecutedContext` method is similar, but it also contains details about how the rest of the pipeline executed. You can check whether an unhandled exception occurred, you can see if another filter from the same stage short-circuited the pipeline, or you can see the `IActionResult` used to generate the response.

These context objects are powerful and are the key to advanced filter behaviors like short-circuiting the pipeline and handling exceptions. We’ll make use of them in section 13.2 when creating more complex filter examples.

The async version of the resource filter requires implementing a single method, as shown in listing 13.2. As for the sync version, you’re passed a `ResourceExecutingContext` object as an argument, and you’re passed a delegate representing the remainder of the filter pipeline. You must call this delegate (asynchronously) to execute the remainder of the pipeline, which will return an instance of `ResourceExecutedContext`.

Listing 13.2 Example resource filter implementing `IAsyncResourceFilter`

```
public class LogAsyncResourceFilter : Attribute, IAsyncResourceFilter
{
    public async Task OnResourceExecutionAsync(                #A
        ResourceExecutingContext context,
        ResourceExecutionDelegate next)                        #B
    {
        Console.WriteLine("Executing async!");                     #C
        ResourceExecutedContext executedContext = await next();      #D
        Console.WriteLine("Executed async!");                        #E
    }
}
```

#A Executed at the start of the pipeline, after authorization filters.
#B You’re provided a delegate, which encapsulates the remainder of the filter pipeline.
#C Called before the rest of the pipeline executes.
#D Executes the rest of the pipeline and obtains a ResourceExecutedContext instance
#E Called after the rest of the pipeline executes.

The sync and async filter implementations have subtle differences, but for most purposes they’re identical. I recommend implementing the sync version if possible, and only falling back to the async version if you need to.

You’ve created a couple of filters now, so we should look at how to use them in the application. In the next section, we’ll tackle two specific issues: how to control which requests execute your new filters and how to control the order in which they execute.

13.1.5 Adding filters to your actions, controllers, Razor Pages, and globally

In section 13.1.2, I discussed the similarities and differences between middleware and filters. One of those differences is that filters can be scoped to specific actions or controllers, so that they only run for certain requests. Alternatively, you can apply a filter globally, so that it runs for every MVC action and Razor Page.

By adding filters in different ways, you can achieve several different results. Imagine you have a filter that forces you to log in to execute an action. How you add the filter to your app will significantly change your app’s behavior:

- *Apply the filter to a single action or Razor Page*—Anonymous users could browse the app as normal, but if they tried to access the protected action or Razor Page, they would be forced to log in.
- *Apply the filter to a controller*—Anonymous users could access actions from other controllers, but accessing any action on the protected controller would force them to log in.
- *Apply the filter globally*—Users couldn’t use the app without logging in. Any attempt to access an action or Razor Page would redirect the user to the login page.

> **NOTE** **ASP.NET Core comes with just such a filter out of the box,** `AuthorizeFilter`**. I’ll discuss this filter in section 13.2.1, and you’ll be seeing a lot more of it in chapter 15.**

As I described in the previous section, you normally create filters as attributes, and for good reason—it makes it easy for you to apply them to MVC controllers, actions, and Razor Pages. In this section, you’ll see how to apply `LogResourceFilter` from listing 13.1 to an action, a controller, a Razor Page, and globally. The level at which the filter applies is called its *scope*.

DEFINITION The *scope* of a filter refers to how many different actions it applies to. A filter can be scoped to the action method, to the controller, to a Razor Page, or globally.

You'll start at the most specific scope—applying filters to a single action. The following listing shows an example of an MVC controller that has two action methods: one with `LogResourceFilter` and one without.

Listing 13.3 Applying filters to an action method

```
public class RecipeController : ControllerBase
{
    [LogResourceFilter]              #A
    public IActionResult Index()     #A
    {                                #A
        return Ok();                 #A
    }                                #A
    public IActionResult View()      #B
    {                                #B
        return OK();                 #B
    }                                #B
}
```

#A LogResourceFilter will run as part of the pipeline when executing this action.
#B This action method has no filters at the action level.

Alternatively, if you want to apply the same filter to every action method, you could add the attribute at the controller scope, as in the next listing. Every action method in the controller will use `LogResourceFilter`, without having to specifically decorate each method:

Listing 13.4 Applying filters to a controller

```
[LogResourceFilter]                        #A
public class RecipeController : ControllerBase
{
    public IActionResult Index ()          #B
    {                                      #B
        return Ok();                       #B
    }                                      #B
    public IActionResult View()            #B
    {                                      #B
        return Ok();                       #B
    }                                      #B
}
```

#A The LogResourceFilter Is added to every action on the controller.
#B Every action in the controller is decorated with the filter.

For Razor Pages, you can apply attributes to your `PageModel`, as shown in the following listing. The filter applies to all page handlers in the Razor Page—it's not possible to apply filters to a single page handler, you must apply them at the page level.

Listing 13.5 Applying filters to a Razor Page

```
[LogResourceFilter]                      #A
public class IndexModel : PageModel
{
    public void OnGet()                  #B
    {                                      #B
    }                                      #B

    public void OnPost()                   #B
    {                                      #B
    }                                      #B
}
```

#A The LogResourceFilter Is added to the Razor Page’s PageModel.
#B The filter applies to every page handler in the page.

Filters you apply as attributes to controllers, actions, and Razor Pages are automatically discovered by the framework when your application starts up. For common attributes, you can go one step further and apply filters globally, without having to decorate individual classes.

You add global filters in a different way to controller- or action-scoped filters—by adding a filter directly to the MVC services, when configuring your controllers and Razor Pages in `Startup`. This listing shows three equivalent ways to add a globally scoped filter.

Listing 13.6 Applying filters globally to an application

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services)
    {
        services.AddControllers(options =>         #A
        {
            options.Filters.Add(new LogResourceFilter());       #B
            options.Filters.Add(typeof(LogResourceFilter));     #C
            options.Filters.Add<LogResourceFilter>();           #D
        });
    }
}
```

#A Adds filters using the MvcOptions object
#B You can pass an instance of the filter directly. . .
#C . . . or pass in the Type of the filter and let the framework create it.
#D Alternatively, the framework can create a global filter using a generic type parameter.

You can configure the `MvcOptions` by using the `AddControllers()` overload. When you configure filters globally, they apply both to controllers *and* to any Razor Pages in your application. If you’re using Razor Pages in your application instead, there isn’t an overload for configuring the `MvcOptions`. Instead you need to use the `AddMvcOptions()` extension method to configure the filters, as shown in the following listing.

Listing 13.7 Applying filters globally to a Razor Pages application

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services)
    {
        services.AddRazorPages()                                #A
            .AddMvcOptions(options =>                           #B
            {
                options.Filters.Add(new LogResourceFilter());       #C
                options.Filters.Add(typeof(LogResourceFilter));     #C
                options.Filters.Add<LogResourceFilter>();           #C
            });
    }
}
```

#A This method doesn't let you pass a lambda to configure the MvcOptions
#B ...so you must use an extension method to add the filters to the MvcOptions object
#C You can configure the filters in any of the ways shown previously.

With potentially three different scopes in play, you'll often find action methods that have multiple filters applied to them, some applied directly to the action method, and others inherited from the controller or globally. The question then becomes: which filter runs first?

13.1.6 Understanding the order of filter execution

You've seen that the filter pipeline contains five different *stages*, one for each type of filter. These stages always run in the fixed order I described in sections 13.1.1 and 13.1.2. But within each stage, you can also have multiple filters of the same type (for example, multiple resource filters) that are part of a single action method's pipeline. These could all have multiple *scopes*, depending on how you added them, as you saw in the last section.

In this section, we're thinking about the *order of filters within a given stage* and how scope affects this. We'll start by looking at the default order, then move on to ways to customize the order to your own requirements.

THE DEFAULT SCOPE EXECUTION ORDER

When thinking about filter ordering, it's important to remember that resource, action, and result filters implement two methods: an `*Executing` before method and an `*Executed` after method. On top of that, page filters implement three methods! The order in which each method executes depends on the scope of the filter, as shown in figure 13.4 for the resource filter stage.

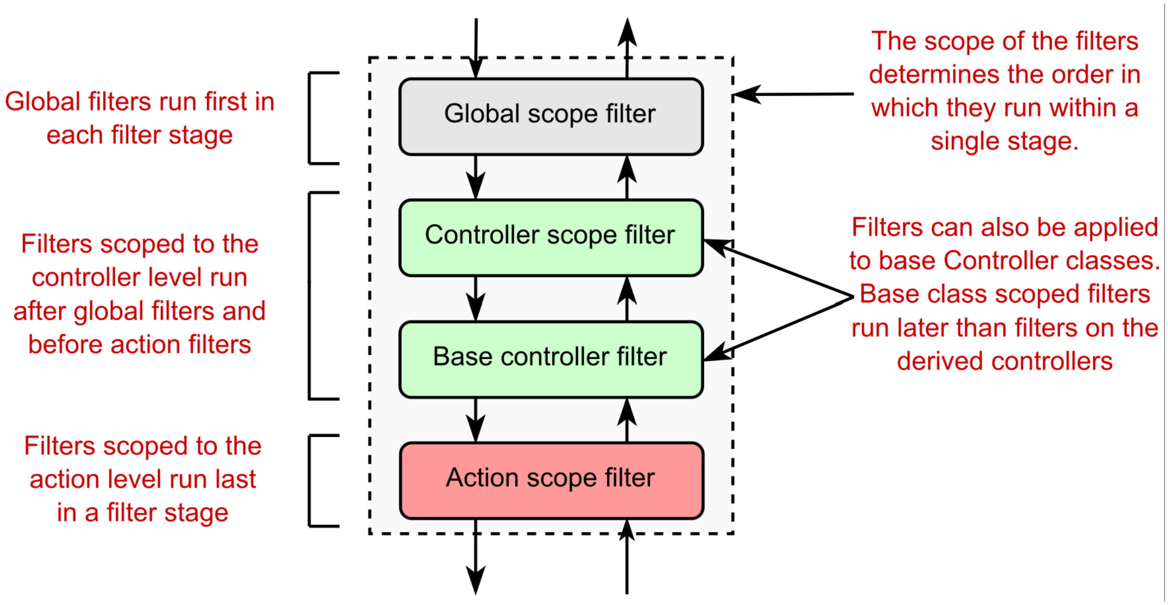

Global filters run first in each filter stage
Filters scoped to the controller level run after global filters and before action filters
Filters scoped to the action level run last in a filter stage
Global scope filter
Controller scope filter
Base controller filter
Action scope filter
The scope of the filters determines the order in which they run within a single stage.
Filters can also be applied to base Controller classes. Base class scoped filters run later than filters on the derived controllers

Figure 13.4 The default filter ordering within a given stage, based on the scope of the filters. For the `*Executing` method, globally scoped filters run first, followed by controller-scoped, and finally, action-scoped filters. For the `*Executed` method, the filters run in reverse order.

By default, filters execute from the broadest scope (global) to the narrowest (action) when running the `*Executing` method for each stage. The `*Executed` methods run in reverse order, from the narrowest scope (action) to the broadest (global).

The ordering for Razor Pages is somewhat simpler, given that you only have two scopes—global scope filters and Razor Page scope filters. For Razor Pages, global scope filters run the `*Executing` and `PageHandlerSelected` methods first, followed by the page scope filters. For the `*Executed` methods, the filters run in reverse order.

You'll sometimes find you need a bit more control over this order, especially if you have, for example, multiple action filters applied at the same scope. The filter pipeline caters to this requirement by way of the `IOrderedFilter` interface.

OVERRIDING THE DEFAULT ORDER OF FILTER EXECUTION WITH IORDEREDFILTER

Filters are great for extracting crosscutting concerns from your controller actions and Razor Page, but if you have multiple filters applied to an action, then you'll often need to control the precise order in which they execute.

Scope can get you some of the way, but for those other cases, you can implement `IOrderFilter`. This interface consists of a single property, `Order`:

```
public interface IOrderedFilter
{
    int Order { get; }
}
```

You can implement this property in your filters to set the order in which they execute. The filter pipeline orders the filters in a stage based on this value first, from lowest to highest, and uses the default scope order to handle ties, as shown in figure 13.5.

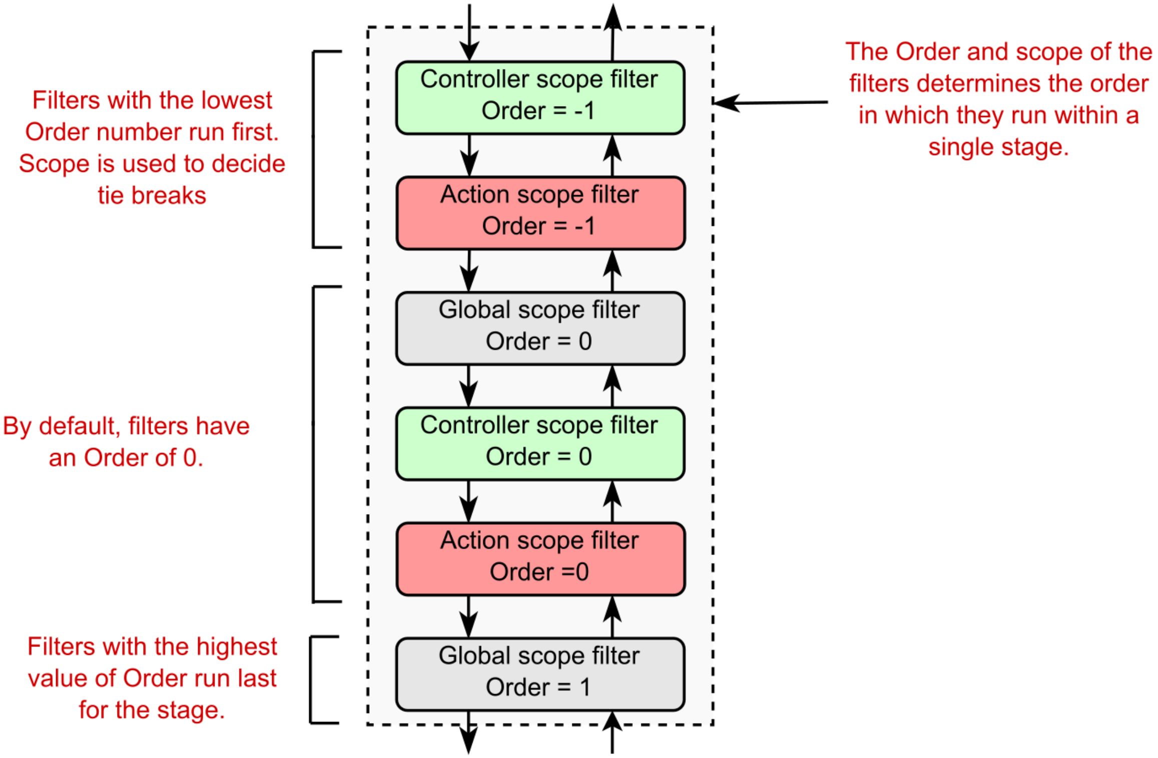

Filters with the lowest Order number run first. Scope is used to decide tie breaks
By default, filters have an Order of 0.
Filters with the highest value of Order run last for the stage.
Controller scope filter Order = -1
Action scope filter Order = -1
Global scope filter Order = 0
Controller scope filter Order = 0
Action scope filter Order =0
Global scope filter Order = 1
The Order and scope of the filters determines the order in which they run within a single stage.

Figure 13.5 Controlling the filter order for a stage using the `IOrderedFilter` interface. Filters are ordered by the `Order` property first, and then by scope.

The filters for `Order = -1` execute first, as they have the lowest `Order` value. The controller filter executes first because it has a broader scope than the action-scope filter. The filters with `Order=0` execute next, in the default scope order, as shown in figure 13.5. Finally, the filter with `Order=1` executes.

By default, if a filter doesn't implement `IOrderedFilter`, it's assumed to have `Order = 0`. All the filters that ship as part of ASP.NET Core have `Order = 0`, so you can implement your own filters relative to these.

This section has covered most of the technical details you need to use filters and create custom implementations for your own application. In the next section, you'll see some of the built-in filters provided by ASP.NET Core, as well as some practical examples of filters you might want to use in your own applications.

13.2 Creating custom filters for your application

ASP.NET Core includes a number of filters that you can use, but often, the most useful filters are the custom ones that are specific to your own apps. In this section, you'll work through each of the six types of filters. I'll explain in more detail what they're for and when you should use them. I'll point out examples of these filters that are part of ASP.NET Core itself and you'll see how to create custom filters for an example application.

To give you something realistic to work with, you'll start with a Web API controller for accessing the recipe application from chapter 12. This controller contains two actions: one for fetching a `RecipeDetailViewModel` and another for updating a `Recipe` with new values. This listing shows your starting point for this chapter, including both of the action methods.

Listing 13.8 Recipe Web API controller before refactoring to use filters

```
[Route("api/recipe")]
public class RecipeApiController : ControllerBase
{
    private const bool IsEnabled = true;           #A
    public RecipeService _service;
    public RecipeApiController(RecipeService service)
    {
        _service = service;
    }

    [HttpGet("{id}")]
    public IActionResult Get(int id)
    {
        if (!IsEnabled) { return BadRequest(); }   #B
        try
        {
            if (!_service.DoesRecipeExist(id))     #C
            {                                      #C
                return NotFound();                 #C
            }                                      #C
            var detail = _service.GetRecipeDetail(id);    #D
            Response.GetTypedHeaders().LastModified =     #E
                detail.LastModified;                      #E
            return Ok(detail);                            #F
        }
        catch (Exception ex)                 #G
        {                                    #G
            return GetErrorResponse(ex);     #G
        }                                    #G
    }

    [HttpPost("{id}")]
    public IActionResult Edit(
        int id, [FromBody] UpdateRecipeCommand command)
    {
        if (!IsEnabled) { return BadRequest(); }     #H
        try
        {
            if (!ModelState.IsValid)               #I
            {                                      #I
                return BadRequest(ModelState);     #I
            }                                      #I
            if (!_service.DoesRecipeExist(id))     #J
            {                                      #J
                return NotFound();                #J
            }                                     #J
            _service.UpdateRecipe(command);     #K
            return Ok();                        #K
        }
        catch (Exception ex)                 #L
        {                                    #L
            return GetErrorResponse(ex);     #L
        }                                    #L
    }

    private static IActionResult GetErrorResponse(Exception ex)
    {
        var error = new ProblemDetails
        {
            Title = "An error occured",
            Detail = context.Exception.Message,
            Status = 500,
            Type = "https://httpstatuses.com/500"
        };

        return new ObjectResult(error)
        {
            StatusCode = 500
        };
    }
}
```

#A This field would be passed in as configuration and is used to control access to actions.
#B If the API isn’t enabled, block further execution.
#C If the requested Recipe doesn’t exist, return a 404 response.
#D Fetch RecipeDetailViewModel.
#E Sets the Last-Modified response header to the value in the model
#F Returns the view model with a 200 response
#G If an exception occurs, catch it, and return the error in an expected format, as a 500 error.
#H If the API isn’t enabled, block further execution.
#I Validates the binding model and returns a 400 response if there are errors
#J If the requested Recipe doesn’t exist, return a 404 response.
#K Updates the Recipe from the command and returns a 200 response
#L If an exception occurs, catch it, and return the error in an expected format, as a 500 error.

These action methods currently have a *lot* of code to them, which hides the intent of each action. There’s also quite a lot of duplication between the methods, such as checking that the `Recipe` entity exists, and formatting exceptions.

In this section, you’re going to refactor this controller to use filters for all the code in the methods that’s unrelated to the intent of each action. By the end of the chapter, you’ll have a much simpler controller that’s far easier to understand, as shown here.

Listing 13.9 Recipe Web API controller after refactoring to use filters

```
[Route("api/recipe")]
[ValidateModel, HandleException, FeatureEnabled(IsEnabled = true)]    #A
public class RecipeApiController : ControllerBase
{
    public RecipeService _service;
    public RecipeApiController(RecipeService service)
    {
        _service = service;
    }

    [HttpGet("{id}"), EnsureRecipeExists, AddLastModifedHeader]     #B
    public IActionResult Get(int id)
    {
        var detail = _service.GetRecipeDetail(id);      #C
        return Ok(detail);                              #C
    }

    [HttpPost("{id}"), EnsureRecipeExists]      #D
    public IActionResult Edit(
        int id, [FromBody] UpdateRecipeCommand command)
    {
        _service.UpdateRecipe(command);     #E
        return Ok();                        #E
    }
}
```

#A The filters encapsulate the majority of logic common to multiple action methods.
#B Placing filters at the action level limits them to a single action.
#C The intent of the action, return a Recipe view model, is much clearer.
#D Placing filters at the action level can be used to control the order in which they execute.
#E The intent of the action, update a Recipe, is much clearer.

I think you'll have to agree, the controller in listing 13.9 is much easier to read! In this section, you’ll refactor the controller bit by bit, removing crosscutting code to get to something more manageable. All the filters I’ll create in this section will use the sync filter interfaces—I’ll leave it as an exercise for the reader to create their async counterparts. You’ll start by looking at authorization filters and how they relate to security in ASP.NET Core.

13.2.1 Authorization filters: protecting your APIs

Authentication and *authorization* are related, fundamental concepts in security that we’ll be looking at in detail in chapters 14 and 15.

> **DEFINITION** *Authentication* is concerned with determining *who* made a request. *Authorization* is concerned with *what* a user is allowed to access.

Authorization filters run first in the MVC filter pipeline, before any other filters. They control access to the action method by immediately short-circuiting the pipeline when a request doesn't meet the necessary requirements.

ASP.NET Core has a built-in authorization framework that you should use when you need to protect your MVC application or your Web APIs. You can configure this framework with custom policies that let you finely control access to your actions.

> **TIP** It's possible to write your own authorization filters by implementing `IAuthorizationFilter` or `IAsyncAuthorizationFilter`, but I strongly advise against it. The ASP.NET Core authorization framework is highly configurable and should meet all your needs.

At the heart of the ASP.NET Core authorization framework is an Authorization filter, `AuthorizeFilter`, which you can add to the filter pipeline by decorating your actions or controllers with the `[Authorize]` attribute. In its simplest form, adding the `[Authorize]` attribute to an action, as in the following listing, means the request must be made by an authenticated user to be allowed to continue. If you're not logged in, it will short-circuit the pipeline, returning a `401 Unauthorized` response to the browser.

Listing 13.10 Adding `[Authorize]` to an action method

```
public class RecipeApiController : ControllerBase
{
    public IActionResult Get(int id)        #A
    {
        // method body
    }

    [Authorize]                             #B
    public IActionResult Edit(                              #C
        int id, [FromBody] UpdateRecipeCommand command)     #C
    {
        // method body
    }
}
```

#A The Get method has no [Authorize] attribute, so can be executed by anyone.
#B Adds the AuthorizeFilter to the filter pipeline using [Authorize]
#C The Edit method can only be executed if you're logged in.

As with all filters, you can apply the `[Authorize]` attribute at the controller level to protect all the actions on a controller, to a Razor Page to protect all the page handler methods in a page, or even globally, to protect every endpoint in your app.

> **NOTE** We'll explore authorization in detail in chapter 15, including how to add more detailed requirements, so that only specific sets of users can execute an action.

The next filters in the pipeline are resource filters. In the next section, you'll extract some of the common code from RecipeApiController and see how easy it is to create a short-circuiting filter.

13.2.2 Resource filters: short-circuiting your action methods

Resource filters are the first general-purpose filters in the MVC filter pipeline. In section 13.1.4, you saw minimal examples of both sync and async resource filters, which logged to the console. In your own apps, you can use resource filters for a wide range of purposes, thanks to the fact that they execute so early (and late) in the filter pipeline.

The ASP.NET Core framework includes a few different implementations of resource filters you can use in your apps, for example:

- ConsumesAttribute—Can be used to restrict the allowed formats an action method can accept. If your action is decorated with [Consumes("application/json")] but the client sends the request as XML, then the resource filter will short-circuit the pipeline and return a 415 Unsupported Media Type response.
- DisableFormValueModelBindingAttribute—This filter prevents model binding from binding to form data in the request body. This can be useful if you know an action method will be handling large file uploads that you need to manage manually yourself. The resource filters run before model binding, so you can disable the model binding for a single action in this way.[59]

Resource filters are useful when you want to ensure the filter runs early in the pipeline, before model binding. They provide an early hook into the pipeline for your logic, so you can quickly short-circuit the request if you need to.

Look back at listing 13.8 and see if you can refactor any of the code into a Resource filter. One candidate line appears at the start of both the Get and Edit methods:

```
if (!IsEnabled) { return BadRequest(); }
```

This line of code is a *feature toggle* that you can use to disable the availability of the whole API, based on the IsEnabled field. In practice, you'd probably load the IsEnabled field from a database or configuration file so you could control the availability dynamically at runtime but, for this example, I'm using a hardcoded value.[60]

This piece of code is self-contained, crosscutting logic, which is somewhat tangential to the main intent of each action method—a perfect candidate for a filter. You want to execute the feature toggle early in the pipeline, before any other logic, so a resource filter makes sense.

[59] For details on handling file uploads, see https://docs.microsoft.com/aspnet/core/mvc/models/file-uploads.
[60] To read more about using feature toggles in your applications, see https://andrewlock.net/series/adding-feature-flags-to-an-asp-net-core-app/.

TIP Technically, you could also use an Authorization filter for this example, but I'm following my own advice of "Don't write your own Authorization filters!"

The next listing shows an implementation of FeatureEnabledAttribute, which extracts the logic from the action methods and moves it into the filter. I've also exposed the IsEnabled field as a property on the filter.

Listing 13.11 The FeatureEnabledAttribute resource filter

```
public class FeatureEnabledAttribute : Attribute, IResourceFilter
{
    public bool IsEnabled { get; set; }        #A
    public void OnResourceExecuting(           #B
        ResourceExecutingContext context)      #B
    {
        if (!IsEnabled)                                  #C
        {                                                #C
            context.Result = new BadRequestResult();     #C
        }                                                #C
    }
    public void OnResourceExecuted(             #D
        ResourceExecutedContext context) { }    #D
}
```

#A Defines whether the feature is enabled
#B Executes before model binding, early in the filter pipeline
#C If the feature isn't enabled, short-circuits the pipeline by setting the context.Result property
#D Must be implemented to satisfy IResourceFilter, but not needed in this case.

This simple resource filter demonstrates a number of important concepts, which are applicable to most filter types:

- The filter is an attribute as well as a filter. This lets you decorate your controller, action methods, and Razor Pages with it using [FeatureEnabled(IsEnabled = true)].
- The filter interface consists of two methods—*Executing that runs before model binding and *Executed that runs after the result has been executed. You must implement both, even if you only need one for your use case.
- The filter execution methods provide a context object. This provides access to, among other things, the HttpContext for the request and metadata about the action method the middleware will execute.
- To short-circuit the pipeline, set the context.Result property to an IActionResult instance. The framework will execute this result to generate the response, bypassing any remaining filters in the pipeline, and skipping the action method (or page handler) entirely. In this example, if the feature isn't enabled, you bypass the pipeline by returning BadRequestResult, which will return a 400 error to the client.

By moving this logic into the resource filter, you can remove it from your action methods, and instead decorate the whole API controller with a simple attribute:

```
[Route("api/recipe"), FeatureEnabled(IsEnabled = true)]
public class RecipeApiController : ControllerBase
```

You've only extracted two lines of code from your action methods so far, but you're on the right track. In the next section, we'll move on to Action filters and extract two more filters from the action method code.

13.2.3 Action filters: customizing model binding and action results

Action filters run just after model binding, before the action method executes. Thanks to this positioning, action filters can access all the arguments that will be used to execute the action method, which makes them a powerful way of extracting common logic out of your actions.

On top of this, they also run just after the action method has executed and can completely change or replace the IActionResult returned by the action if you want. They can even handle exceptions thrown in the action.

> **REMINDER** Action filters don't execute for Razor Pages. Similarly, page filters don't execute for action methods.

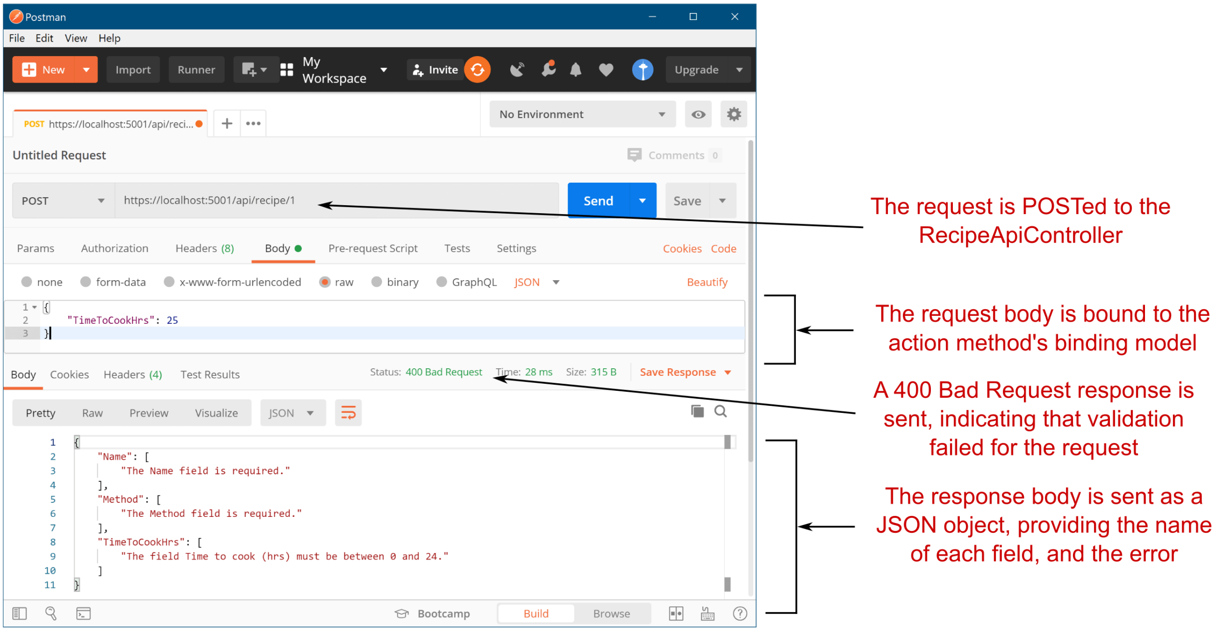
The ASP.NET Core framework includes several action filters out of the box. One of these commonly used filters is ResponseCacheFilter, which sets HTTP caching headers on your action-method responses.

> **TIP** Caching is a broad topic that aims to improve the performance of an application over the naive approach. But caching can also make debugging issues difficult and may even be undesirable in some situations. Consequently, I often apply ResponseCacheFilter to my action methods to set HTTP caching headers that *disable* caching! You can read about this and other approaches to caching in the docs at https://docs.microsoft.com/aspnet/core/performance/caching/response.

The real power of action filters comes when you build filters tailored to your own apps by extracting common code from your action methods. To demonstrate, I'm going to create two custom filters for RecipeApiController:

- ValidateModelAttribute—This will return BadRequestResult if the model state indicates that the binding model is invalid and will short-circuit the action execution. This attribute used to be a staple of my Web API applications, but the [ApiController] attribute now handles this (and more) for you. Nevertheless, I think it's useful to understand what's going on behind the scenes!
- EnsureRecipeExistsAttribute—This will use each action method's id argument to validate that the requested Recipe entity exists before the action method runs. If the Recipe doesn't exist, the filter will return NotFoundResult and will short-circuit the pipeline.

As you saw in chapter 6, the MVC framework automatically validates your binding models before executing your actions, but it's up to you to decide what to do about it. For Web API controllers, it’s common to return a 400 Bad Request response containing a list of the errors, as shown in figure 13.6.



POST https://localhost:5001/api/recipe/1

```
{
    "TimeToCookHrs": 25
}
```

Status: 400 Bad Request Time: 28 ms Size: 315 B

```
{
    "Name": [
        "The Name field is required."
    ],
    "Method": [
        "The Method field is required."
    ],
    "TimeToCookHrs": [
        "The field Time to cook (hrs) must be between 0 and 24."
    ]
}
```

The request is POSTed to the RecipeApiController

The request body is bound to the action method's binding model

A 400 Bad Request response is sent, indicating that validation failed for the request

The response body is sent as a JSON object, providing the name of each field, and the error

Figure 13.6 Posting data to a Web API using Postman. The data is bound to the action method’s binding model and validated. If validation fails, it’s common to return a 400 BadRequest response with a list of the validation errors.

You should ordinarily use the `[ApiController]` attribute on your Web API controllers, which gives you this behavior automatically. But if you can’t, or don’t want to, use that attribute, you can create a custom action filter instead. Listing 13.12 shows a basic implementation that is similar to the behavior you get with the `[ApiController]` attribute.

Listing 13.12 The action filter for validating `ModelState`

```
public class ValidateModelAttribute : ActionFilterAttribute     #A
{
    public override void OnActionExecuting(         #B
        ActionExecutingContext context)             #B
    {
        if (!context.ModelState.IsValid)            #C
        {
            context.Result =                                    #D
                new BadRequestObjectResult(context.ModelState);    #D
        }
    }
}
```

#A For convenience, you derive from the ActionFilterAttribute base class.
#B Overrides the Executing method to run the filter before the Action executes
#C Model binding and validation have already run at this point, so you can check the state.
#D If the model isn't valid, set the Result property; this short-circuits the action execution.

This attribute is self-explanatory and follows a similar pattern to the resource filter in section 13.2.2, but with a few interesting points:

- I have derived from the abstract `ActionFilterAttribute`. This class implements `IActionFilter` and `IResultFilter`, as well as their async counterparts, so you can override the methods you need as appropriate. This avoids needing to add an unused `OnActionExecuted()` method, but using the base class is entirely optional and a matter of preference.
- Action filters run after model binding has taken place, so `context.ModelState` contains the validation errors if validation failed.
- Setting the `Result` property on `context` short-circuits the pipeline. But, due to the position of the action filter stage, only the action method execution and later action filters are bypassed; all the other stages of the pipeline run as though the action had executed as normal.

If you apply this action filter to your `RecipeApiController`, you can remove

```
if (!ModelState.IsValid)
{
    return BadRequest(ModelState);
}
```

from the start of both the action methods, as it will run automatically in the filter pipeline. You'll use a similar approach to remove the duplicate code checking whether the `id` provided as an argument to the action methods corresponds to an existing Recipe entity.

This listing shows the `EnsureRecipeExistsAttribute` action filter. This uses an instance of `RecipeService` to check whether the `Recipe` exists and returns a 404 Not Found if it doesn't.

Listing 13.13 An action filter to check whether a Recipe exists

```
public class EnsureRecipeExistsAtribute : ActionFilterAttribute
{
    public override void OnActionExecuting(
        ActionExecutingContext context)
    {
        var service = (RecipeService) context.HttpContext        #A
            .RequestServices.GetService(typeof(RecipeService));  #A
        var recipeId = (int) context.ActionArguments["id"];      #B
        if (!service.DoesRecipeExist(recipeId))                  #C
        {
            context.Result = new NotFoundResult();               #D
        }
    }
}
```

#A Fetches an instance of RecipeService from the DI container
#B Retrieves the id parameter that will be passed to action method when it executes
#C Checks whether a Recipe entity with the given RecipeId exists
#D If it doesn't exist, returns a 404 Not Found result and short-circuits the pipeline.

As before, you've derived from `ActionFilterAttribute` for simplicity and overridden the `OnActionExecuting` method. The main functionality of the filter relies on the `DoesRecipeExist()` method of `RecipeService`, so the first step is to obtain an instance of `RecipeService`. The `context` parameter provides access to the `HttpContext` for the request, which in turn lets you access the DI container and use `RequestServices.GetService()` to return an instance of `RecipeService`.

> **WARNING** **This technique for obtaining dependencies is known as *service location* and is generally considered an antipattern.[61] In section 13.4, I'll show a better way to use the DI container to inject dependencies into your filters.**

As well as `RecipeService`, the other piece of information you need is the `id` argument of the `Get` and `Edit` action methods. In action filters, model binding has already occurred, so the arguments that the framework will use to execute the action method are already known and are exposed on `context.ActionArguments`.

The action arguments are exposed as `Dictionary<string, object>`, so you can obtain the `id` parameter using the `"id" string` key. Remember to cast the object to the correct type.

> **TIP** **Whenever I see magic strings like this, I always like to try to replace them by using the `nameof` operator. Unfortunately, `nameof` won't work for method arguments like this, so be careful when refactoring your code. I suggest explicitly applying the action filter to the action method (instead of globally, or to a controller) to remind you about that implicit coupling.**

With `RecipeService` and `id` in place, it's a case of checking whether the identifier corresponds to an existing `Recipe` entity and, if not, setting `context.Result` to `NotFoundResult`. This short-circuits the pipeline and bypasses the action method altogether.

> **NOTE** **Remember, you can have multiple action filters running in a single stage. Short-circuiting the pipeline by setting `context.Result` will prevent later filters in the stage from running, as well as bypassing the action method execution.**

[61] For a detailed discussion on DI patterns and antipatterns, see *Dependency Injection Principles, Practices, and Patterns* by Steven van Deursen and Mark Seemann (Manning, 2019) https://livebook.manning.com/book/dependency-injection-principles-practices-patterns/chapter-5.

Before we move on, it's worth mentioning a special case for action filters. The ControllerBase base class implements IActionFilter and IAsyncActionFilter itself. If you find yourself creating an action filter for a single controller and you want to apply it to every action in that controller, then you can override the appropriate methods on your controller.

Listing 13.14 Overriding action filter methods directly on ControllerBase

```
public class HomeController : ControllerBase       #A
{
    public override void OnActionExecuting(      #B
        ActionExecutingContext context)          #B
    { }                                          #B
    public override void OnActionExecuted(       #C
        ActionExecutedContext context)           #C
    { }                                          #C
}
```

#A Derives from the ControllerBase class
#B Runs before any other action filters for every action in the controller
#C Runs after all other action filters for every action in the controller

If you override these methods on your controller, they'll run in the action filter stage of the filter pipeline for every action on the controller. The OnActionExecuting ControllerBase method runs before any other action filters, regardless of ordering or scope, and the OnActionExecuted method runs after all other action filters.

> **TIP** **The controller implementation can be useful in some cases, but you can't control the ordering related to other filters. Personally, I generally prefer to break logic into explicit, declarative filter attributes but, as always, the choice is yours.**

With the resource and action filters complete, your controller is looking much tidier, but there's one aspect in particular that would be nice to remove: the exception handling. In the next section, we'll look at how to create a custom exception filter for your controller, and why you might want to do this instead of using exception-handling middleware.

13.2.4 Exception filters: custom exception handling for your action methods

In chapter 3, I went into some depth about types of error-handling middleware you can add to your apps. These let you catch exceptions thrown from any later middleware and handle them appropriately. If you're using exception-handling middleware, you may be wondering why we need exception filters at all!

The answer to this is pretty much the same as I outlined in section 13.1.3: filters are great for crosscutting concerns, when you need behavior that's either specific to MVC or should only apply to certain routes.

Both of these can apply in exception handling. Exception filters are part of the MVC framework, so they have access to the context in which the error occurred, such as the action or Razor Page that was executing. This can be useful for logging additional details when errors occur, such as the action parameters that caused the error.

> **WARNING** If you use exception filters to record action method arguments, make sure you're not storing sensitive data, such as passwords or credit card details, in your logs.

You can also use exception filters to handle errors from different routes in different ways. Imagine you have both Razor Pages and Web API controllers in your app, as we do in the recipe app. What happens when an exception is thrown by a Razor Page?

As you saw in chapter 3, the exception travels back up the middleware pipeline, and is caught by exception-handler middleware. The exception-handler middleware will re-execute the pipeline and generate an HTML error page.

That's great for your Razor Pages, but what about exceptions in your Web API controllers? If your API throws an exception, and consequently returns HTML generated by the exception-handler middleware, that's going to break a client who has called the API expecting a JSON response!

Instead, exception filters let you handle the exception in the filter pipeline and generate an appropriate response body. The exception handler middleware only intercepts errors without a body, so it will let the modified Web API response pass untouched.

> **NOTE** The `[ApiController]` attribute converts error `StatusCodeResults` to a `ProblemDetails` object, but it *doesn't* catch exceptions.

Exception filters can catch exceptions from more than just your action methods and page handlers. They'll run if an exception occurs:

- During model binding or validation
- When the action method or page handler is executing
- When an action filter or page filter is executing

You should note that exception filters won't catch exceptions thrown in any filters other than action and page filters, so it's important your resource and result filters don't throw exceptions. Similarly, they won't catch exceptions thrown when executing an `IActionResult`, for example when rendering a Razor view to HTML.

Now that you know why you might want an exception filter, go ahead and implement one for `RecipeApiController`, as shown next. This lets you safely remove the `try-catch` block from your action methods, knowing that your filter will catch any errors.

Listing 13.15 The `HandleExceptionAttribute` exception filter

```
public class HandleExceptionAttribute : ExceptionFilterAttribute      #A
{
    public override void OnException(ExceptionContext context)        #B
    {
        var error = new ProblemDetails              #C
        {                                           #C
            Title = "An error occured",             #C
            Detail = context.Exception.Message,     #C
            Status = 500,                           #C
            Type = "https://httpstatuses.com/500"     #C
        };                                          #C

        context.Result = new ObjectResult(error)   #D
        {                                          #D
            StatusCode = 500                       #D
        };                                         #D
        context.ExceptionHandled = true;           #E
    }
}
```

#A ExceptionFilterAttibute is an abstract base class that implements IExceptionFilter
#B There's only a single method to override for IExceptionFilter
#C Building a problem details object to return in the response
#D Creates an ObjectResult to serialize the ProblemDetails and to set the response status code
#E Marks the exception as handled to prevent it propagating into the middleware pipeline

It's quite common to have an exception filter in your application, especially if you are mixing API controllers and Razor Pages in your application, but they're not always necessary. If you can handle all the exceptions in your application with a single piece of middleware, then ditch the exception filters and go with that instead.

You're almost done refactoring your `RecipeApiController`, you just have one more filter type to add: result filters. Custom result filters tend to be relatively rare in the apps I've written, but they have their uses, as you'll see.

13.2.5 Result filters: customizing action results before they execute

If everything runs successfully in the pipeline, and there's no short-circuiting, then the next stage of the pipeline after action filters are result filters. These run just before and after the `IActionResult` returned by the Action method (or action filters) is executed.

> **WARNING** **If the pipeline is short-circuited by setting `context.Result`, the result filter stage won't be run, but `IActionResult` will still be executed to generate the response. The exceptions to this rule are action and page filters—these only short-circuit the action execution, as you saw in figures 13.2 and 13.3, and so result filters run as normal, as though the action or page handler itself generated the response.**

Result filters run immediately after action filters, so many of their use-cases are similar, but you typically use result filters to customize the way the `IActionResult` executes. For example, ASP.NET Core has several result filters built into its framework:

- `ProducesAttribute`—This forces a Web API result to be serialized to a specific output format. For example, decorating your action method with `[Produces("application/xml")]` forces the formatters to try to format the response as XML, even if the client doesn't list XML in its `Accept` header.

- FormatFilterAttribute—Decorating an action method with this filter tells the formatter to look for a route value or query string parameter called format, and to use that to determine the output format. For example, you could call /api/recipe/11?format=json and FormatFilter will format the response as JSON, or call api/recipe/11?format=xml and get the response as XML.[62]

As well as controlling the output formatters, you can use result filters to make any last-minute adjustments before IActionResult is executed and the response is generated.

As an example of the kind of flexibility available, in the following listing I demonstrate setting the LastModified header, based on the object returned from the action. This is a somewhat contrived example—it's specific enough to a single action that it doesn't warrant being moved to a result filter—but, hopefully, you get the idea!

Listing 13.16 Setting a response header in a result filter

```
public class AddLastModifedHeaderAttribute : ResultFilterAttribute     #A
{
    public override void OnResultExecuting(         #B
        ResultExecutingContext context)             #B
    {
        if (context.Result is OkObjectResult result            #C
            && result.Value is RecipeDetailViewModel detail)   #D
        {
            var viewModelDate = detail.LastModified;             #E
            context.HttpContext.Response                         #E
              .GetTypedHeaders().LastModified = viewModelDate;   #E
        }
    }
}
```

#A ResultFilterAttribute provides a useful base class you can override
#B You could also override the Executed method, but the response would already be sent by then
#C Checks whether the action result returned a 200 Ok result with a view model
#D Checks whether the view model type is RecipeDetailViewModel . . .
#E . . . if it is, fetches the LastModified property and sets the Last-Modified header in the response

I've used another helper base class here, ResultFilterAttribute, so you only need to override a single method to implement the filter. Fetch the current IActionResult, exposed on context.Result, and check that it's an OkObjectResult instance with a RecipeDetailViewModel value. If it is, then fetch the LastModified field from the view model and add a Last-Modified header to the response.

[62] Remember, you need to explicitly configure the XML formatters if you want to serialize to XML. For details on formatting results based on the URL, see https://andrewlock.net/formatting-response-data-as-xml-or-json-based-on-the-url-in-asp-net-core/.

TIP GetTypedHeaders() **is an extension method that provides strongly typed access to request and response headers. It takes care of parsing and formatting the values for you. You can find it in the** Microsoft.AspNetCore.Http **namespace.**

As with resource and action filters, result filters can implement a method that runs *after* the result has been executed, OnResultExecuted. You can use this method, for example, to inspect exceptions that happened during the execution of IActionResult.

WARNING **Generally, you can't modify the response in the** OnResultExecuted **method, as you may have already started streaming the response to the client.**

We've finished simplifying the RecipeApiController now. By extracting various pieces of functionality to filters, the original controller in listing 13.8 can be simplified to the version in 13.9. This is obviously a somewhat extreme and contrived demonstration, and I'm not advocating that filters should always be your go-to option.

TIP **Filters should be a last resort in most cases. Where possible, it is often preferable to use a simple private method in a controller, or push functionality into the domain instead of using filters. Filters should generally be used to extract repetitive, HTTP-related, or common cross-cutting code from your controllers.**

There's still one more filter we haven't looked at yet, because it only applies to Razor Pages: page filters.

13.2.6 Page filters: customizing model binding for Razor Pages

As already discussed, action filters only apply to controllers and actions; they have no effect on Razor Pages. Similarly, page filters have no effect on controllers and actions. Nevertheless, page filters and action filters fulfil similar roles.

Just like action filters, The ASP.NET Core framework includes several page filters out of the box. One of these is the Razor Page equivalent of the caching action filter, ResponseCacheFilter, called PageResponseCacheFilter. This works identically to the action-filter equivalent I described in section 13.2.3, setting HTTP caching headers on your Razor Page responses.

Page filters are somewhat unusual, as they implement three methods, as discussed in section 13.1.2. In practice, I've rarely seen a page filter that implements all three. It's unusual to need to run code immediately after page handler selection and before model validation. It's far more common to perform a role directly analogous to action filters.

For example, the following listing shows a page filter equivalent to the EnsureRecipeExistsAttribute action filter.

Listing 13.17 A page filter to check whether a Recipe **exists**

```
public class PageEnsureRecipeExistsAtribute : Attribute, IPageFilter    #A
{
    public void OnPageHandlerSelected(            #B
        PageHandlerSelectedContext context)       #B
    {}                                            #B

    public void OnPageHandlerExecuting(            #C
        PageHandlerExecutingContext context)       #C
    {
        var service = (RecipeService) context.HttpContext            #D
            .RequestServices.GetService(typeof(RecipeService));      #D
        var recipeId = (int) context.HandlerArguments["id"];         #E
        if (!service.DoesRecipeExist(recipeId))                      #F
        {
            context.Result = new NotFoundResult();                   #G
        }
    }

    public void OnPageHandlerExecuted(              #H
        PageHandlerExecutedContext context)         #H
    { }                                             #H
}
```

#A Implement IPageFilter and as an attribute so you can decorate the Razor Page PageModel
#B Executed after handler selection, before model binding. Not used in this example
#C Executed after model binding and validation, before page handler execution
#D Fetches an instance of RecipeService from the DI container
#E Retrieves the id parameter that will be passed to page handler method when it executes
#F Checks whether a Recipe entity with the given RecipeId exists
#G If it doesn't exist, returns a 404 Not Found result and short-circuits the pipeline
#H Executed after page handler execution (or short-circuiting). Not used in this example

The page filter is very similar to the action filter equivalent. The most obvious difference is the need to implement three methods to satisfy the `IPageFilter` interface. You'll commonly want to implement the `OnPageHandlerExecuting` method, which runs just after model binding and validation, and before the page handler executes.

A subtle difference between the action filter code and the page filter code is that the action filter accesses the model-bound action arguments using `context.ActionArguments`. The page filter uses `context.HandlerArguments` in the example, but there's also another option.

Remember from chapter 6 that Razor Pages often bind to public properties on the `PageModel` using the `[BindProperty]` attribute. You can access those properties directly, instead of having to use magic strings, by casting a `HandlerInstance` property to the correct `PageModel` type, and accessing the property directly. For example,

```
var recipeId = ((ViewRecipePageModel)context.HandlerInstance).Id
```

Just as the `ControllerBase` class implements `IActionFilter`, so `PageModel` implements `IPageFilter` and `IAsyncPageFilter`. If you want to create an action filter for a single Razor Page, then you could save yourself the trouble of creating a separate page filter, and override these methods directly in your Razor Page.

TIP I generally find it's not worth the hassle of using page filters unless you have a *very* common requirement. The extra level of indirection page filters add, coupled with the typically "bespoke" nature of individual Razor

Pages, means I normally find they aren't worth using. Your mileage may vary of course, but don't jump to them as a first option!

That brings us to the end of this detailed look at each of the filters in the MVC pipeline. Looking back and comparing listings 13.8 and 13.9, you can see filters allowed us to refactor the controllers and make the intent of each action method much clearer. Writing your code in this way makes it easier to reason about, as each filter and action has a single responsibility.

In the next section, I'll take a slight detour into exactly what happens when you short-circuit a filter. I've described *how* to do this, by setting the `context.Result` property on a filter, but I haven't yet described exactly what happens. For example, what if there are multiple filters in the stage when it's short-circuited? Do those still run?

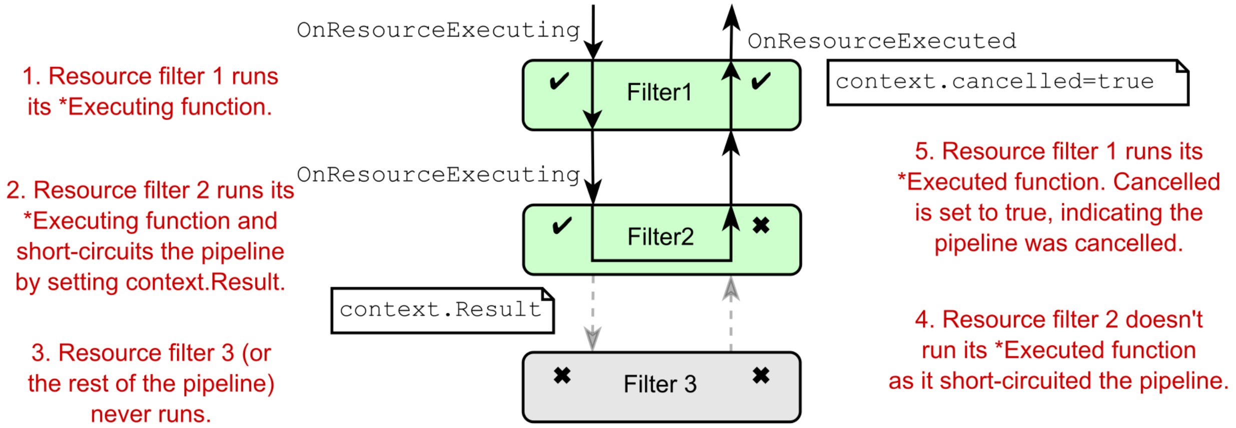
13.3 Understanding pipeline short-circuiting

In this short section you'll learn about the details of filter-pipeline short-circuiting. You'll see what happens to the other filters in a stage when the pipeline is short-circuited, and how to short-circuit each type of filter.

A brief warning: the topic of filter short-circuiting can be a little confusing. Unlike middleware short-circuiting, which is cut-and-dried, the filter pipeline is a bit more nuanced. Luckily, you won't often find you need to dig into it, but when you do, you'll be glad of the detail.

You short-circuit the authorization, resource, action, page, and result filters by setting `context.Result` to `IActionResult`. Setting an action result in this way causes some, or all, of the remaining pipeline to by bypassed. But the filter pipeline isn't entirely linear, as you saw in figures 13.2 and 13.3, so short-circuiting doesn't always do an about-face back down the pipeline. For example, short-circuited action filters only bypass action method execution—the result filters and result execution stages still run.

The other difficultly is what happens if you have more than one type of filter. Let's say you have three resource filters executing in a pipeline. What happens if the second filter causes a short circuit? Any remaining filters are bypassed, but the first resource filter has already run its `*Executing` command, as shown in figure 13.7. This earlier filter gets to run its `*Executed` command too, with `context.Cancelled = true`, indicating that a filter in that stage (the resource filter stage) short-circuited the pipeline.



1. Resource filter 1 runs its *Executing function.

2. Resource filter 2 runs its *Executing function and short-circuits the pipeline by setting context.Result.

3. Resource filter 3 (or the rest of the pipeline) never runs.

4. Resource filter 2 doesn't run its *Executed function as it short-circuited the pipeline.

5. Resource filter 1 runs its *Executed function. Cancelled is set to true, indicating the pipeline was cancelled.

Figure 13.7 The effect of short-circuiting a resource filter on other resource filters in that stage. Later filters in the stage won't run at all, but earlier filters run their `OnResourceExecuted` function.

Understanding which other filters will run when you short-circuit a filter can be somewhat of a chore, but I've summarized each filter in table 13.1. You'll also find it useful to refer to figures 13.2 and 13.3 to visualize the shape of the pipeline when thinking about short-circuits.

Table 13.1 The effect of short-circuiting filters on filter-pipeline execution

Filter type	How to short-circuit?	What else runs?
Authorization filters	Set `context.Result`	Nothing, the pipeline is immediately halted.
Resource filters	Set `context.Result`	Resource-filter `*Executed` functions from earlier filters run with `context.Cancelled = true`.
Action filters	Set `context.Result`	Only bypasses action method execution. Action filters earlier in the pipeline run their `*Executed` methods with `context.Cancelled = true`, then result filters, result execution, and resource filters' `*Executed` methods all run as normal.
Page filters	Set `context.Result` in `OnPageHandlerSelected`	Only bypasses page handler execution. Page filters earlier in the pipeline run their `*Executed` methods with `context.Cancelled = true`, then result filters, result execution, and resource filters' `*Executed` methods all

		run as normal.
Exception filters	**Set** `context.Result` **and** `Exception.Handled = true`	**All resource-filter** *****`Executed` **functions run.**
Result filters	**Set** `context.Cancelled = true`	**Result filters earlier in the pipeline run their** *****`Executed` **functions with** `context.Cancelled = true`**. All resource–filter** *****`Executed` **functions run as normal.**

The most interesting point here is that short-circuiting an action filter (or a page filter) doesn't short-circuit much of the pipeline at all. In fact, it only bypasses later action filters and the action method execution itself. By primarily building action filters, you can ensure that other filters, such as result filters that define the output format, run as usual, even when your action filters short-circuit.

The last thing I'd like to talk about in this chapter is how to use DI with your filters. You saw in chapter 10 that DI is integral to ASP.NET Core, and in the next section, you'll see how to design your filters so that the framework can inject service dependencies into them for you.

13.4 Using dependency injection with filter attributes

In this section you'll learn how to inject services into your filters, so you can take advantage of the simplicity of DI in your filters. You'll learn to use two helper filters to achieve this `TypeFilterAttribute` and `ServiceFilterAttribute`, and you'll see how they can be used to simplify the action filter you defined in section 13.2.3.

The previous version of ASP.NET used filters, but they suffered from one problem in particular: it was hard to use services from them. This was a fundamental issue with implementing them as attributes that you decorate your actions with. C# attributes don't let you pass dependencies into their constructors (other than constant values), and they're created as singletons, so there's only a single instance for the lifetime of your app.

In ASP.NET Core, this limitation is still there in general, in that filters are typically created as attributes that you add to your controller classes, action methods, and Razor Pages. What happens if you need to access a transient or scoped service from inside the singleton attribute?

Listing 13.13 showed one way of doing this, using a pseudo service locator pattern to reach into the DI container and pluck out `RecipeService` at runtime. This works but is generally frowned upon as a pattern, in favor of proper DI. How can you add DI to your filters?

The key is to split the filter into two. Instead of creating a class that's both an attribute and a filter, create a filter class that contains the functionality and an attribute that tells the framework when and where to use the filter.

Let's apply this to the action filter from listing 13.13. Previously, I derived from `ActionFilterAttribute` and obtained an instance of `RecipeService` from the `context` passed to the method. In the following listing, I show two classes, `EnsureRecipeExistsFilter` and `EnsureRecipeExistsAttribute`. The filter class is responsible for the functionality and takes in `RecipeService` as a constructor dependency.

Listing 13.18 Using DI in a filter by not deriving from `Attribute`

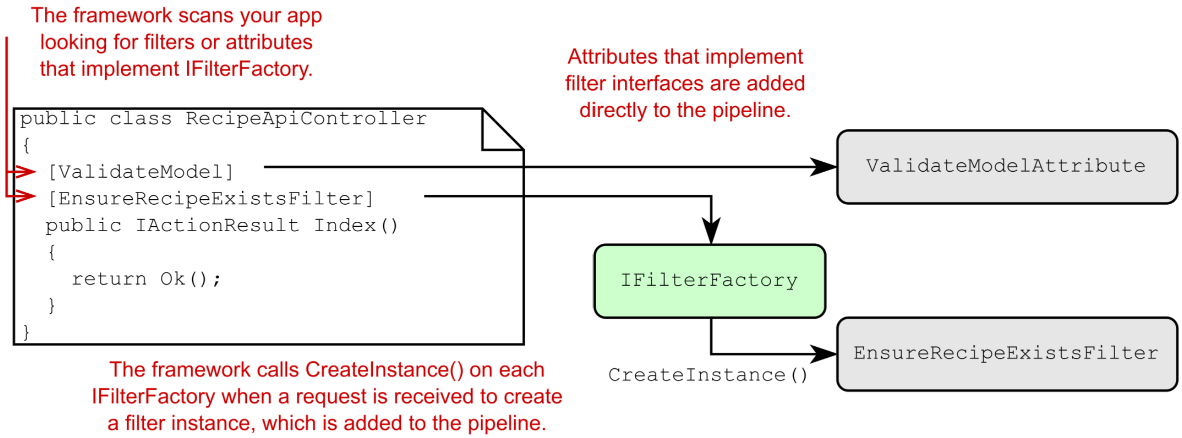
```
public class EnsureRecipeExistsFilter : IActionFilter            #A
{
    private readonly RecipeService _service;                    #B
    public EnsureRecipeExistsFilter(RecipeService service)      #B
    {                                                           #B
        _service = service;                                     #B
    }                                                           #B

    public void OnActionExecuting(ActionExecutingContext context)      #C
    {                                                                  #C
        var recipeId = (int) context.ActionArguments["id"];            #C
        if (!_service.DoesRecipeExist(recipeId))                       #C
        {                                                              #C
            context.Result = new NotFoundResult();                     #C
        }                                                              #C
    }                                                                  #C

    public void OnActionExecuted(ActionExecutedContext context) { }    #D
}

public class EnsureRecipeExistsAttribute : TypeFilterAttribute       #E
{
    public EnsureRecipeExistsAttribute()                             #F
        : base(typeof(EnsureRecipeExistsFilter)) {}                  #F
}
```

#A Doesn't derive from an Attribute class
#B RecipeService is injected into the constructor
#C The rest of the method remains the same
#D You must implement the Executed action to satisfy the interface
#E Derives from TypeFilter, which is used to fill dependencies using the DI container
#F Passes the type EnsureRecipeExistsFilter as an argument to the base TypeFilter constructor

`EnsureRecipeExistsFilter` is a valid filter; you could use it on its own by adding it as a global filter (as global filters don't need to be attributes). But you can't use it directly by decorating controller classes and action methods, as it's not an attribute. That's where `EnsureRecipeExistsAttribute` comes in.

You can decorate your methods with `EnsureRecipeExistsAttribute` instead. This attribute inherits from `TypeFilterAttribute` and passes the `Type` of filter to create as an argument to the base constructor. This attribute acts as a *factory* for `EnsureRecipeExistsFilter` by implementing `IFilterFactory`.

When ASP.NET Core initially loads your app, it scans your actions and controllers, looking for filters and filter factories. It uses these to form a filter pipeline for every action in your app, as shown in figure 13.8.



The framework scans your app looking for filters or attributes that implement IFilterFactory.

```
public class RecipeApiController
{
  [ValidateModel]
  [EnsureRecipeExistsFilter]
  public IActionResult Index()
  {
    return Ok();
  }
}
```

Attributes that implement filter interfaces are added directly to the pipeline.

The framework calls CreateInstance() on each IFilterFactory when a request is received to create a filter instance, which is added to the pipeline.

Figure 13.8 The framework scans your app on startup to find both filters and attributes that implement `IFilterFactory`. At runtime, the framework calls `CreateInstance()` to get an instance of the filter.

When an action decorated with `EnsureRecipeExistsAttribute` is called, the framework calls `CreateInstance()` on the attribute. This creates a new instance of `EnsureRecipeExistsFilter` and uses the DI container to populate its dependencies (`RecipeService`).

By using this `IFilterFactory` approach, you get the best of both worlds; you can decorate your controllers and actions with attributes, and you can use DI in your filters. Out of the box, two similar classes provide this functionality, which have slightly different behaviors:

- `TypeFilterAttribute`—Loads all of the filter's dependencies from the DI container and uses them to create a new instance of the filter.
- `ServiceFilterAttribute`—Loads the filter *itself* from the DI container. The DI container takes care of the service lifetime and building the dependency graph. Unfortunately, you also have to explicitly register your filter with the DI container in `ConfigureServices` in `Startup`:

```
services.AddTransient<EnsureRecipeExistsFilter>();
```

Whether you choose to use `TypeFilterAttribute` or `ServiceFilterAttribute` is somewhat a matter of preference, and you can always implement a custom `IFilterFactory` if you need to. The key takeaway is that you can now use DI in your filters. If you don't need to use DI for a filter, then implement it as an attribute directly for simplicity.

> **TIP** I like to create my filters as a nested class of the attribute class when using this pattern. This keeps all the code nicely contained in a single file and indicates the relationship between the classes.

That brings us to the end of this chapter on the filter pipeline. Filters are a somewhat advanced topic, in that they aren't strictly necessary for building basic apps, but I find them extremely useful for ensuring my controller and action methods are simple and easy to understand.

In the next chapter, we'll take our first look at securing your app. We'll discuss the difference between authentication and authorization, the concept of identity in ASP.NET Core, and how you can use the ASP.NET Core Identity system to let users register and log in to your app.

13.5 Summary

- The filter pipeline executes as part of the MVC or Razor Pages execution. It consists of authorization filters, resource filters, action filters, page filters, exception filters, and Result filters. Each filter type is grouped into a *stage* and can be used to achieve effects specific to that stage.
- Resource, action, and result filters run twice in the pipeline: an `*Executing` method on the way in and an `*Executed` method on the way out. Page filters run three times: after page handler selection, and before and after page handler execution.
- Authorization and exception filters only run once as part of the pipeline; they don't run after a response has been generated.
- Each type of filter has both a sync and an async version. For example, resource filters can implement either the `IResourceFilter` interface or the `IAsyncResourceFilter` interface. You should use the synchronous interface unless your filter needs to use asynchronous method calls.
- You can add filters globally, at the controller level, at the Razor Page level, or at the action level. This is called the *scope* of the filter. Which scope you should choose depends on how broadly you want to apply the filter.
- Within a given stage, global-scoped filters run first, then controller-scoped, and finally, action-scoped. You can also override the default order by implementing the `IOrderedFilter` interface. Filters will run from lowest to highest `Order` and use scope to break ties.
- Authorization filters run first in the pipeline and control access to APIs. ASP.NET Core includes an `[Authorization]` attribute that you can apply to action methods so that only logged-in users can execute the action.
- Resource filters run after authorization filters, and again after a result has been executed. They can be used to short-circuit the pipeline, so that an action method is

never executed. They can also be used to customize the model binding process for an action method.

- Action filters run after model binding has occurred, just before an action method executes. They also run after the action method has executed. They can be used to extract common code out of an action method to prevent duplication. They don't execute for Razor Pages, only for MVC controllers.
- The `ControllerBase` base class also implements `IActionFilter` and `IAsyncActionFilter`. They run at the start and end of the action filter pipeline, regardless of the ordering or scope of other action filters. They can be used to create action filters that are specific to one controller.
- Page filters run three times: after page handler selection, after model binding, and after the page handler method executes. You can use page filters for similar purposes as action filters. Page filters only execute for Razor Pages, they don't run for MVC controllers.
- Razor Page `PageModels` implement `IPageFilter` and `IAsyncPageFilter`, so can be used to implement page-specific page filters. These are rarely used, as you can typically achieve similar results with simple private methods.
- Exception filters execute after action and page filters, when an action method or page handler has thrown an exception. They can be used to provide custom error handling specific to the action executed.
- Generally, you should handle exceptions at the middleware level, but you can use exception filters to customize how you handle exceptions for specific actions, controllers, or Razor Pages.
- Result filters run just before and after an `IActionResult` is executed. You can use them to control how the action result is executed, or to completely change the action result that will be executed.
- You can use `ServiceFilterAttribute` and `TypeFilterAttribute` to allow dependency injection in your custom filters. `ServiceFilterAttribute` requires that you register your filter and all its dependencies with the DI container, whereas `TypeFilterAttribute` only requires that the filter's dependencies have been registered.

14

Authentication: adding users to your application with Identity

This chapter covers

- **How authentication works in web apps in ASP.NET Core**
- **Creating a project using the ASP.NET Core Identity system**
- **Adding user functionality to an existing web app**
- **Customizing the default ASP.NET Core Identity UI**

One of the selling points of a web framework like ASP.NET Core is the ability to provide a dynamic app, customized to individual users. Many apps have the concept of an "account" with the service, which you can "sign in" to and get a different experience.

Depending on the service, an account gives you varying things: on some apps you may have to sign in to get access to additional features, on others you might see suggested articles. On an e-commerce app, you'd be able to make and view your past orders, on Stack Overflow you can post questions and answers, whereas on a news site you might get a customized experience based on previous articles you've viewed.

When you think about adding users to your application, you typically have two aspects to consider:

- *Authentication*—The process of creating users and letting them log in to your app
- *Authorization*—Customizing the experience and controlling what users can do, based on the current logged-in user

In this chapter, I'm going to be discussing the first of these points, authentication and membership, and in the next chapter, I'll tackle the second point, authorization. In section 14.1, I discuss the difference between authentication and authorization, how authentication works in a traditional ASP.NET Core web app, and ways you can architect your system to provide sign-in functionality.

I also touch on the typical differences in authentication between a traditional web app and Web APIs used with client-side or mobile web apps. This book focuses on traditional web apps for authentication, but many of the principles are applicable to both.

In section 14.2, I introduce a user management system called ASP.NET Core Identity (or Identity for short). Identity integrates with EF Core and provides services for creating and managing users, storing and validating passwords, and signing users in and out of your app.

In section 14.3, you'll create an app using a default template that includes ASP.NET Core Identity out of the box. This will give you an app to explore, to see the features Identity provides, as well as everything it doesn't.

Creating an app is great for seeing an example of how the pieces fit together, but you'll often need to add users to an existing app. In section 14.4, you'll see each of the steps required to add ASP.NET Core Identity to an existing app: the recipe application from chapters 12 and 13.

In sections 14.5 and 14.6 you'll learn how to replace pages from the default Identity UI by "scaffolding" individual pages. In section 14.5 you'll see how to customize the Razor templates to generate different HTML on the user registration page, and in section 14.6 you'll learn how to customize the logic associated with a Razor Page. You'll see how to store additional information about a user (such as their name or date of birth) and to provide permissions to them that you can later use to customize the app's behavior (if the user is a VIP, for example).

Before we look at the ASP.NET Core Identity system specifically, let's take a look at authentication and authorization in ASP.NET Core, what's happening when you sign in to a website, and some of the ways to design your apps to provide this functionality.

14.1 Introducing authentication and authorization

When you add sign-in functionality to your app and control access to certain functions based on the currently-signed-in user, you're using two distinct aspects of security:

- *Authentication*—The process of determining *who you are*
- *Authorization*—The process of determining *what you're allowed to do*

Generally, you need to know *who* the user is before you can determine *what* they're allowed to do, so authentication always comes first, followed by authorization. In this chapter, we're only looking at authentication; we'll cover authorization in chapter 15.

In this section I start by discussing how ASP.NET Core thinks about users, and cover some of the terminology and concepts that are central to authentication. I always found this to be the hardest part to grasp when first learning about authentication, so I'll take it slow!

Next, we'll look at what it *means* to sign in to a traditional web app. After all, you only provide your password and sign in to an app on a single page—how does the app know the request came from *you* for subsequent requests?

Finally, we'll look at how authentication works when you need to support client-side apps and mobile apps that call Web APIs, in addition to traditional web apps. Many of the concepts are similar, but the requirement to support multiple types of users, traditional apps, client-side apps, and mobile apps has led to alternative solutions.

In the next section, we'll look at a practical implementation of a user management system called ASP.NET Core Identity, and how you can use this in your own projects.

14.1.1 Understanding users and claims in ASP.NET Core

The concept of a user is baked-in to ASP.NET Core. In this section, we'll look at the fundamental model used to describe a user, including its properties, such as an associated email address, as well as any permission-related properties, such as whether the user is an admin user.

In chapter 3, you learned that the HTTP server, Kestrel, creates an `HttpContext` object for every request it receives. This object is responsible for storing all the details related to that request, such as the request URL, any headers sent, the body of the request, and so on.

The `HttpContext` object also exposes the current *principal* for a request as the `User` property. This is ASP.NET Core's view of which user made the request. Any time your app needs to know who the current user is, or what they're allowed to do, it can look at the `HttpContext.User` principal.

> **DEFINITION** You can think of the *principal* as the user of your app.

In ASP.NET Core, principals are implemented as `ClaimsPrincipal`s, which has a collection of *claims* associated with it, as shown in figure 14.1.

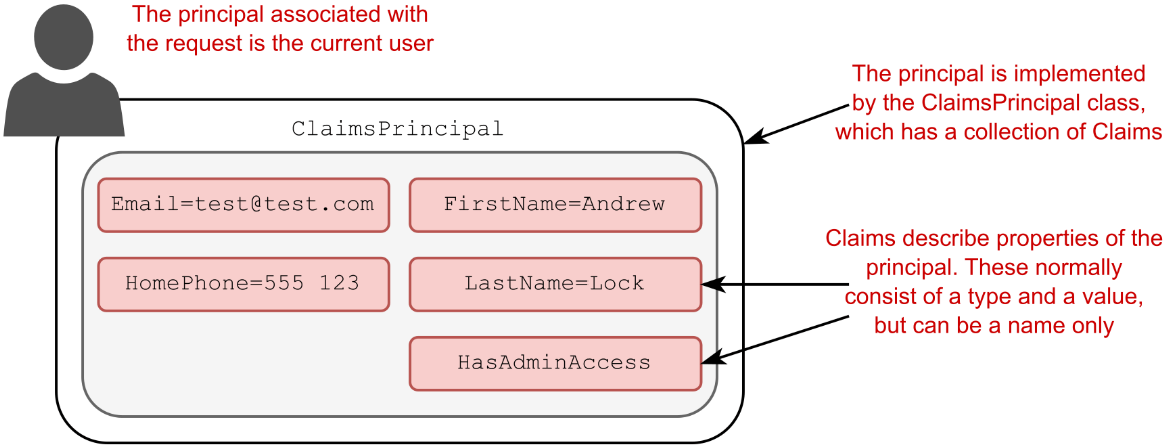

The principal associated with the request is the current user
ClaimsPrincipal
Email=test@test.com
FirstName=Andrew
HomePhone=555 123
LastName=Lock
HasAdminAccess
The principal is implemented by the ClaimsPrincipal class, which has a collection of Claims
Claims describe properties of the principal. These normally consist of a type and a value, but can be a name only

Figure 14.1 The principal is the current user, implemented as `ClaimsPrincipal`. It contains a collection of `Claim`s that describe the user.

You can think about claims as properties of the current user. For example, you could have claims for things like email, name, or date of birth.

> **DEFINITION** A claim is a single piece of information about a principal, which consists of a *claim type* and an optional *value*.

Claims can also be indirectly related to permissions and authorization, so you could have a claim called `HasAdminAccess` or `IsVipCustomer`. These would be stored in exactly the same way—as claims associated with the user principal.

> **NOTE** Earlier versions of ASP.NET used a role-based approach to security, rather than claims-based. The `ClaimsPrincipal` used in ASP.NET Core is compatible with this approach for legacy reasons, but you should use the claims-based approach for new apps.

Kestrel assigns a user principal to every request that arrives at your app. Initially, that principal is a generic, anonymous, unauthenticated principal with no claims. How do you log in, and how does ASP.NET Core know that you've logged in on subsequent requests?

In the next section, we'll look at how authentication works in a traditional web app using ASP.NET Core, and the process of signing in to a user account.

14.1.2 Authentication in ASP.NET Core: services and middleware

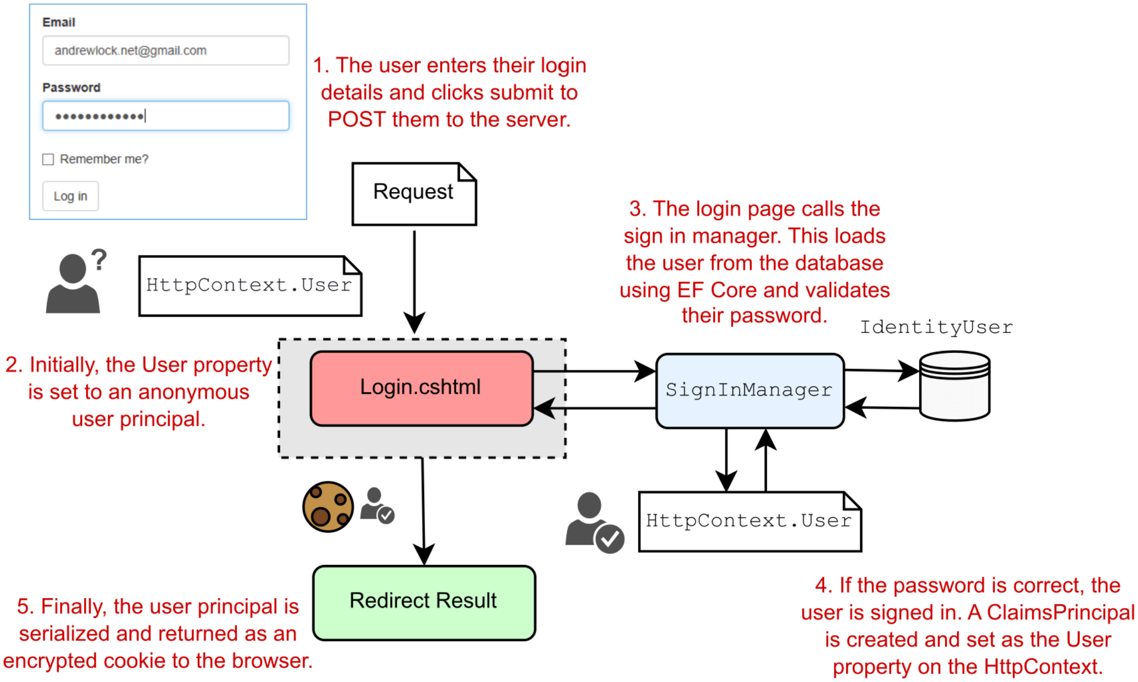
Adding authentication to any web app involves a number of moving parts. The same general process applies whether you're building a traditional web app or a client-side app, though there are often differences in implementation, as I'll discuss in section 14.1.3:

- The client sends an identifier and a secret to the app, which identify the current user. For example, you could send an email (identifier) and a password (secret).
- The app verifies that the identifier corresponds to a user known by the app and that the corresponding secret is correct.
- If the identifier and secret are valid, the app can set the principal for the current request, but it also needs a way of storing these details for subsequent requests. For traditional web apps, this is typically achieved by storing an encrypted version of the user principal in a cookie.

This is the typical flow for most web apps, but in this section, I'm going to look at how it works in ASP.NET Core. The overall process is the same, but it's good to see how this pattern fits into the services, middleware, and MVC aspects of an ASP.NET Core application. We'll step through the various pieces at play in a typical app when you sign in as a user, what that means, and how you can make subsequent requests as that user.

SIGNING IN TO AN ASP.NET CORE APPLICATION

When you first arrive on a site and sign in to a traditional web app, the app will send you to a sign-in page and ask you to enter your username and password. After you submit the form to the server, the app redirects you to a new page, and you're magically logged in! Figure 14.2 shows what's happening behind the scenes in an ASP.NET Core app when you submit the form.



Email
andrewlock.net@gmail.com
Password
•••••••••••••
☐ Remember me?

1. The user enters their login details and clicks submit to POST them to the server.

2. Initially, the User property is set to an anonymous user principal.

3. The login page calls the sign in manager. This loads the user from the database using EF Core and validates their password.

4. If the password is correct, the user is signed in. A ClaimsPrincipal is created and set as the User property on the HttpContext.

5. Finally, the user principal is serialized and returned as an encrypted cookie to the browser.

Figure 14.2 Signing in to an ASP.NET Core application. `SignInManager` **is responsible for setting** `HttpContext.User` **to the new principal and serializing the principal to the encrypted cookie.**

This shows the series of steps from the moment you submit the login form on a Razor Page, to the point the redirect is returned to the browser. When the request first arrives, Kestrel creates an anonymous user principal and assigns it to the `HttpContext.User` property. The request is then routed to the Login.chtml Razor Page, which reads the email and password from the request using model binding.

The meaty work happens inside the `SignInManager` service. This is responsible for loading a user entity with the provided username from the database and validating that the password they provided is correct.

WARNING Never store passwords in the database directly. They should be *hashed* using a strong one-way algorithm. The ASP.NET Core Identity system does this for you, but it's always wise to reiterate this point!

If the password is correct, `SignInManager` creates a new `ClaimsPrincipal` from the user entity it loaded from the database and adds the appropriate claims, such as the email. It then replaces the old, anonymous, `HttpContext.User` principal with the new, authenticated principal.

Finally, `SignInManager` serializes the principal, encrypts it, and stores it as a *cookie*. A cookie is a small piece of text that's sent back and forth between the browser and your app along with each request, consisting of a name and a value.

This authentication process explains how you can set the user for a request when they *first* log in to your app, but what about subsequent requests? You only send your password when you first log in to an app, so how does the app know that it's the same user making the request?

AUTHENTICATING USERS FOR SUBSEQUENT REQUESTS

The key to persisting your identity across multiple requests lies in the final step of figure 14.2, where you serialized the principal in a cookie. Browsers will automatically send this cookie with all requests made to your app, so you don't need to provide your password with every request.

ASP.NET Core uses the authentication cookie sent with the requests to rehydrate `ClaimsPrincipal` and set the `HttpContext.User` principal for the request, as shown in figure 14.3. The important thing to note is *when* this process happens—in the `AuthenticationMiddleware`.

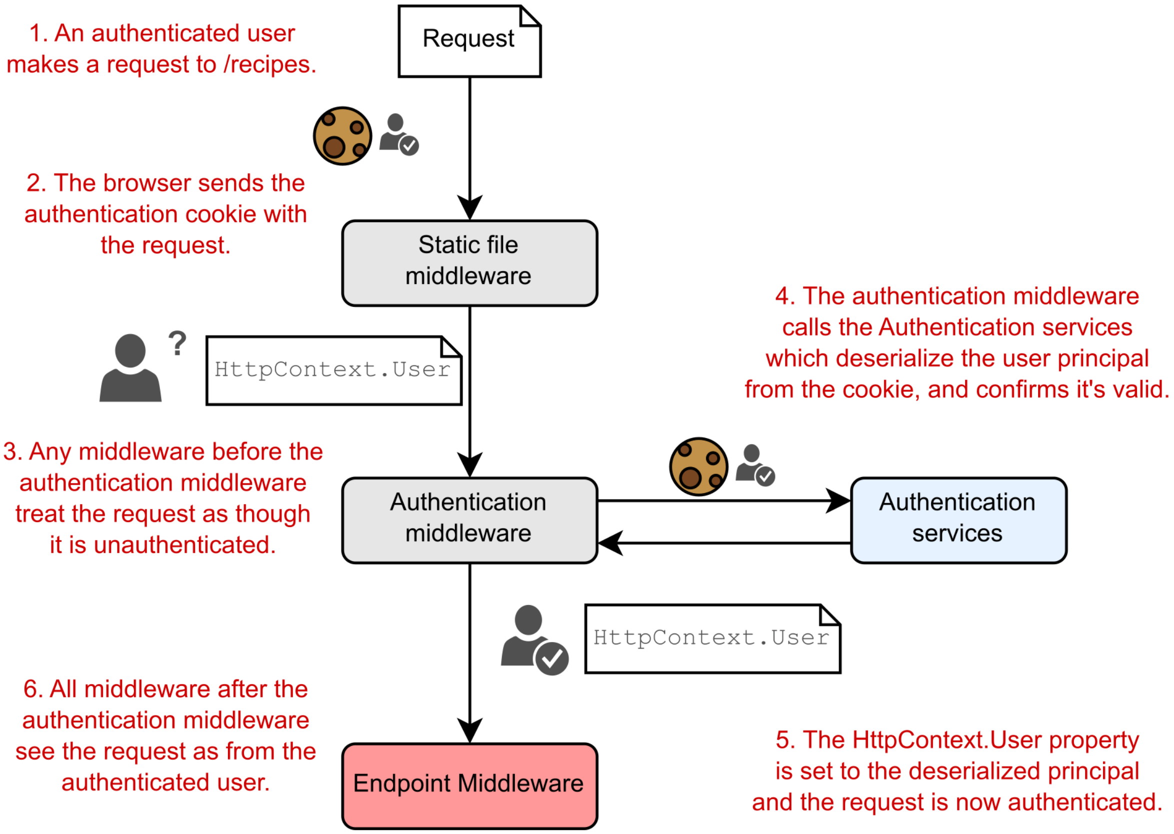

1. An authenticated user makes a request to /recipes.
Request
2. The browser sends the authentication cookie with the request.
Static file middleware
HttpContext.User
?
3. Any middleware before the authentication middleware treat the request as though it is unauthenticated.
4. The authentication middleware calls the Authentication services which deserialize the user principal from the cookie, and confirms it's valid.
Authentication middleware
Authentication services
HttpContext.User
5. The HttpContext.User property is set to the deserialized principal and the request is now authenticated.
6. All middleware after the authentication middleware see the request as from the authenticated user.
Endpoint Middleware

Figure 14.3 A subsequent request after signing in to an application. The cookie sent with the request contains the user principal, which is validated and used to authenticate the request.

When a request containing the authentication cookie is received, Kestrel creates the default, unauthenticated, anonymous principal and assigns it to the `HttpContext.User` principal. Any middleware that runs at this point, before `AuthenticationMiddleware`, will see the request as unauthenticated, even if there's a valid cookie.

> **TIP** If it looks like your authentication system isn't working, double-check your middleware pipeline. Only middleware that runs after `AuthenticationMiddleware` will see the request as authenticated.

`AuthenticationMiddleware` is responsible for setting the current user for a request. The middleware calls authentication services, which reads the cookie from the request, decrypts it, and deserializes it to obtain the `ClaimsPrincipal` created when the user logged in.

`AuthenticationMiddleware` sets the `HttpContext.User` principal to the new, authenticated principal. All subsequent middleware will now know the user principal for the request and can adjust behavior accordingly (for example, displaying the user's name on the homepage, or restricting access to some areas of the app).

> **NOTE** **The `AuthenticationMiddleware` is *only* responsible for authenticating incoming requests and setting the `ClaimsPrincipal` if the request contains an authentication cookie. It is *not* responsible for redirecting unauthenticated requests to the login page or rejecting unauthorized requests—that is handled by the `AuthorizationMiddleware`, as you'll see in chapter 15.**

The process described so far, in which a single app authenticates the user when they log in and sets a cookie that's read on subsequent requests, is common with traditional web apps, but it isn't the only possibility. In the next section, we take a look at authentication for Web API applications, used by client-side and mobile apps, and how the authentication system changes for those scenarios.

14.1.3 Authentication for APIs and distributed applications

The process I've outlined so far applies to traditional web apps, where you have a single endpoint that's doing all the work. It's responsible for authenticating and managing users, as well as serving your app data, as shown in figure 14.4.

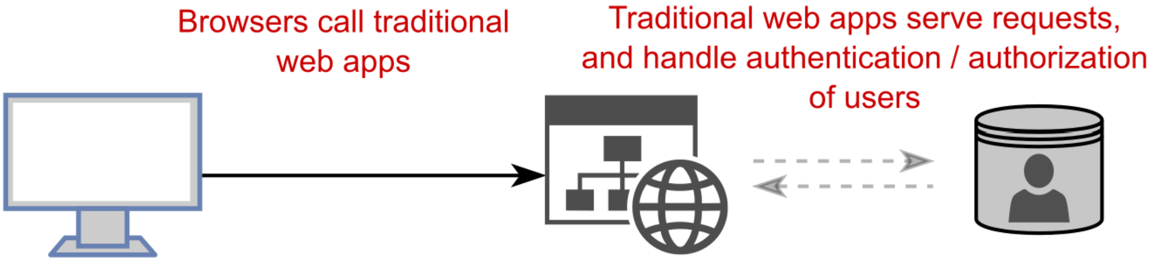

Browsers call traditional web apps
Traditional web apps serve requests, and handle authentication / authorization of users

Figure 14.4 Traditional apps typically handle all the functionality of an app: the business logic, generating the UI, authentication, and user management.

In addition to this traditional web app, it's common to use ASP.NET Core as a Web API to serve data for mobile and client-side SPAs. Similarly, the trend towards microservices on the backend means that even traditional web apps using Razor often need to call APIs behind the scenes, as shown in figure 14.5.

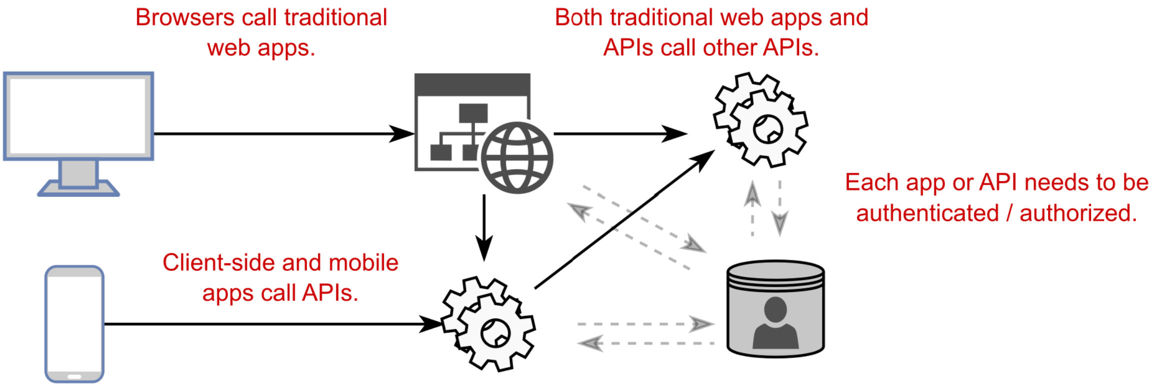

Browsers call traditional web apps.
Both traditional web apps and APIs call other APIs.
Each app or API needs to be authenticated / authorized.
Client-side and mobile apps call APIs.

Figure 14.5 Modern applications typically need to expose Web APIs for mobile and client-side apps, as well as potentially calling APIs on the backend. When all of these services need to authenticate and manage users, this becomes complicated logistically.

In this situation, you have multiple apps and APIs, all of which need to understand that the same user is making a request across all the apps and APIs. If you keep the same approach as before, where each app manages its own users, things can quickly become unmanageable!

You'd need to duplicate all the sign-in logic between the apps and APIs, as well as needing to have some central database holding the user details. Users may need to sign in multiple times to access different parts of the service. On top of that, using cookies becomes problematic for some mobile clients in particular, or where you're making requests to multiple domains (as cookies only belong to a single domain).

How can you improve this? The typical approach is to extract the code that's common to all of the apps and APIs, and move it to an *identity provider*, as shown in figure 14.6.

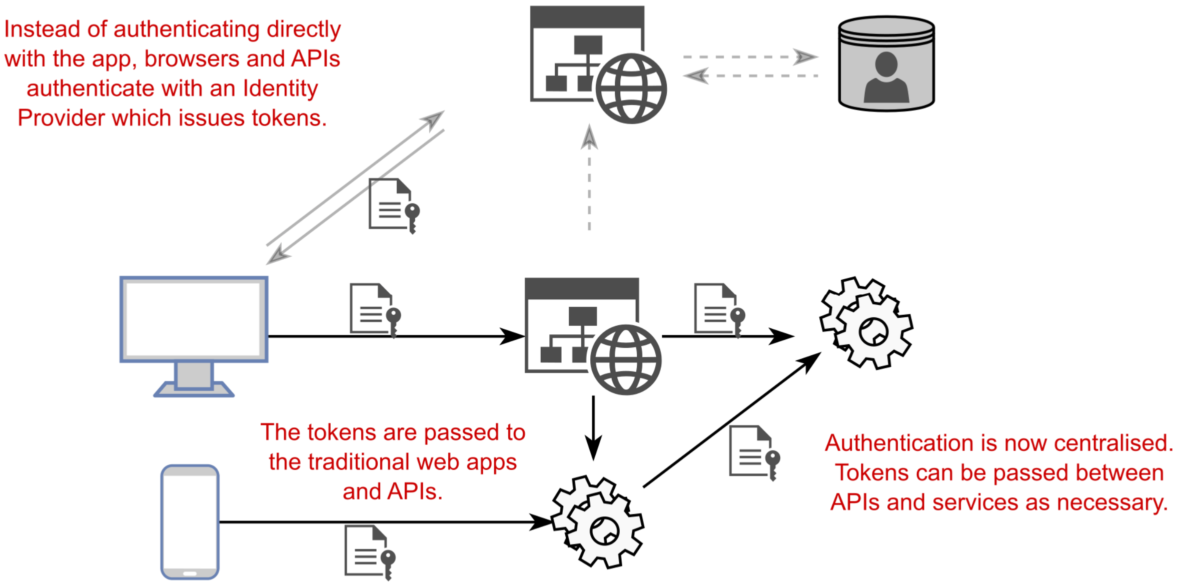

Instead of authenticating directly with the app, browsers and APIs authenticate with an Identity Provider which issues tokens.
The tokens are passed to the traditional web apps and APIs.
Authentication is now centralised. Tokens can be passed between APIs and services as necessary.

Figure 14.6 An alternative architecture involves using a central identity provider to handle all the authentication and user management for the system. Tokens are passed back and forth between the identity provider, apps, and APIs.

Instead of signing in to an app directly, the app redirects to an identity provider app. The user signs in to this identity provider, which passes *bearer tokens* back to the client that indicate who the user is and what they're allowed to access. The clients and apps can pass these tokens to the APIs, to provide information about the logged-in user, without needing to re-authenticate or manage users directly.

This architecture is clearly more complicated on the face of it, as you've thrown a whole new service—the identity provider—into the mix, but in the long run this has a number of advantages:

- *Users can share their identity between multiple services*. As you're logged in to the central identity provider, you're essentially logged in to *all* apps that use that service. This gives you the "single-sign-on" experience, where you don't have to keep logging in to multiple services.
- *Reduced duplication*. All of the sign-in logic is encapsulated in the identity provider, so you don't need to add sign-in screens to all your apps.
- *Can easily add new providers*. Whether you use the identity provider approach or the traditional approach, it's possible to use external services to handle the authentication of users. You'll have seen this on apps that allow you to "log in using Facebook" or "log in using Google," for example. If you use a centralized identity provider, adding support

for additional providers can be handled in one place, instead of having to configure every app and API explicitly.

Out of the box, ASP.NET Core supports architectures like this, and for *consuming* issued bearer tokens, but it doesn't include support for *issuing* those tokens in the core framework. That means you'll need to use another library or service for the identity provider.

One option for an identity provider is to delegate all the authentication responsibilities to a third-party identity provider, such as Facebook, Okta, Auth0, or Azure Active Directory B2C. These manage users for you, so user information and passwords are stored in their database, rather than your own. The biggest advantage of this approach is that you don't have to worry about making sure your customer data is safe; you can be pretty sure that a third party will protect it, as it's their whole business!

> **TIP** Wherever possible, I recommend this approach, as it delegates security responsibilities to someone else. You can't lose your user's details if you never had them!

Another common option is to build your own identity provider. This may sound like a lot of work, but thanks to excellent libraries like OpenIddict (https://github.com/ openiddict) and IdentityServer4 (http://docs.identityserver.io), it's perfectly possible to write your own identity provider to serve bearer tokens that will be consumed by an application.

An aspect often overlooked by people getting started with OpenIddict and IdentityServer is that they aren't prefabricated solutions. You, as a developer, need to write the code that knows how to create a new user (normally in a database), how to load a user's details, and how to validate their password. In that respect, the development process of creating an identity provider is similar to the traditional web app with cookie authentication that I discussed in section 14.1.2.

In fact, you can almost think of an identity provider as a traditional web app that only has account management pages. It also has the ability to generate tokens for other services, but it contains no other app-specific logic. The need to manage users in a database, as well as providing an interface for users to log in, is common to both approaches and is the focus of this chapter.

> **NOTE** Hooking up your apps and APIs to use an identity provider can require a fair amount of tedious configuration, both of the app and the identity provider. For simplicity, this book focuses on traditional web apps using the process outlined in section 14.1.2. ASP.NET Core includes a helper library for working with IdentityServer and client-side SPAs. For details on how to get started see the documentation at https://docs.microsoft.com/aspnet/core/security/authentication/identity-api-authorization and http://docs.identityserver.io.

ASP.NET Core Identity (hereafter shortened to Identity) is a system that makes building the user management aspect of your app (or identity provider app) simpler. It handles all of the boilerplate for saving and loading users to a database, as well as a number of best practices for security, such as user lock out, password hashing, and *two-factor authentication*.

> **DEFINITION** *Two-factor authentication* (2FA) is where you require an extra piece of information to sign in, in addition to a password. This could involve sending a code to a user's phone by SMS, or using a mobile app to generate a code, for example.

In the next section, I'm going to talk about the ASP.NET Core Identity system, the problems it solves, when you'd want to use it, and when you might not want to use it. In section 14.3, we'll take a look at some code and see ASP.NET Core Identity in action.

14.2 What is ASP.NET Core Identity?

In this section I introduce ASP.NET Core Identity, describe the features it provides, and the features that you must provide yourself. I also address some of the arguments against ASP.NET Core Identity, and when you should and shouldn't consider using it.

Whether you're writing a traditional web app using Razor Pages or are setting up a new identity provider using a library like IdentityServer, you'll need a way of persisting details about your users, such as their usernames and passwords.

This might seem like a relatively simple requirement but, given this is related to security and people's personal details, it's important you get it right. As well as storing the claims for each user, it's important to store passwords using a strong hashing algorithm, to allow users to use 2FA where possible, and to protect against brute force attacks, to name a few of the many requirements!

Although it's perfectly possible to write all the code to do this manually and to build your own authentication and membership system, I highly recommend you don't.

I've already mentioned third-party identity providers such as Auth0 or Azure Active Directory B2C. These are Software-as-a-Service (SaaS) solutions that take care of the user management and authentication aspects of your app for you. If you're in the process of moving apps to the cloud generally, then solutions like these can make a lot of sense.

If you can't or don't want to use these third-party solutions, then I recommend you consider using the ASP.NET Core Identity system to store and manage user details in your database. ASP.NET Core Identity takes care of most of the boilerplate associated with authentication, but remains flexible and lets you control the login process for users if you need to.

> **NOTE** ASP.NET *Core* Identity is an evolution of ASP.NET Identity, with some design improvements and converted to work with ASP.NET Core.

By default, ASP.NET Core Identity uses EF Core to store user details in the database. If you're already using EF Core in your project, then this is a perfect fit. Alternatively, it's possible to write your own stores for loading and saving user details in another way.

Identity takes care of the low-level parts of user management, as shown in table 14.1. As you can see from this list, Identity gives you a lot, but not everything—by a long shot!

Table 14.1 Which services are and aren’t handled by ASP.NET Core Identity

Managed by ASP.NET Core Identity	Requires implementing by the developer
Database schema for storing users and claims.	UI for logging in, creating, and managing users (Razor Pages or controllers). This is included in an optional package, which provides a default UI.
Creating a user in the database.	Sending emails messages.
Password validation and rules.	Customizing claims for users (adding new claims).
Handling user account lockout (to prevent brute-force attacks).	Configuring third-party identity providers.
Managing and generating 2FA codes.	
Generating password-reset tokens.	
Saving additional claims to the database.	
Managing third-party identity providers (for example Facebook, Google, Twitter).	

The biggest missing piece is the fact that you need to provide all the UI for the application, as well as tying all the individual Identity services together to create a functioning sign-in process. That’s a pretty big missing piece, but it makes the Identity system extremely flexible.

Luckily, ASP.NET Core includes a helper NuGet library, Microsoft.AspNetCore.Identity.UI, that gives you the whole of the UI boilerplate for free. That’s over 30 Razor Pages, with functionality for logging in, registering users, using two-factor authentication, and using external login providers, among others! You can still customize these pages if you need to, but having a whole login process working out of the box, with no code required on your part is a huge win. We’ll look at this library and how you use it in sections 14.3 and 14.4.

For that reason, I strongly recommend using the default UI as a starting point, whether you’re creating an app or adding user management to an existing app. But the question still remains: when should you use Identity, and when should you consider rolling your own?

I’m a big fan of Identity, so I tend to suggest it in most situations, as it handles a lot of security-related things for you that are easy to mess up. I’ve heard several arguments against it, some of which are valid, and others less so:

- *I already have user authentication in my app*. Great! In that case, you’re probably right, Identity may not be necessary. But does your custom implementation use 2FA? Do you have account lockout? If not, and you need to add them, then considering Identity may be worthwhile.

- *I don't want to use EF Core*. That's a reasonable stance. You could be using Dapper, some other ORM, or even a document database for your database access. Luckily, the database integration in Identity is pluggable, so you could swap out the EF Core integration and use your own database integration libraries instead.
- *My use case is too complex for Identity*. Identity provides lower-level services for authentication, so you can compose the pieces however you like. It's also extensible, so if you need to, for example, transform claims before creating a principal, you can.
- *I don't like the default Razor Pages UI*. The default UI for Identity is entirely optional. You can still use the Identity services and user management but provide your own UI for logging in and registering users. However, be aware that although doing this gives you a lot of flexibility, it's also very easy to introduce a security flaw in your user management system, the last place you want security flaws!
- *I'm not using Bootstrap to style my application*. The default Identity UI uses Bootstrap as a styling framework, the same as the default ASP.NET Core templates. Unfortunately, you can't easily change that, so if you're using a different framework, or need to customise the HTML generated, then you can still use Identity, but you'll need to provide your own UI.
- *I don't want to build my own identity system*. I'm glad to hear it. Using an external identity provider like Azure Active Directory B2C or Auth0 is a great way of shifting the responsibility and risk associated with storing users' personal information onto a third party.

Any time you're considering adding user management to your ASP.NET Core application, I'd recommend looking at Identity as a great option for doing so. In the next section, I'll demonstrate what Identity provides by creating a new Razor Pages application using the default Identity UI. In section 14.4, we'll take that template and apply it to an existing app instead, and in sections 14.5 and 14.6 you'll see how to override the default pages.

14.3 Creating a project that uses ASP.NET Core Identity

I've covered authentication and Identity in general terms a fair amount now, but the best way to get a feel for it is to see some working code. In this section, we're going to look at the default code generated by the ASP.NET Core templates with Identity, how the project works, and where Identity fits in.

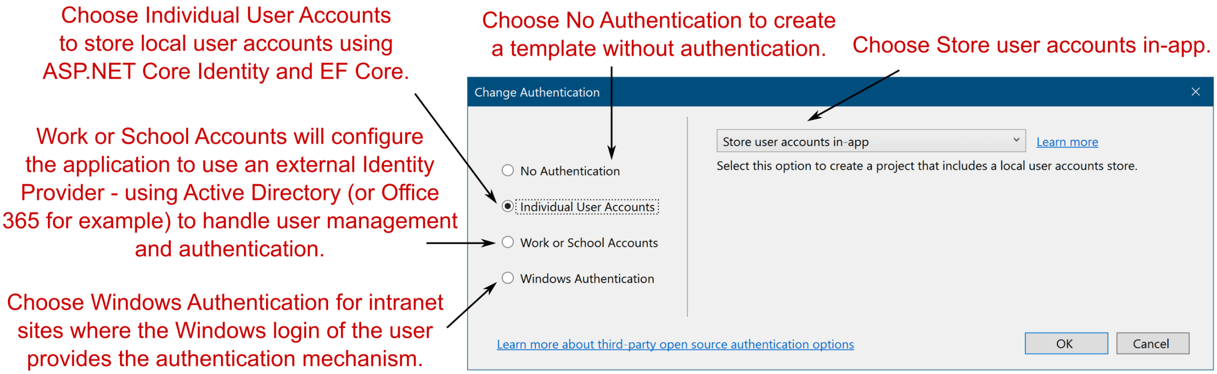
14.3.1 Creating the project from a template

You'll start by using the Visual Studio templates to generate a simple Razor Pages application that uses Identity for storing individual user accounts in a database.

> **TIP** **You can create an equivalent project using the .NET CLI by running** `dotnet new webapp -au Individual -uld`

To create the template using Visual Studio, you must be using VS 2019 or later and have the ASP.NET Core 3.1 SDK installed:

1. Choose File > New > Project or choose Create a New Project from the splash screen
2. From the list of templates, choose ASP.NET Core Web Application, ensuring you select the C# language template.
3. On the next screen, enter a project name, Location, and a solution name, and click Create.
4. Choose the Web Application template and click Change under Authentication to bring up the Authentication dialog, shown in figure 14.7.



Choose Individual User Accounts to store local user accounts using ASP.NET Core Identity and EF Core.

Choose No Authentication to create a template without authentication.

Choose Store user accounts in-app.

Work or School Accounts will configure the application to use an external Identity Provider - using Active Directory (or Office 365 for example) to handle user management and authentication.

Choose Windows Authentication for intranet sites where the Windows login of the user provides the authentication mechanism.

Change Authentication

○ No Authentication
● Individual User Accounts
○ Work or School Accounts
○ Windows Authentication

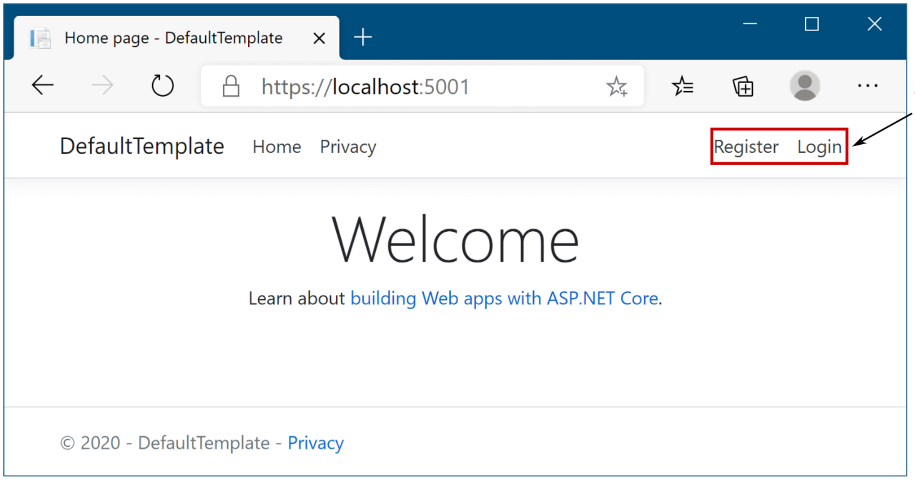
Store user accounts in-app

Select this option to create a project that includes a local user accounts store.

Learn more
Learn more about third-party open source authentication options
OK
Cancel

Figure 14.7 Choosing the authentication mode of the new ASP.NET Core application template in VS 2019

5. Choose Individual User Accounts to create an application configured with EF Core and ASP.NET Core Identity. Click OK.
6. Click Create to create the application. Visual Studio will automatically run `dotnet restore` to restore all the necessary NuGet packages for the project.
7. Run the application to see the default app, as shown in figure 14.8.


Home page - DefaultTemplate
https://localhost:5001
DefaultTemplate
Home
Privacy
Register
Login

Welcome

Learn about building Web apps with ASP.NET Core.

© 2020 - DefaultTemplate - Privacy

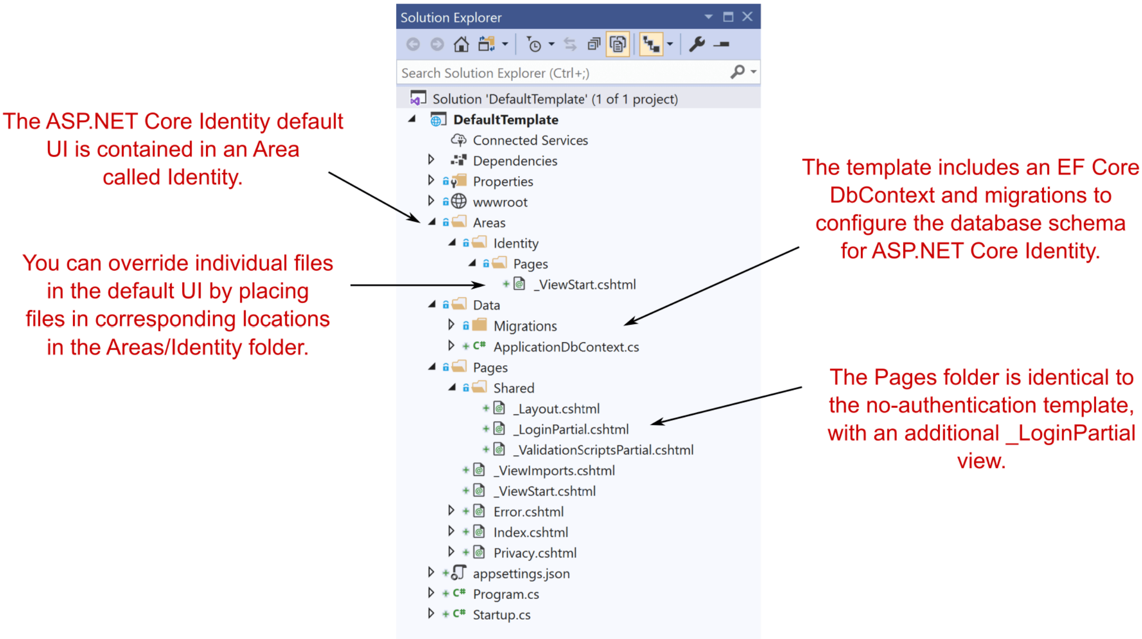
You can create new users and sign in using the log in widget.

Figure 14.8 The default template with individual account authentication looks similar to the no authentication template, with the addition of a login widget in the top right of the page.

This template should look familiar, with one twist: you now have Register and Login buttons! Feel free to play with the template—creating a user, logging in and out—to get a feel for the app. Once you're happy, look at the code generated by the template and the boilerplate it saved you from writing!

14.3.2 Exploring the template in Solution Explorer

The project generated by the template, shown in figure 14.9, is very similar to the default no-authentication template. That's largely due to the default UI library which brings in a big chunk of functionality without exposing you to the nitty gritty details.



The ASP.NET Core Identity default UI is contained in an Area called Identity.

You can override individual files in the default UI by placing files in corresponding locations in the Areas/Identity folder.

The template includes an EF Core DbContext and migrations to configure the database schema for ASP.NET Core Identity.

The Pages folder is identical to the no-authentication template, with an additional _LoginPartial view.

Figure 14.9 The project layout of the default template. Depending on your version of Visual Studio, the exact files may vary slightly.

The biggest addition is the Areas folder in the root of your project which contains an Identity subfolder. Areas are sometimes used for organizing sections of functionality. Each area can contain its own Pages folder, which is analogous to the main Pages folder in your application.

> **DEFINITION** ***Areas*** **are used to group Razor Pages into separate hierarchies for organizational purposes. I rarely use areas and prefer to create sub folders in the main Pages folder instead. The one exception is the default Identity UI which uses a separate Identity area by default. For more details on areas, see https://docs.microsoft.com/aspnet/core/mvc/controllers/areas.**

The Microsoft.AspNetCore.Identity.UI package creates Razor Pages in the “Identity” area. You can override any page in this default UI by creating a corresponding page in the Areas/Identity/Pages folder in your application. For example, as shown in figure 14.9, the default template adds a _ViewStart.cshtml file that overrides the version that is included as part of the default UI. This file contains the following code, which sets the default Identity UI Razor Pages to use your project’s default _Layout.cshtml file:

```
@{
    Layout = "/Pages/Shared/_Layout.cshtml";
}
```

Some obvious questions at this point might be "how do you know what's included in the default UI", and "which files you can override"? You'll see the answer to both of those in section 14.5, but in general you should try and avoid overriding files where possible. After all, the goal with the default UI is to *reduce* the amount of code you have to write!

The Data folder in your new project template contains your application's EF Core `DbContext`, called `ApplicationDbContext`, and the migrations for configuring the database schema to use Identity. I'll discuss this schema in more detail in section 14.3.3.

The final additional file included in this template compared to the no-authentication version is the partial Razor view Pages/Shared/_LoginPartial.cshtml. This provides the Register and Login links you saw in figure 14.8, and is rendered in the default Razor layout, _Layout.cshtml.

If you look inside _LoginPartial.cshtml, you can see how routing works with areas, by combining the Razor Page path with an `{area}` route parameter using Tag Helpers. For example, the Login link specifies that the Razor Page /Account/Login is in the `Identity` area using the asp-area attribute:

```
<a asp-area="Identity" asp-page="/Account/Login">Login</a>
```

TIP You can reference Razor Pages in the `Identity` area by setting the `area` route value to `Identity`. You can use the `asp-area` attribute in Tag Helpers that generate links.

In addition to the new files included thanks to ASP.NET Core Identity, it's worth opening up Startup.cs and looking at the changes there. The most obvious change is the additional configuration in `ConfigureServices`, which adds all the services Identity requires.

Listing 14.1 Adding ASP.NET Core Identity services to `ConfigureServices`

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddDbContext<ApplicationDbContext>(options =>              #A
        options.UseSqlServer(                                           #A
            Configuration.GetConnectionString("DefaultConnection")));   #A
    services.AddDefaultIdentity<IdentityUser>(options =>                #B
            options.SignIn.RequireConfirmedAccount = true)              #C
          .AddEntityFrameworkStores<ApplicationDbContext>();               #D
    services.AddRazorPages();
}
```

#A ASP.NET Core Identity uses EF Core, so it includes the standard EF Core configuration.
#B Adds the Identity system, including the default UI, and configures the user type as IdentityUser
#C Require users to confirm their accounts (typically by email) before they log in
#D Configures Identity to store its data in EF Core

The `AddDefaultIdentity()` extension method does several things:

- Adds the core ASP.NET Core Identity services.

- Configures the application user type to be `IdentityUser`. This is the entity model that is stored in the database and represents a "user" in your application. You can extend this type if you need to, but that's not always necessary, as you'll see in section 14.6.
- Adds the default UI Razor Pages for registering, logging in, and managing users.
- Configures token providers for generating 2FA and email confirmation tokens.

There's another, very important, change in `Startup`, in the `Configure` method:

```
app.UseAuthentication();
```

This adds `AuthenticationMiddleware` to the pipeline, so that you can authenticate incoming requests, as you saw in figure 14.3. *The location of this middleware is very important*. It should be placed after `UseRouting()`, and before `UseAuthorization()` and `UseEndpoints()` as shown in the following listing.

Listing 14.2 Adding `AuthenticationMiddleware` to your middleware pipeline

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    app.UseStaticFiles();                #A

    app.UseRouting();                    #B

    app.UseAuthentication();             #C
    app.UseAuthorization();              #D

    app.UseEndpoints(endpoints =>        #E
    {                                    #E
        endpoints.MapRazorPages();       #E
    });                                  #E
}
```

#A Middleware placed before UseAuthentication will see all requests as anonymous
#B The routing middleware determines which page is requested based on the request URL
#C UseAuthentication should be placed after UseRouting
#D UseAuthorization should be placed after UseAuthentication, so it can access the user principal
#E UseEndpoints should be last, after the user principal is set and authorization has been applied

If you don't use this specific order of middleware, you can run into strange bugs where users aren't authenticated correctly, or authorization policies aren't correctly applied. This order is configured for you automatically in your templates, but it's something to be careful about if you're upgrading an existing application, or moving middleware around.

> **IMPORTANT** `UseAuthentication()` **and** `UseAuthorization()` **must be placed between** `UseRouting()` **and** `UseEndpoints()`**. Additionally,** `UseAuthorization()` **must be placed after** `UseAuthentication()`**. You can add additional middleware between each of these calls, as long as this overall middleware order is preserved.**

Now you've got an overview of the additions made by Identity, we'll look in a bit more detail at the database schema and how Identity stores users in the database.

14.3.3 The ASP.NET Core Identity data model

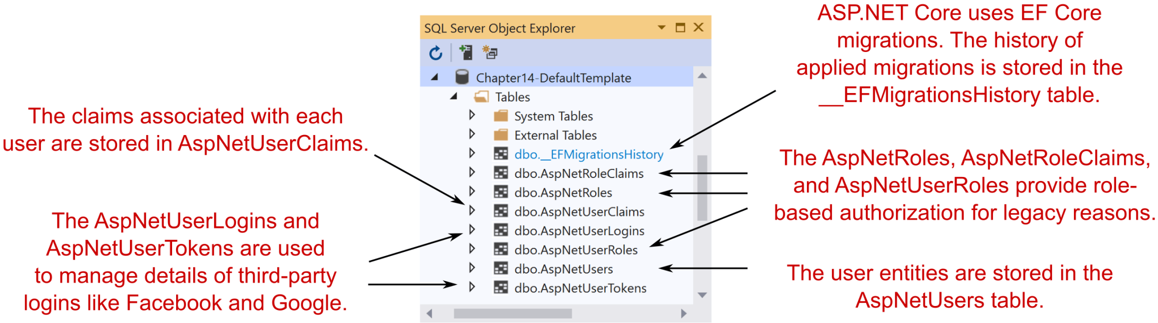
Out of the box, and in the default templates, Identity uses EF Core to store user accounts. It provides a base `DbContext` that you can inherit from, called `IdentityDbContext`, which uses an `IdentityUser` as the user entity for your application.

In the template, the app's `DbContext` is called `ApplicationDbContext`. If you open up this file, you'll see it's very sparse; it inherits from the `IdentityDbContext` base class I described earlier, and that's it. What does this base class give you? The easiest way to see is to update a database with the migrations and take a look!

Applying the migrations is the same process as in chapter 12. Ensure the connection string points to where you want to create the database, open a command prompt in your project folder, and run

```
dotnet ef database update
```

to update the database with the migrations. If the database doesn't yet exist, the CLI will create it. Figure 14.10 shows what the database looks like for the default template.[63]



The claims associated with each user are stored in AspNetUserClaims.

The AspNetUserLogins and AspNetUserTokens are used to manage details of third-party logins like Facebook and Google.

ASP.NET Core uses EF Core migrations. The history of applied migrations is stored in the __EFMigrationsHistory table.

The AspNetRoles, AspNetRoleClaims, and AspNetUserRoles provide role-based authorization for legacy reasons.

The user entities are stored in the AspNetUsers table.

Figure 14.10 The database schema used by ASP.NET Core Identity

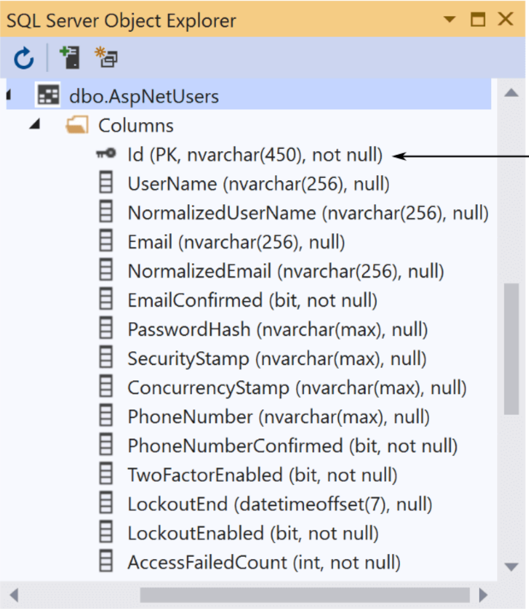
That's a lot of tables! You shouldn't need to interact with these tables directly—Identity handles that for you—but it doesn't hurt to have a basic grasp of what they're for:

- *__EFMigrationsHistory*—The standard EF Core migrations table that records which migrations have been applied.
- *AspNetUsers*—The user profile table itself. This is where `IdentityUser` is serialized to. We'll take a closer look at this table shortly.

[63] If you're using MS SQL Server (or LocalDB), you can use the SQL Server Object Explorer in Visual Studio to browse tables and objects in your database. See https://docs.microsoft.com/sql/ssdt/how-to-connect-to-a-database-and-browse-existing-objects for details.

- *AspNetUserClaims*—The claims associated with a given user. A user can have many claims, so it's modeled as a many-to-one relationship.
- *AspNetUserLogins and AspNetUserTokens*—These are related to third-party logins. When configured, these let users sign in with a Google or Facebook account (for example), instead of creating a password on your app.
- *AspNetUserRoles, AspNetRoles, and AspNetRoleClaims*—These tables are somewhat of a legacy left over from the old role-based permission model of the pre-.NET 4.5 days, instead of the claims-based permission model. These tables let you define roles that multiple users can belong to. Each role can be assigned a number of claims. These claims are effectively inherited by a user principal when they are assigned that role.

You can explore these tables yourself, but the most interesting of them is the AspNetUsers table, shown in figure 14.11.



dbo.AspNetUsers
Columns
Id (PK, nvarchar(450), not null)
UserName (nvarchar(256), null)
NormalizedUserName (nvarchar(256), null)
Email (nvarchar(256), null)
NormalizedEmail (nvarchar(256), null)
EmailConfirmed (bit, not null)
PasswordHash (nvarchar(max), null)
SecurityStamp (nvarchar(max), null)
ConcurrencyStamp (nvarchar(max), null)
PhoneNumber (nvarchar(max), null)
PhoneNumberConfirmed (bit, not null)
TwoFactorEnabled (bit, not null)
LockoutEnd (datetimeoffset(7), null)
LockoutEnabled (bit, not null)
AccessFailedCount (int, not null)

By default, ASP.NET Core Identity uses Guids for the user Id, stored as strings in the database.

The table contains all the neccessary fields for authenticating a user, email and phone number confirmation, two factor authentication, and account lockout.

Figure 14.11 The AspNetUsers table is used to store all the details required to authenticate a user.

Most of the columns in the AspNetUsers table are security related—the user's email, password hash, whether they have confirmed their email, whether they have 2FA enabled, and so on. By default, there are no columns for additional information, like the user's name, for example.

> **NOTE** You can see from figure 14.11 that the primary key `Id` is stored as a string column. By default, Identity uses `Guid` for the identifier. To customize the data type, see

https://docs.microsoft.com/aspnet/core/security/authentication/customize-identity-model#change-the-primary-key-type.

Any additional properties of the user are stored as claims in the AspNetUserClaims table associated with that user. This lets you add arbitrary additional information, without having to change the database schema to accommodate it. Want to store the user's date of birth? You could add a claim to that user—no need to change the database schema. You can see this in action in section 14.6, when you add a Name claim to every new user.

> **NOTE** Adding claims is often the easiest way to extend the default `IdentityUser`, but you can also add additional properties to the `IdentityUser` directly. This requires database changes but is nevertheless useful in many situations. You can read how to add custom data using this approach here: https://docs.microsoft.com/aspnet/core/security/authentication/add-user-data.

It's important to understand the difference between the `IdentityUser` entity (stored in the AspNetUsers table) and the `ClaimsPrincipal` which is exposed on `HttpContext.User`. When a user first logs in, an `IdentityUser` is loaded from the database. This entity is combined with additional claims for the user from the AspNetUserClaims table to create a `ClaimsPrincipal`. It's this `ClaimsPrincipal` which is used for authentication, and is serialized to the authentication cookie, not the `IdentityUser`.

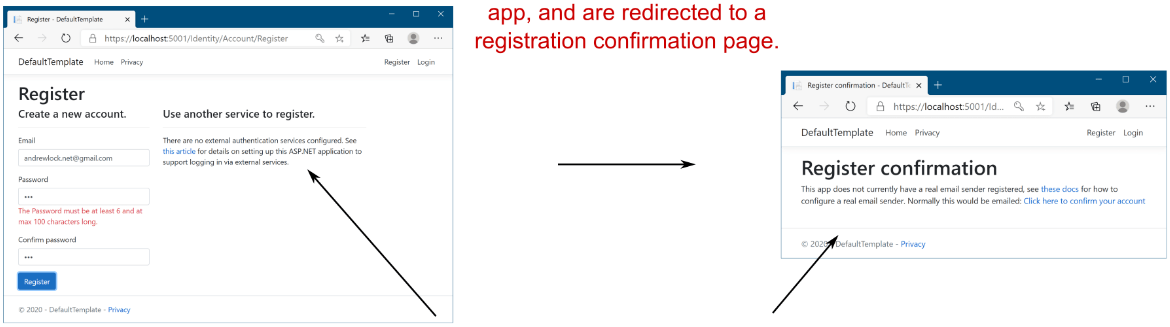
It's useful to have a mental model of the underlying database schema Identity uses, but in day-to-day work, you shouldn't have to interact with it directly—that's what Identity is for after all! In the next section, we'll look at the other end of the scale—the UI of the app, and what you get out-of-the box with the default UI.

14.3.4 Interacting with ASP.NET Core Identity

You'll want to explore the default UI yourself, to get a feel for how the pieces fit together, but in this section, I'll highlight what you get out of the box, as well as areas that typically require additional attention right away.

The entry point to the default UI is the user registration page of the application, shown in figure 14.12. The register page enables users to sign up to your application by creating a new `IdentityUser` with an email and a password. After creating an account, users are redirected to a screen indicating they should confirm their email. No email service is enabled by default, as this is dependent on you configuring an external email service. You can read how to enable email sending at https://docs.microsoft.com/aspnet/core/security/authentication/accconfirm. Once you configure this, users will automatically receive an email with a link to confirm their account.

Users enter an email and password to register with the app, and are redirected to a registration confirmation page.


Register - DefaultTemplate
https://localhost:5001/Identity/Account/Register
DefaultTemplate
Home
Privacy
Register
Login
Register
Email
Password
Confirm password
Register
Register confirmation - DefaultTe
https://localhost:5001/Id...
DefaultTemplate
Home
Privacy
Register
Login

Register

Create a new account.

Email: andrewlock.net@gmail.com

Password: •••

The Password must be at least 6 and at max 100 characters long.

Confirm password: •••

Use another service to register.

There are no external authentication services configured. See this article for details on setting up this ASP.NET application to support logging in via external services.

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Register confirmation

This app does not currently have a real email sender registered, see these docs for how to configure a real email sender. Normally this would be emailed: Click here to confirm your account

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The default UI templates include links to ASP.NET Core documentation for enabling external login providers and an email sending service.

Figure 14.12 The registration flow for users using the default Identity UI. Users enter an email and password and are redirected to a "confirm your email page". This is a placeholder page by default, but if you enable email confirmation, this page will update appropriately.

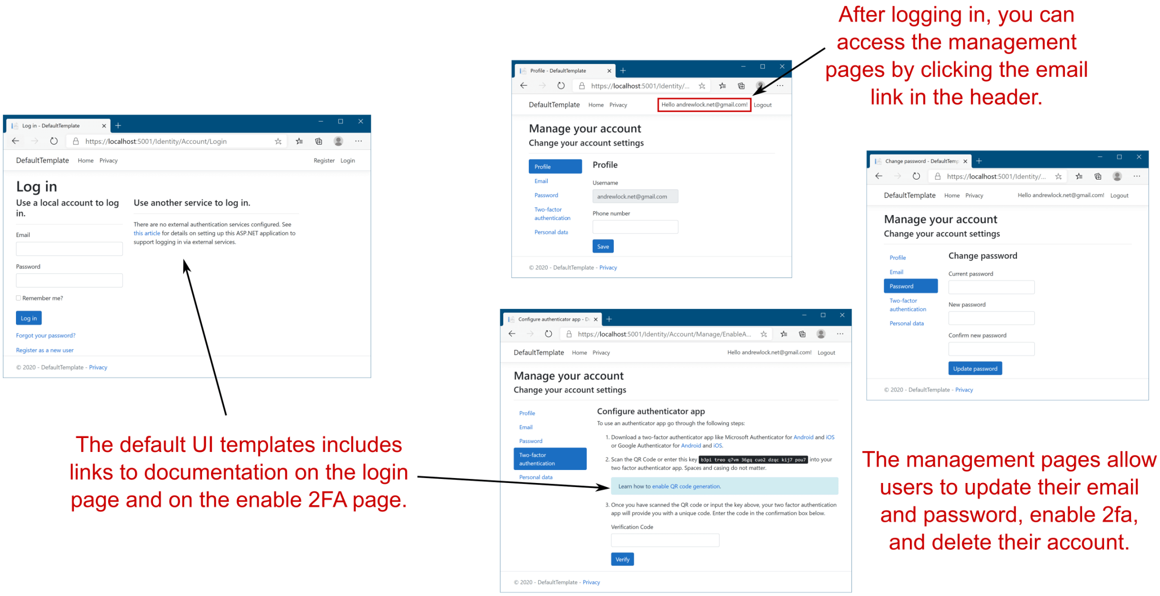
By default, user emails must be unique (you can't have two users with the same email) and the password must meet various length and complexity requirements. You can customize these options and more in the configuration lambda of the call to `AddDefaultIdentity()` in Startup.cs, as shown in the following listing.

Listing 14.3 Customizing Identity settings in ConfigurationService in Startup.cs

```
services.AddDefaultIdentity<ApplicationUser>(options =>
{
    options.SignIn.RequireConfirmedAccount = true;        #A
    options.Lockout.AllowedForNewUsers = true;            #B
    options.Password.RequiredLength = 12;                 #C
    options.Password.RequireNonAlphanumeric = false;      #C
    options.Password.RequireDigit = false;                #C
})
.AddEntityFrameworkStores<AppDbContext>();
```

#A Require users to confirm their account by email before they can log in
#B Enables user-lockout, to prevent brute-force attacks against user passwords
#C Update password requirements. Current guidance is to require long passwords.

After a user has registered with your application, they need to log in, as shown in figure 14.13. On the right-hand side of the login page, the default UI templates describe how you, the developer, can configure external login providers, such as Facebook and Google. This is useful information for you, but is one of the reasons you may need to customize the default UI templates, as you'll see in section 14.5.



Log in - DefaultTemplate
https://localhost:5001/Identity/Account/Login
DefaultTemplate
Home
Privacy
Register
Login
Log in
Use a local account to log in.
Email
Password
Remember me?
Log in
Forgot your password?
Register as a new user
Use another service to log in.
© 2020 - DefaultTemplate - Privacy
Profile - DefaultTemplate
https://localhost:5001/Identity/...
Hello andrewlock.net@gmail.com!
Logout
Manage your account
Change your account settings
Profile
Email
Password
Two-factor authentication
Personal data
Username
andrewlock.net@gmail.com
Phone number
Save
Change password - DefaultTemplate
Change password
Current password
New password
Confirm new password
Update password
Configure authenticator app - D
https://localhost:5001/Identity/Account/Manage/EnableA...
Configure authenticator app
Verification Code
Verify

There are no external authentication services configured. See this article for details on setting up this ASP.NET application to support logging in via external services.

To use an authenticator app go through the following steps:

1. Download a two-factor authenticator app like Microsoft Authenticator for Android and iOS or Google Authenticator for Android and iOS.
2. Scan the QR Code or enter this key `b3pi treo q7vm 36gq cuo2 dzqc kij7 pou7` into your two factor authenticator app. Spaces and casing do not matter.

   Learn how to enable QR code generation.

3. Once you have scanned the QR code or input the key above, your two factor authentication app will provide you with a unique code. Enter the code in the confirmation box below.

After logging in, you can access the management pages by clicking the email link in the header.

The default UI templates includes links to documentation on the login page and on the enable 2FA page.

The management pages allow users to update their email and password, enable 2fa, and delete their account.

Figure 14.13. Logging in with an existing user and managing the user account. The Login page describes how to configure external login providers, such as Facebook and Google. The user management pages allow users to change their email and password, and to configure Two Factor Authentication (2FA).

Once a user has signed in, they can access the management pages of the identity UI. These allow users to change their email, change their password, configure 2FA with an authenticator app, or delete all their personal data. Most of these functions work without any effort on your part, assuming you've already configured an email sending service.[64]

That covers everything you get in the default UI templates. It may seem somewhat minimal, but it covers a lot of the requirements that are common to almost all apps. Nevertheless, there are a few things you'll nearly always want to customize:

- Configure an email sending service, to enable account confirmation and password recovery, as described in the documentation: https://docs.microsoft.com/aspnet/core/security/authentication/accconfirm.
- Add a QR code generator for the enable 2FA page, as described in the documentation: https://docs.microsoft.com/aspnet/core/security/authentication/identity-enable-qrcodes.

[64] You can improve the 2FA authenticator page by enabling QR code generation, as described in this document: https://docs.microsoft.com/aspnet/core/security/authentication/identity-enable-qrcodes.

- Customise the register and log in pages to remove the documentation link for enabling external services. You'll see how to do this in section 14.5. Alternatively, you may want to disable user registration entirely, as described in the documentation: https://docs.microsoft.com/aspnet/core/security/authentication/scaffold-identity#disable-register-page.
- Collect additional information about users on the registration page. You'll see how to do this in section 14.6.

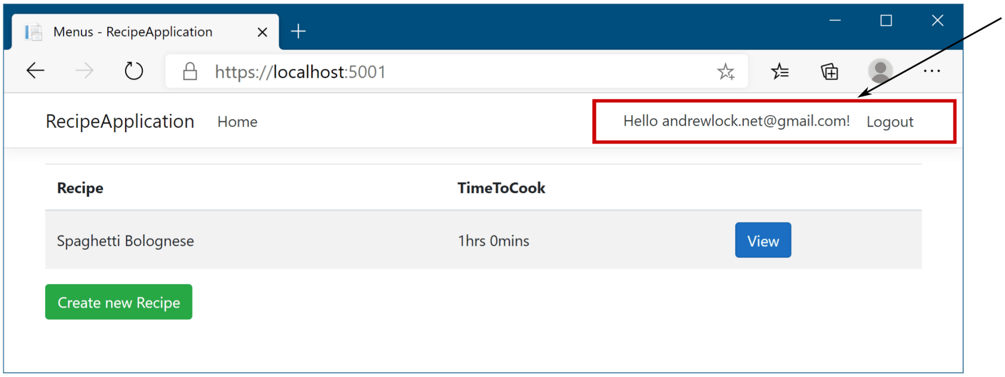
There are many more ways you can extend or update the Identity system, and lots of options available, so I encourage you to explore the documentation at https://docs.microsoft.com/aspnet/core/security/authentication to see your options. In the next section, you'll see how to achieve another common requirement: adding users to an existing application.

14.4 Adding ASP.NET Core Identity to an existing project

In this section, we're going to add users to the recipe application from chapters 12 and 13. This is a working app that you want to add user functionality to. In chapter 15, we'll extend this work to restrict control regarding who's allowed to edit recipes on the app.

By the end of this section, you'll have an application with a registration page, a login screen, and a manage account screen, like the default templates. You'll also have a persistent widget in the top right of the screen, showing the login status of the current user, as shown in figure 14.14.

The Login widget shows the current signed in user's email, and a link for them to log out.



Recipe	TimeToCook	
Spaghetti Bolognese	1hrs 0mins	View

Figure 14.14 The recipe app after adding authentication, showing the login widget.

As in section 14.3, I'm not going to customize any of the defaults at this point, so we won't set up external login providers, email confirmation, or 2FA; I'm only concerned with adding ASP.NET Core Identity to an existing app that's already using EF Core.

> **TIP** It's worth making sure you're comfortable with the new project templates before you go about adding Identity to an existing project. Create a test app and consider setting up an external login provider, configuring an email provider, and enabling 2FA. This will take a bit of time, but it'll be invaluable for deciphering errors when you come to adding Identity to existing apps.

To add Identity to your app, you'll need to:

1. Add the ASP.NET Core Identity NuGet packages.
2. Configure `Startup` to use `AuthenticationMiddleware` and add Identity services to the DI container.
3. Update the EF Core data model with the Identity entities.
4. Update your Razor Pages and layouts to provide links to the Identity UI.

This section will tackle each of these steps in turn. At the end of section 14.4, you'll have successfully added user accounts to the recipe app.

14.4.1 Configuring the ASP.NET Core Identity services and middleware

You can add ASP.NET Core Identity with the default UI to an existing app by referencing two NuGet packages:

- Microsoft.AspNetCore.Identity.EntityFrameworkCore—Provides all the core Identity services and integration with EF Core.
- Microsoft.AspNetCore.Identity.UI—Provides the default UI Razor Pages.

Update your project .csproj to include these two packages:

```
<PackageReference
    Include="Microsoft.AspNetCore.Identity.EntityFrameworkCore"
    Version="3.1.3" />
<PackageReference
    Include="Microsoft.AspNetCore.Identity.UI" Version="3.1.3" />
```

These packages bring in all the additional required dependencies you need to add Identity with the default UI. Be sure to run `dotnet restore` after adding them to your project.

Once you've added the Identity packages, you can update your Startup.cs file to include the Identity services, as shown next. This is similar to the default template setup you saw in listing 14.1, but make sure to reference your existing `AppDbContext`.

Listing 14.4 Adding ASP.NET Core Identity services to the recipe app

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddDbContext<AppDbContext>(options =>                    #A
        options.UseSqlServer(                                         #A
            Configuration.GetConnectionString("DefaultConnection")));    #A

    services.AddDefaultIdentity<ApplicationUser>(options =>              #B
            options.SignIn.RequireConfirmedAccount = true)               #B
        .AddEntityFrameworkStores<AppDbContext>();                       #C

    services.AddRazorPages();
    services.AddScoped<RecipeService>();
}
```

#A The existing service configuration is unchanged.
#B Adds the Identity services to the DI container. Uses a custom user type, ApplicationUser
#C Makes sure you use the name of your existing DbContext app

This adds all the necessary services and configures Identity to use EF Core. I've introduced a new type here `ApplicationUser`, which we'll use to customize our user entity later. You'll see how to add this type in section 14.4.2.

Configuring `AuthenticationMiddleware` is somewhat easier: add it to the pipeline in the `Configure` method. As you can see in listing 14.7, I've added the middleware after `UseRouting()`, just before `UseAuthorization()`. As I mentioned in section 14.3.2, it's important you use this order for middleware in your application.

Listing 14.5 Adding `AuthenticationMiddleware` to the recipe app

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    // other configuration not shown
    app.UseStaticFiles();             #A

    app.UseRouting();

    app.UseAuthentication();          #B
    app.UseAuthorization();           #C

    app.UseEndpoints(endpoints =>     #C
    {                                 #C
        endpoints.MapRazorPages();    #C
    });                               #C
}
```

#A StaticFileMiddleware will never see requests as authenticated, even after you sign in.
#B Adds AuthenticationMiddleware, after UseRouting() and before UseAuthorization
#C Middleware after AuthenticationMiddleware can read the user principal from HttpContext.User.

You've configured your app to use Identity, so the next step is to update EF Core's data model. You're already using EF Core in this app, so you need to update your database schema to include the tables that Identity requires.

14.4.2 Updating the EF Core data model to support Identity

The code in listing 14.4 won't compile, as it references the `ApplicationUser` type, which doesn't yet exist. Create the `ApplicationUser` in the Data folder, using the following:

```
public class ApplicationUser : IdentityUser { }
```

It’s not strictly necessary to create a custom user type (for example the default templates use the raw `IdentityUser`) but I find it’s easier to add now rather than try and retrofit it later if you need to customize the type.

In section 14.3.3 you saw that Identity provides a `DbContext` called `IdentityDbContext`, which you can inherit from. The `IdentityDbContext` base class includes the necessary `DbSet<T>` to store your user entities using EF Core.

Updating an existing `DbContext` for Identity is simple—update your app’s `DbContext` to inherit from `IdentityDbContext`, as shown in the following listing. We’re using the generic version of the base Identity context in this case and providing the `ApplicationUser` type.

Listing 14.6 Updating `AppDbContext` to use `IdentityDbContext`

```
public class AppDbContext : IdentityDbContext<ApplicationUser>      #A
{
    public AppDbContext(DbContextOptions<AppDbContext> options)    #B
        : base(options)                                            #B
    { }                                                            #B
                                                                   #B
    public DbSet<Recipe> Recipes { get; set; }                     #B
}
```

#A Updates to inherit from the Identity context, instead of directly from DbContext
#B The remainder of the class remains the same

Effectively, by updating the base class of your context in this way, you’ve added a whole load of new entities to EF Core’s data model. As you saw in chapter 12, whenever EF Core’s data model changes, you need to create a new migration and apply those changes to the database.

At this point, your app should compile, so you can add a new migration called `AddIdentitySchema` using

```
dotnet ef migrations add AddIdentitySchema.
```

The final step is to update your application’s Razor Pages and layouts to reference the default identity UI. Normally, adding 30 new Razor Pages to your application would be a lot of work, but using the default Identity UI makes it a breeze.

14.4.3 Updating the Razor views to link to the Identity UI

Technically, you don’t *have* to update your Razor Pages to reference the pages included in the default UI, but you probably want to add the login widget to your app’s layout at a minimum. You’ll also want to make sure that your Identity Razor Pages use the same base Layout.cshtml as the rest of your application.

We’ll start by fixing the layout for your Identity pages. Create a file at the “magic” path Areas/Identity/Pages/_ViewStart.cshtml, and add the following contents:

```
@{ Layout = "/Pages/Shared/_Layout.cshtml"; }
```

This sets the default layout for your Identity pages to your application's default layout. Next, add a _LoginPartial.cshtml file in Pages/Shared to define the login widget, as shown in the following listing. This is pretty much identical to the template generated by the default template, but using our custom `ApplicationUser` instead of the default `IdentityUser`.

Listing 14.7 Adding a _LoginPartial.cshtml to an existing app.

```
@using Microsoft.AspNetCore.Identity
@using RecipeApplication.Data;                          #A
@inject SignInManager<ApplicationUser> SignInManager    #B
@inject UserManager<ApplicationUser> UserManager        #B

<ul class="navbar-nav">
@if (SignInManager.IsSignedIn(User))
{
  <li class="nav-item">
    <a  class="nav-link text-dark" asp-area="Identity"
    asp-page="/Account/Manage/Index" title="Manage">Hello
    User.Identity.Name!</a>
  </li>
    <li class="nav-item">
      <form class="form-inline" asp-page="/Account/Logout"
      asp-route-returnUrl="@Url.Page("/", new { area = "" })"
      asp-area="Identity" method="post" >
        <button  class="nav-link btn btn-link text-dark"
          type="submit">Logout</button>
        </form>
    </li>
}
else
{
  <li class="nav-item">
    <a class="nav-link text-dark" asp-area="Identity"
      asp-page="/Account/Register">Register</a>
  </li>
  <li class="nav-item">
    <a class="nav-link text-dark" asp-area="Identity"
      asp-page="/Account/Login">Login</a>
  </li>
}
</ul>
```

#A Update to your project's namespace that contains ApplicationUser
#B The default template uses IdentityUser. Update to use ApplicationUser instead.

This partial shows the current login status of the user and provides links to register or sign in. All that remains is to render the partial by calling

```
<partial name="_LoginPartial" />
```

in the main layout file of your app, _Layout.cshtml.

And there you have it: you've added Identity to an existing application. The Default UI makes doing this relatively simple, and you can be sure you haven't introduced any security holes by building your own UI!

As I described in section 14.3.4, there are some features that the default UI doesn't provide that you need to implement yourself, such as email confirmation and 2FA QR code generation. It's also common to find that you want to update a single page, here and there. In the next section I show how you can replace a page in the default UI, without having to rebuild the entire UI yourself.

14.5 Customizing a page in ASP.NET Core Identity's default UI

In this section you'll learn how to use "scaffolding" to replace individual pages in the default Identity UI. You'll learn to scaffold a page so that it overrides the default UI, allowing you to customize both the Razor template and the `PageModel` page handlers.

Having Identity provide the whole UI for your application is great in theory, but in practice there are a few wrinkles, as you've already seen in section 14.3.4. The default UI provides as much as it can, but there's some things you may want to tweak. For example, both the login and register pages describe how to configure external login providers for your ASP.NET Core applications, as you saw in figures 14.12 and 14.13. That's useful information for you as a developer, but not something you want to be showing to your users! Another often-cited requirement is the desire to change the look and feel of one or more pages.

Luckily, the default Identity UI is designed to be incrementally replaceable, so that you can "override" a single page, without having to rebuild the entire UI yourself. On top of that, both Visual Studio and the .NET CLI have functions that allow you to "scaffold" any (or all) of the pages in the default UI, so that you don't have to start from scratch when you want to tweak a page.

> **DEFINITION** Scaffolding is the process of generating files in your project that serve as the basis for customization. The Identity scaffolder adds Razor Pages in the correct locations, so they override equivalent pages with the default UI. Initially, the code in the scaffolded pages matches that in the default Identity UI, but you are free to customize it.

As an example of the changes you can easily make, we'll scaffold the registration page, and remove the additional information section about external providers. The following steps describe how to scaffold the Register.cshtml page in Visual Studio. Alternatively, you can use the .NET CLI to scaffold the registration page.[65]

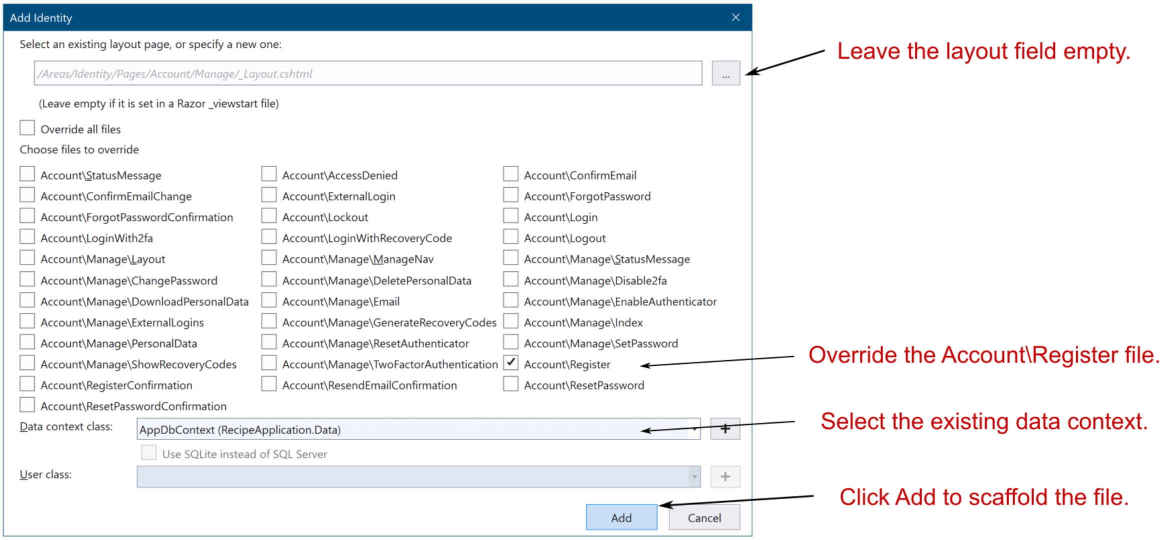
1. Add the Microsoft.VisualStudio.Web.CodeGeneration.Design and Microsoft.EntityFrameworkCore.Tools NuGet packages to your project file, if they're not

[65] Install the necessary .NET CLI tools and packages as described in the documentation https://docs.microsoft.com/aspnet/core/security/authentication/scaffold-identity. Then run `dotnet aspnet-codegenerator identity -dc RecipeApplication.Data.AppDbContext --files "Account.Register"`

already added. Visual Studio uses these packages to scaffold your application correctly, and without them you will get an error running the scaffolder.

```
<PackageReference Version="3.1.3"
    Include="Microsoft.VisualStudio.Web.CodeGeneration.Design" />
<PackageReference Version="3.1.3"
    Include="Microsoft.EntityFrameworkCore.Tools" />
```

2. Ensure your project builds—if it doesn't build, the scaffolder will fail before adding your new pages.
3. Right-click your project and choose Add > New Scaffolded Item.
4. In the selection dialog, choose Identity from the category, and click Add.
5. In the Add Identity dialog, select the Account/Register page, and select your application's `AppDbContext` as the Data context class, as shown in figure 14.15. Click Add to scaffold the page.



Select an existing layout page, or specify a new one:

/Areas/Identity/Pages/Account/Manage/_Layout.cshtml

(Leave empty if it is set in a Razor _viewstart file)

□ Override all files

Choose files to override

□ Account\StatusMessage
□ Account\ConfirmEmailChange
□ Account\ForgotPasswordConfirmation
□ Account\LoginWith2fa
□ Account\Manage\Layout
□ Account\Manage\ChangePassword
□ Account\Manage\DownloadPersonalData
□ Account\Manage\ExternalLogins
□ Account\Manage\PersonalData
□ Account\Manage\ShowRecoveryCodes
□ Account\RegisterConfirmation
□ Account\ResetPasswordConfirmation
□ Account\AccessDenied
□ Account\ExternalLogin
□ Account\Lockout
□ Account\LoginWithRecoveryCode
□ Account\Manage\ManageNav
□ Account\Manage\DeletePersonalData
□ Account\Manage\Email
□ Account\Manage\GenerateRecoveryCodes
□ Account\Manage\ResetAuthenticator
□ Account\Manage\TwoFactorAuthentication
□ Account\ResendEmailConfirmation
□ Account\ConfirmEmail
□ Account\ForgotPassword
□ Account\Login
□ Account\Logout
□ Account\Manage\StatusMessage
□ Account\Manage\Disable2fa
□ Account\Manage\EnableAuthenticator
□ Account\Manage\Index
□ Account\Manage\SetPassword
☑ Account\Register
□ Account\ResetPassword

Data context class: AppDbContext (RecipeApplication.Data) +

□ Use SQLite instead of SQL Server

User class: +

Leave the layout field empty.

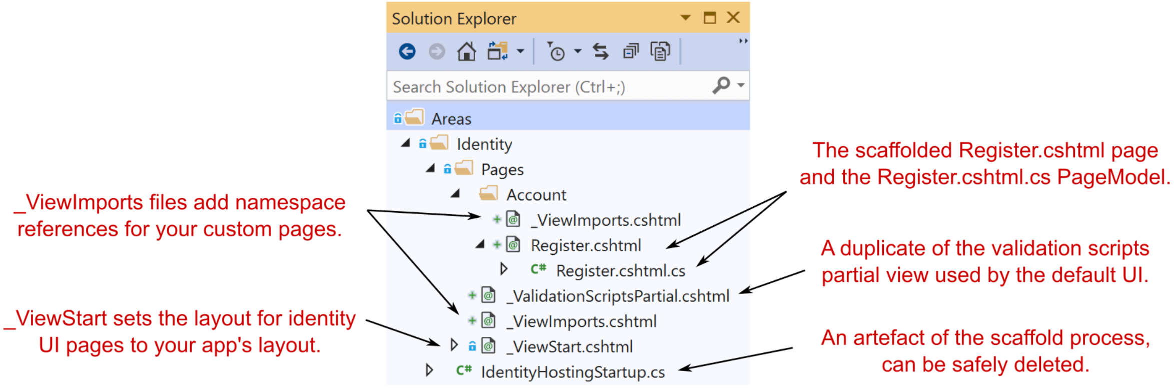
Override the Account\Register file.

Select the existing data context.

Click Add to scaffold the file.

Figure 14.15 Using Visual Studio to scaffold Identity pages. The generated Razor Pages will override the versions provided by the Default UI.

Visual Studio builds your application, and then generates the Register.cshtml page for you, placing it into the Areas/Identity/Pages/Account folder. It also generates several supporting files, as shown in figure 14.16. These are mostly required to ensure your new Register.cshtml Page can reference the remaining pages in the default Identity UI.



_ViewImports files add namespace references for your custom pages.

_ViewStart sets the layout for identity UI pages to your app's layout.

The scaffolded Register.cshtml page and the Register.cshtml.cs PageModel.

A duplicate of the validation scripts partial view used by the default UI.

An artefact of the scaffold process, can be safely deleted.

Figure 14.16 The Scaffolder generates the Register.cshtml Razor Page, along with supporting files required to integrate with the remainder of the default Identity UI.

We're interested in the Register.cshtml page, as we want to customize the UI on the Register page, but if you look inside the code-behind page, Register.cshtml.cs, you'll see how much complexity the default Identity UI is hiding from you. It's not insurmountable (we'll customize the page handler in section 14.6) but it's always good to avoid writing code if you can help it!

Now you have the Razor template in your application, you can customize it to your heart's content. The downside is that you're now maintaining more code than you were with the default UI. You didn't have to write it, but you may still have to *update* it when a new version of ASP.NET Core is released.

I like to use a bit of a "trick" when it comes to overriding default identity UI like this. In many cases, you don't actually want to change the *page handlers* for the Razor Page, just the Razor *view*. You can achieve this by deleting the Register.cshtml.cs `PageModel` file, and pointing your newly-scaffolded cshtml file at the *original* `PageModel`, which is part of the default UI NuGet package.

The other benefit of this approach is that you can delete some of the other files that were auto-scaffolded. In total, you can make the following changes:

1. Update the `@model` directive in Register.cshtml to point to the default UI `PageModel`:

```
@model Microsoft.AspNetCore.Identity.UI.V4.Pages.Account.Internal.RegisterModel
```

2. Update Areas/Identity/Pages/_ViewImports.chstml to the following:

```
@addTagHelper *, Microsoft.AspNetCore.Mvc.TagHelpers
```

3. Delete Areas/Identity/Pages/IdentityHostingStartup.cs
4. Delete Areas/Identity/Pages/_ValidationScriptsPartial.cshtml
5. Delete Areas/Identity/Pages/Account/Register.cshtml.cs
6. Delete Areas/Identity/Pages/Account/_ViewImports.cshtml

After making all these changes, you'll have the best of both worlds—you can update the default UI Razor Pages HTML, without taking on the responsibility of maintaining the default UI code behind.

> **TIP** In the source code for the book you can see these changes in action, where the Register view has been customized to remove the references to external identity providers.

Unfortunately, it's not always possible to use the default UI `PageModel`. Sometimes, you *need* to update the page handlers, such as when you want to change the functionality of your Identity area, rather than just the look and feel. A common requirement is needing to store additional information about a user, as you'll see in the next section.

14.6 Managing users: adding custom data to users

In this section you'll see how to customize the `ClaimsPrincipal` assigned to your users by adding additional claims to the AspNetUserClaims table when the user is created. You'll also see how to access these claims in your Razor Pages and templates.

Very often, the next step after adding Identity to an application is to customize it. The default templates only require an email and password to register. What if you need more details, like a friendly name for the user? Also, I've mentioned that we use claims for security, so what if you want to add a claim called `IsAdmin` to certain users?

You know that every user principal has a collection of claims so, conceptually, adding any claim just requires adding it to the user's collection. There are two main times that you would want to grant a claim to a user:

- *For every user, when they first register on the app.* For example, you might want to add a "Name" field to the Register form and add that as a claim to the user when they register.
- *Manually, after the user has already registered.* This is common for claims used as "permissions," where an existing user might want to add an `IsAdmin` claim to a specific user after they have registered on the app.

In this section, I show you the first approach, automatically adding new claims to a user when they're created. The latter approach is the more flexible and, ultimately, is the approach many apps will need, especially line-of-business apps. Luckily, there's nothing conceptually difficult to it; it requires a simple UI that lets you view users and add a claim through the same mechanism I'll show here.

> **TIP** Another common approach is to customize the `IdentityUser` entity, by adding a `Name` property for example. This approach is sometimes easier to work with if you want to give users the ability to edit that property. The documentation describes the steps required to achieve that: https://docs.microsoft.com/aspnet/core/security/authentication/add-user-data.

Let’s say you want to add a new Claim to a user called FullName. A typical approach would be:

1. Scaffold the Register.cshtml Razor Page, as you did in section 14.5.
2. Add a “Name” field to the InputModel in the Register.cshtml.cs PageModel.
3. Add a “Name” input field to the Register.cshtml Razor view template.
4. Create the new ApplicationUser entity as before in the OnPost() page handler, by calling CreateAsync on UserManager<ApplicationUser>.
5. Add a new Claim to the user by calling UserManager.AddClaimAsync().
6. Continue the method as before, sending a confirmation email, or signing the user in if email confirmation is not required.

Steps 1-3 are fairly self-explanatory and just require updating the existing templates with the new field. Steps 4-6 all take place in Register.cshtml.cs in the OnPost() page handler, which is summarized in the following listing. In practice the page handler has more error checking and boilerplate; our focus here is on the additional lines that add the extra Claim to the ApplicationUser.

Listing 14.8 Adding a custom claim to a new user in the Register.cshtml.cs page

```
public async Task<IActionResult> OnPostAsync(string returnUrl = null)
{
    if (ModelState.IsValid)
    {
        var user = new ApplicationUser {                      #A
            UserName = Input.Email, Email = Input.Email };    #A
        var result = await _userManager.CreateAsync(          #B
            user, Input.Password);                            #B
        if (result.Succeeded)
        {
            var claim = new Claim("FullName", Input.Name);    #C
            await _userManager.AddClaimAsync(user, claim);    #D

            var code = await _userManager                      #E
                .GenerateEmailConfirmationTokenAsync(user);    #E
            await _emailSender.SendEmailAsync(                 #E
                 Input.Email, "Confirm your email", code );    #E
            await _signInManager.SignInAsync(user);            #F
            return LocalRedirect(returnUrl);
        }
        foreach (var error in result.Errors)                  #G
        {                                                     #G
            ModelState.AddModelError(                         #G
                string.Empty, error.Description);             #G
        }                                                     #G
    }
       return Page();                                            #G
}
```

#A Creates an instance of the ApplicationUser entity, as usual
#B Validates that the provided password is valid and creates the user in the database
#C Creates a claim, with a string name of "FullName" and the provided value
#D Adds the new claim to the ApplicationUser’s collection

#E Sends a confirmation email to the user, if you have configured the email sender
#F Signs the user in by setting the HttpContext.User, the principal will include the custom claim
#G There was a problem creating the user. Add the errors to the ModelState, and redisplay the page

This is all that's required to *add* the new claim, but you're not *using* it anywhere currently. What if you want to display it? Well, you've added a claim to the `ClaimsPrincipal`, which was assigned to the `HttpContext.User` property when you called `SignInAsync`. That means you can retrieve the claims anywhere you have access to the `ClaimsPrincipal`—including in your page handlers and in view templates. For example, you could display the user's `FullName` claim anywhere in a Razor template with the following statement:

```
@User.Claims.FirstOrDefault(x=>x.Type == "FullName")?.Value
```

This finds the first claim on the current user principal with a `Type` of `"FullName"` and prints the assigned value (if the claim is not found, it prints nothing). The Identity system even includes a handy extension method that tidies up this LINQ expression (found in the `System.Security.Claims` namespace):

```
@User.FindFirstValue("FullName")
```

And with that last tidbit, we've reached the end of this chapter on ASP.NET Core Identity. I hope you've come to appreciate the amount of effort using Identity can save you, especially when you make use of the default Identity UI package.

Adding user accounts and authentication to an app is typically the first step to customizing your app further. Once you have authentication, you can have authorization, which lets you lock down certain actions in your app, based on the current user. In the next chapter, you'll learn about the ASP.NET Core authorization system and how you can use it to customize your apps, in particular, the recipe application, which is coming along nicely!

14.7 Summary

- Authentication is the process of determining who you are and authorization is the process of determining what you're allowed to do. You need to authenticate users before you can apply authorization.
- Every request in ASP.NET Core is associated with a user, also known as a principal. By default, without authentication, this is an anonymous user. You can use the claims principal to behave differently depending on who made a request.
- The current pr1incipal for a request is exposed on `HttpContext.User`. You can access this value from your Razor Pages and views to find out properties of the user such as their, ID, Name or Email.
- Every user has a collection of claims. These claims are single pieces of information about the user. Claims could be properties of the physical user, such as `Name` and `Email`, or they could be related to things the user has, such as `HasAdminAccess` or `IsVipCustomer`.

- Earlier versions of ASP.NET used roles instead of claims. You can still use roles if you need to, but you should use claims where possible.
- Authentication in ASP.NET Core is provided by `AuthenticationMiddleware` and a number of authentication services. These services are responsible for setting the current principal when a user logs in, saving it to a cookie, and loading the principal from the cookie on subsequent requests.
- The `AuthenticationMiddleware` is added by calling `UseAuthentication()` in your middleware pipeline. This must be placed after the call to `UseRouting()` and before `UseAuthorization()` and `UseEndpoints()`.
- ASP.NET Core includes support for consuming bearer tokens for authenticating API calls and includes helper libraries for configuring IdentityServer. For more details see https://docs.microsoft.com/aspnet/core/security/authentication/identity-api-authorization.
- ASP.NET Core Identity handles low-level services needed for storing users in a database, ensuring their passwords are stored safely, and for logging users in and out. You must provide the UI for the functionality yourself and wire it up to the Identity sub-system.
- The Microsoft.AspNetCore.Identity.UI package provides a default UI for the Identity system, and includes email confirmation, 2FA, and external login provider support. You need to do some additional configuration to enable these features.
- The default template for a Web Application with Individual Account Authentication uses ASP.NET Core Identity to store users in the database with EF Core. It includes all the boilerplate code required to wire the UI up to the Identity system.
- You can use the `UserManager<T>` class to create new user accounts, load them from the database, and change their passwords. `SignInManager<T>` is used to sign a user in and out, by assigning the principal for the request and by setting an authentication cookie. The default UI uses these classes for you to facilitate user registration and login.
- You can update an EF Core `DbContext` to support Identity by deriving from `IdentityDbContext<TUser>` where `TUser` is a class that derives from `IdentityUser`.
- You can add additional claims to a user using the `UserManager<TUser>.AddClaimAsync(TUser user, Claim claim)` method. These claims are added to the `HttpContext.User` object when the user logs in to your app.
- Claims consist of a type and a value. Both values are strings. You can use standard values for types exposed on the `ClaimTypes` class, such as `ClaimTypes .GivenName` and `ClaimTypes.FirstName`, or you can use a custom string, such as `"FullName"`.

15

Authorization: securing your application

This chapter covers

- **Using authorization to control who can use your app**
- **Using claims-based authorization with policies**
- **Creating custom policies to handle complex requirements**
- **Authorizing a request depending upon the resource being accessed**
- **Hiding elements from a Razor template that the user is unauthorized to access**

In chapter 14, I showed how to add users to an ASP.NET Core application by adding authentication. With authentication, users can register and log in to your app using an email and password. Whenever you add authentication to an app, you inevitably find you want to be able to restrict what some users can do. The process of determining whether a user can perform a given action on your app is called *authorization*.

On an e-commerce site, for example, you may have admin users who are allowed to add new products and change prices, sales users who are allowed to view completed orders, and customer users who are only allowed to place orders and buy products.

In this chapter, I show how to use authorization in an app to control what your users can do. In section 15.1, I introduce authorization and put it in the context of a real-life scenario you've probably experienced: an airport. I describe the sequence of events, from checking in, passing through security, to entering an airport lounge, and how these relate to the authorization concepts you'll see in this chapter.

In section 15.2, I show how authorization fits into an ASP.NET Core web application and how it relates to the `ClaimsPrincipal` class that you saw in the previous chapter. You'll see how to enforce the simplest level of authorization in an ASP.NET Core app, ensuring that only authenticated users can execute a Razor Page or MVC action.

We'll extend that approach in section 15.3 by adding in the concept of policies. These let you make specific requirements about a given authenticated user, requiring that they have specific pieces of information in order to execute an action or Razor Page.

You'll use policies extensively in the ASP.NET Core authorization system, so in section 15.4, we explore how to handle more complex scenarios. You'll learn about authorization requirements and handlers, and how you can combine them to create specific policies that you can apply to your Razor Pages and actions.

Sometimes, whether a user is authorized depends on which resource or document they're attempting to access. A resource is anything that you're trying to protect, so it could be a document or a post in a social media app for example.

For example, you may allow users to create documents, or to read documents from other users, but only to edit documents that they created themselves. This type of authorization, where you need the details of the document to determine if the user is authorized, is called resource-based authorization, and is the focus of section 15.5.

In the final section of this chapter, I show how you can extend the resource-based authorization approach to your Razor view templates. This lets you modify the UI to hide elements that users aren't authorized to interact with. In particular, you'll see how to hide the Edit button when a user isn't authorized to edit the entity.

We'll start by looking more closely at the concept of authorization, how it differs from authentication, and how it relates to real-life concepts you might see in an airport.

15.1 Introduction to authorization

In this section, I provide an introduction to authorization, and how it compares to authentication. I use the real-life example of an airport as a case study to understand how claims-based authorization works.

For people who are new to web apps and security, authentication and authorization can sometimes be a little daunting. It certainly doesn't help that the words look so similar! The two concepts are often used together, but they're definitely distinct:

- *Authentication*—The process of determining who made a request
- *Authorization*—The process of determining whether the requested action is allowed

Typically, authentication occurs first, so that you know who is making a request to your app. For traditional web apps, your app authenticates a request by checking the encrypted cookie that was set when the user logged in (as you saw in the previous chapter). Web APIs typically use a header instead of a cookie for authentication, but the process is the same.

Once a request is authenticated and you know who is making the request, you can determine whether they're allowed to execute an action on your server. This process is called authorization and is the focus of this chapter.

Before we dive into code and start looking at authorization in ASP.NET Core, I'll put these concepts into a real-life scenario you're hopefully familiar with: checking in at an airport. To enter an airport and board a plane, you must pass through several steps: an initial step to prove who you are (authentication); and subsequent steps that check whether you're allowed to proceed (authorization). In simplified form, these might look like:

1. Show passport at check-in desk. Receive a boarding pass.
2. Show boarding pass to enter security. Pass through security.
3. Show frequent flyer card to enter the airline lounge. Enter lounge.
4. Show boarding pass to board flight. Enter airplane.

Obviously, these steps, also shown in figure 15.1, will vary somewhat (I don't have a frequent flyer card!), but we'll go with them for now. Let's explore each step a little further.

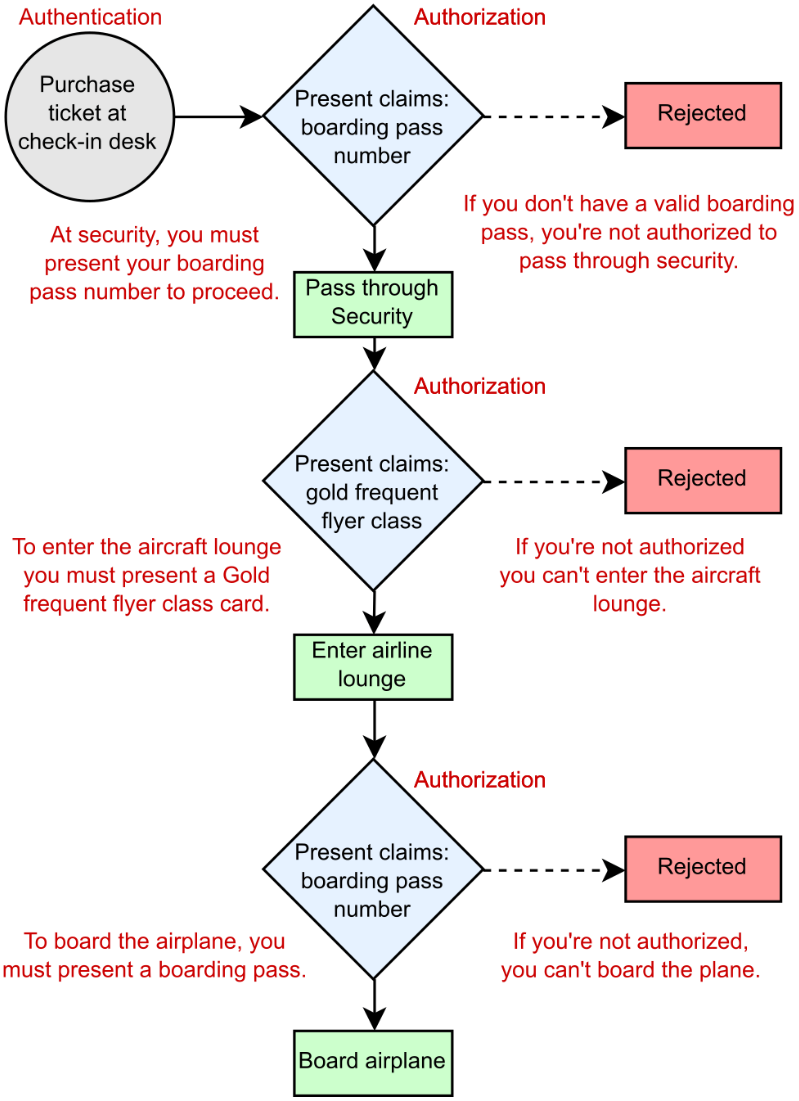

Authentication
Purchase ticket at check-in desk
Authorization
Present claims: boarding pass number
Rejected
If you don't have a valid boarding pass, you're not authorized to pass through security.
At security, you must present your boarding pass number to proceed.
Pass through Security
Authorization
Present claims: gold frequent flyer class
Rejected
To enter the aircraft lounge you must present a Gold frequent flyer class card.
If you're not authorized you can't enter the aircraft lounge.
Enter airline lounge
Authorization
Present claims: boarding pass number
Rejected
To board the airplane, you must present a boarding pass.
If you're not authorized, you can't board the plane.
Board airplane

Figure 15.1 When boarding a plane at an airport, you pass through several authorization steps. At each authorization step, you must present a claim in the form of a boarding pass or a frequent flyer card. If you're not authorized, then access will be denied.

When you arrive at the airport, the first thing you do is go to the check-in counter. Here, you can purchase a plane ticket, but to do so, you need to prove who you are by providing a passport; you *authenticate* yourself. If you've forgotten your passport, you can't authenticate, and you can't go any further.

Once you've purchased your ticket, you're issued a boarding pass, which says which flight you're on. We'll assume it also includes a `BoardingPassNumber`. You can think of this number as an additional *claim* associated with your identity.

> **DEFINITION** A *claim* is a piece of information about a user that consists of a *type* and an optional *value*.

The next step is security. The security guards will ask you to present your boarding pass for inspection, which they'll use to check that you have a flight and so are allowed deeper into the airport. This is an authorization process: you must have the required claim (a `BoardingPassNumber`) to proceed.

If you don't have a valid `BoardingPassNumber`, there are two possibilities for what happens next:

- *If you haven't yet purchased a ticket*—You'll be directed back to the check-in desk, where you can authenticate and purchase a ticket. At that point, you can try to enter security again.
- *If you have an invalid ticket*—You won't be allowed through security and there's nothing else you can do. If, for example, you show up with a boarding pass a week late for your flight, they probably won't let you through. (Ask me how I know!)

Once you're through security, you need to wait for your flight to start boarding, but unfortunately there aren't any seats free. Typical! Luckily, you're a regular flier, and you've notched up enough miles to achieve a "Gold" frequent flyer status, so you can use the airline lounge.

You head to the lounge, where you're asked to present your Gold Frequent Flyer card to the attendant, and they let you in. This is another example of authorization. You must have a `FrequentFlyerClass` claim with a value of `Gold` to proceed.

> **NOTE** You've used authorization twice so far in this scenario. Each time, you presented a claim to proceed. In the first case, the presence of any `BoardingPassNumber` was sufficient, whereas for the `FrequentFlyerClass` claim, you needed the specific value of `Gold`.

When you're boarding the airplane, you have one final authorization step, in which you must present the `BoardingPassNumber` claim again. You presented this claim earlier, but boarding the aircraft is a distinct action from entering security, so you have to present it again.

This whole scenario has lots of parallels with requests to a web app:

- Both processes start with authentication.
- You have to prove *who* you are in order to retrieve the *claims* you need for authorization.
- You use authorization to protect sensitive actions like entering security and the airline lounge.

I’ll reuse this airport scenario throughout the chapter to build a simple web application that simulates the steps you take in an airport. We’ve covered the concept of authorization in general, so in the next section, we’ll look at how authorization works in ASP.NET Core. You’ll start with the most basic level of authorization, ensuring only authenticated users can execute an action, and look at what happens when you try to execute such an action.

15.2 Authorization in ASP.NET Core

In this section you’ll see how the authorization principles described in the previous section apply to an ASP.NET Core application. You’ll learn about the role of the `[Authorize]` attribute and `AuthorizationMiddleware` in authorizing requests to Razor Pages and MVC actions. Finally, you’ll learn about the process of preventing unauthenticated users from executing endpoints, and what happens when users are unauthorized.

The ASP.NET Core framework has authorization built in, so you can use it anywhere in your app, but it’s most common in .NET Core 3.1 to apply authorization using the `AuthorizationMiddleware`. The `AuthorizationMiddleware` should be placed *after* both the routing middleware and the authentication middleware, but *before* the endpoint middleware, as shown in figure 15.2.

> **REMINDER** **In ASP.NET Core, an *endpoint* refers to the handler selected by the routing middleware, which will generate a response when executed. It is typically a Razor Page, or a Web API action method.**

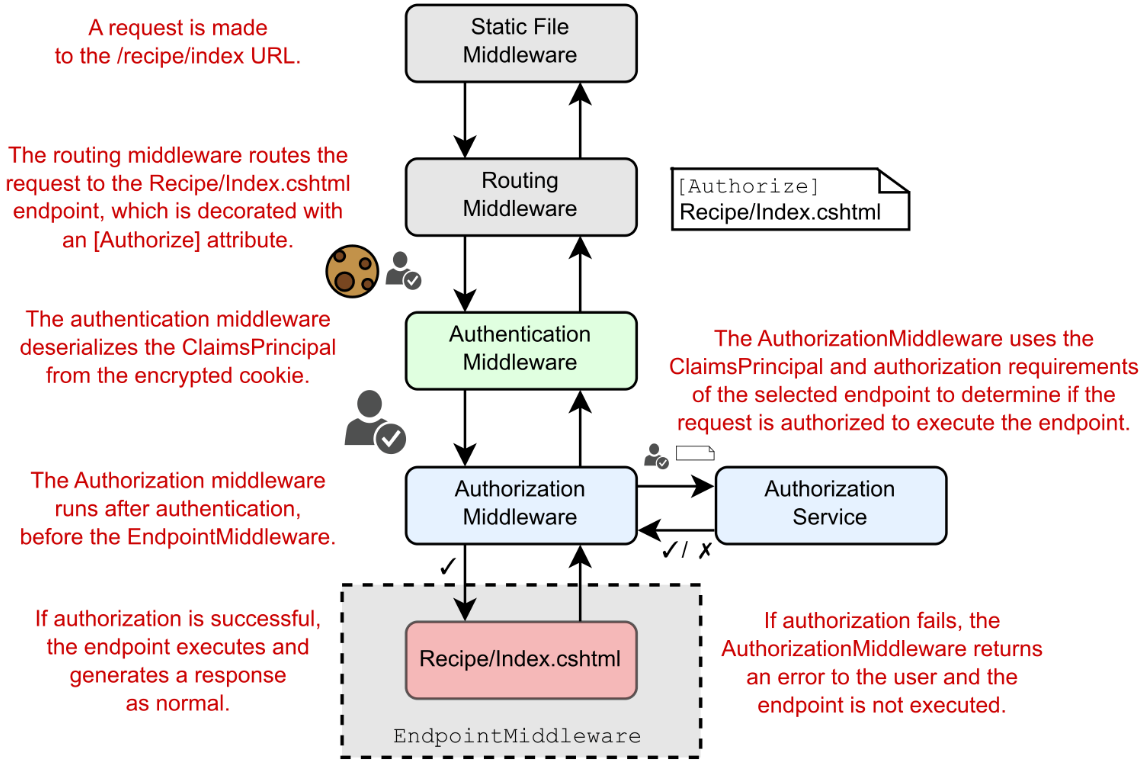

A request is made to the /recipe/index URL.
Static File Middleware
The routing middleware routes the request to the Recipe/Index.cshtml endpoint, which is decorated with an [Authorize] attribute.
Routing Middleware
[Authorize] Recipe/Index.cshtml
The authentication middleware deserializes the ClaimsPrincipal from the encrypted cookie.
Authentication Middleware
The AuthorizationMiddleware uses the ClaimsPrincipal and authorization requirements of the selected endpoint to determine if the request is authorized to execute the endpoint.
The Authorization middleware runs after authentication, before the EndpointMiddleware.
Authorization Middleware
Authorization Service
✓ / ✗
✓
If authorization is successful, the endpoint executes and generates a response as normal.
Recipe/Index.cshtml
EndpointMiddleware
If authorization fails, the AuthorizationMiddleware returns an error to the user and the endpoint is not executed.

Figure 15.2 Authorization occurs after an endpoint has been selected, and after the request is authenticated, but before the action method or Razor Page endpoint is executed.

With this configuration, the `RoutingMiddleware` selects an endpoint to execute based on the request's URL, for example a Razor Page, as you saw in chapter 5. Metadata about the selected endpoint is available to all middleware that occurs after the routing middleware. This metadata includes details about any authorization requirements for the endpoint, and is typically attached by decorating an action or Razor Page with an `[Authorize]` attribute.

The `AuthenticationMiddleware` deserializes the encrypted cookie (or bearer token for APIs) associated with the request to create a `ClaimsPrincipal`. This object is set as the `HttpContext.User` for the request, so all subsequent middleware can access this value. It contains all the `Claims` that were added to the cookie when the user authenticated.

Now we come to the `AuthorizationMiddleware`. This middleware checks if the selected endpoint has any authorization requirements, based on the metadata provided by the `RoutingMiddleware`. If the endpoint has authorization requirements, the `AuthorizationMiddleware` uses the `HttpContext.User` to determine if the current request is authorized to execute the endpoint.

If the request is authorized, the next middleware in the pipeline executes as normal. If the request is not authorized, the AuthorizationMiddleware short-circuits the middleware pipeline, and the endpoint middleware is never executed.

> **REMINDER** The order of middleware in your pipeline is very important. The call to UseAuthorization() must come after UseRouting() and UseAuthentication(), but before UseEndpoints().

Changes to authorization in ASP.NET Core 3.0

The authorization system changed significantly in ASP.NET Core 3.0. Prior to this release, the AuthorizationMiddleware did not exist. Instead, the [Authorize] attribute executed the authorization logic as part of the MVC filter pipeline.

In practice, from the point of view of using authorization in your actions and Razor Pages, there is no real difference from a developer's point of view. Why change it then?

The new design, using the AuthorizationMiddleware in conjunction with endpoint routing (introduced at the same time), enables additional scenarios. The changes make it easier to apply authorization to non-MVC/Razor Page endpoints. You'll see how to create these types of endpoints in chapter 19. You can also read more about the authorization changes here: https://docs.microsoft.com/aspnet/core/migration/22-to-30#authorization.

The AuthorizationMiddleware is responsible for applying authorization requirements and ensuring that only authorized users can execute protected endpoints. In section 15.2.1 you'll learn how to apply the simplest authorization requirement, and in section 15.2.2 you'll see how the framework responds when a user is not authorized to execute an endpoint.

15.2.1 Preventing anonymous users from accessing your application

When you think about authorization, you typically think about checking whether a particular user has permission to execute an endpoint. In ASP.NET Core you normally achieve this by checking whether a user has a given claim.

There's an even more basic level of authorization we haven't considered yet—only allowing authenticated users to execute an endpoint. This is even simpler than the claims scenario (which we'll come to later) as there are only two possibilities:

- *The user is authenticated*—The action executes as normal.
- *The user is unauthenticated*—The user can't execute the endpoint.

You can achieve this basic level of authorization by using the [Authorize] attribute, which you saw in chapter 13, when we discussed authorization filters. You can apply this attribute to your actions, as shown in the following listing, to restrict them to authenticated (logged-in) users only. If an unauthenticated user tries to execute an action or Razor Page protected with the [Authorize] attribute in this way, they'll be redirected to the login page.

Listing 15.1 Applying [Authorize] to an action

```
public class RecipeApiController : ControllerBase
```

```
{
    public IActionResult List()               #A
    {
        return Ok();
    }

    [Authorize]                                #B
    public IActionResult View()                #C
    {
        return Ok();
    }
}
```

#A This action can be executed by anyone, even when not logged in.
#B Applies [Authorize] to individual actions, whole controllers, or Razor Pages.
#C This action can only be executed by authenticated users.

Applying the `[Authorize]` attribute to an endpoint attaches metadata to it, indicating only authenticated users may access the endpoint. As you saw in figure 15.2, this metadata is made available to the `AuthorizationMiddleware` when an endpoint is selected by the `RoutingMiddleware`.

You can apply the `[Authorize]` attribute at the action scope, controller scope, Razor Page scope, or globally, as you saw in chapter 13. Any action or Razor Page that has the `[Authorize]` attribute applied in this way can be executed only by an authenticated user. Unauthenticated users will be redirected to the login page.

> **TIP** **There are several different ways to apply the `[Authorize]` attribute globally. You can read about the different options, and when to choose which option here: https://andrewlock.net/setting-global-authorization-policies-using-the-defaultpolicy-and-the-fallbackpolicy-in-aspnet-core-3/.**

Sometimes, especially when you apply the `[Authorize]` attribute globally, you might need to "poke holes" in this authorization requirement. If you apply the `[Authorize]` attribute globally, then any unauthenticated request will be redirected to the login page for your app. But if the `[Authorize]` attribute is global, then when the login page tries to load, you'll be unauthenticated and redirected to the login page again. And now you're stuck in an infinite redirect loop.

To get around this, you can designate specific endpoints to ignore the `[Authorize]` attribute by applying the `[AllowAnonymous]` attribute to an action or Razor Page, as shown next. This allows unauthenticated users to execute the action, so you can avoid the redirect loop that would otherwise result.

Listing 15.2 Applying `[AllowAnonymous]` to allow unauthenticated access

```
[Authorize]                                   #A
public class AccountController : ControllerBase
{
    public IActionResult ManageAccount()      #B
    {
        return Ok();
    }
    [AllowAnonymous]                          #C
    public IActionResult Login()              #D
    {
        return Ok();
    }
}
```

#A Applied at the controller scope, so user must be authenticated for all actions on the controller.
#B Only authenticated users may execute ManageAccount.
#C [AllowAnonymous] overrides [Authorize] to allow unauthenticated users.
#D Login can be executed by anonymous users.

> **WARNING If you apply the `[Authorize]` attribute globally, be sure to add the `[AllowAnonymous]` attribute to your login actions, error actions, password reset actions, and any other actions that you need unauthenticated users to execute. If you're using the default Identity UI described in chapter 14, then this is already configured for you.**

If an unauthenticated user attempts to execute an action protected by the `[Authorize]` attribute, traditional web apps will redirect them to the login page. But what about web APIs? And what about more complex scenarios, where a user is logged in but doesn't have the necessary claims to execute an action? In section 15.2.2, we'll look at how the ASP.NET Core authentication services handle all of this for you.

15.2.2 Handling unauthorized requests

In the previous section, you saw how to apply the `[Authorize]` attribute to an action to ensure only authenticated users can execute it. In section 15.3, we'll look at more complex examples that require you to also have a specific claim. In both cases, you must meet one or more authorization requirements (for example, you must be authenticated) to execute the action.

If the user meets the authorization requirements, then the request passes unimpeded through the `AuthorizationMiddleware`, and the endpoint is executed in the `EndpointMiddleware`. If they don't meet the requirements for the selected endpoint, the authorization middleware will short-circuit the request. Depending on why the request failed authorization, the authorization middleware generates one of two different types of response:

- Challenge—This response indicates the user was not authorized to execute the action, because they weren't yet logged in.
- Forbid—This response indicates that the user was logged in but didn't meet the requirements to execute the action. They didn't have a required claim, for example.

> **NOTE If you apply the `[Authorize]` attribute in basic form, as you did in section 15.2.1, then you will only generate challenge responses. In this case, a challenge response will be generated for unauthenticated users, but authenticated users will always be authorized.**

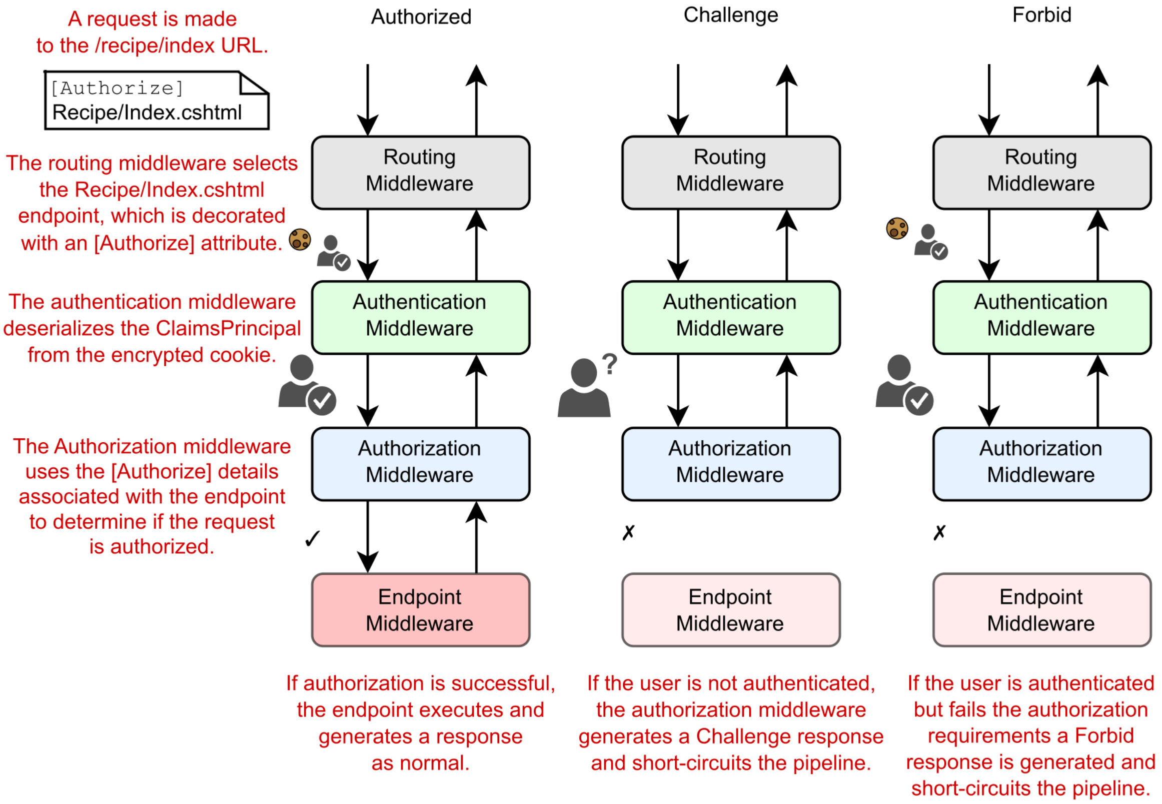
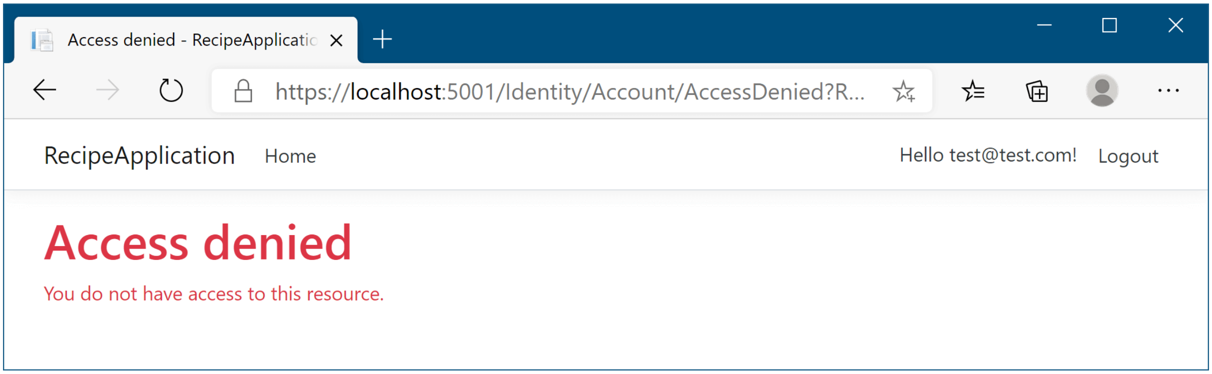

A request is made to the /recipe/index URL.
[Authorize]
Recipe/Index.cshtml
Authorized
Challenge
Forbid
Routing Middleware
Authentication Middleware
Authorization Middleware
Endpoint Middleware
The routing middleware selects the Recipe/Index.cshtml endpoint, which is decorated with an [Authorize] attribute.
The authentication middleware deserializes the ClaimsPrincipal from the encrypted cookie.
The Authorization middleware uses the [Authorize] details associated with the endpoint to determine if the request is authorized.
?
✓
✗
✗
If authorization is successful, the endpoint executes and generates a response as normal.
If the user is not authenticated, the authorization middleware generates a Challenge response and short-circuits the pipeline.
If the user is authenticated but fails the authorization requirements a Forbid response is generated and short-circuits the pipeline.

Figure 15.3. The three types of response to an authorization attempt. In the left example, the request contains an authentication cookie, so the user is authenticated in the `AuthenticationMiddleware`. The `AuthorizationMiddleware` confirms the authenticated user can access the selected endpoint, so the endpoint is executed. In the centre example, the request is not authenticated, so the `AuthorizationMiddleware` generates a Challenge response. In the right example, the request is authenticated, but the user does not have permission to execute the endpoint, so a Forbid response is generated.

The exact HTTP response generated by a challenge or forbid response typically depends on the type of application you're building and so the type of authentication your application uses: a traditional web application with Razor Pages, or an API application.

For traditional web apps using cookie authentication, such as when you use ASP.NET Core Identity, as in chapter 14, the challenge and forbid responses generate an HTTP redirect to a page in your application. A challenge response indicates the user isn't yet authenticated, so they're redirected to the login page for the app. After logging in, they can attempt to execute the protected resource again.

A forbid response means the request was from a user that *already* logged in, but they're still not allowed to execute the action. Consequently, the user is redirected to a Forbidden or Access Denied web page, as shown in figure 15.4, which informs them they can't execute the action or Razor Page.


Access denied - RecipeApplicatio
https://localhost:5001/Identity/Account/AccessDenied?R...
RecipeApplication
Home
Hello test@test.com!
Logout

Access denied

You do not have access to this resource.

Figure 15.4 In traditional web apps using cookie authentication. If you don't have permission to execute a Razor Page and you're already logged in, you'll be redirected to an Access Denied page.

The preceding behavior is standard for traditional web apps, but Web APIs typically use a different approach to authentication, as you saw in chapter 14. Instead of logging in and using the API directly, you'd typically log in to a third-party application that provides a token to the client-side SPA or mobile app. The client-side app sends this token when it makes a request to your Web API.

Authenticating a request for a Web API using tokens is essentially identical to a traditional web app that uses cookies; `AuthenticationMiddleware` deserializes the cookie or token to create the `ClaimsPrincipal`. The difference is in how a Web API handles authorization failures.

When a web API app generates a challenge response, it returns a `401 Unauthorized` error response to the caller. Similarly, when the app generates a forbid response, it returns a `403 Forbidden` response. The traditional web app essentially handled these errors by automatically redirecting unauthorized users to the login or "access denied" page, but the web API doesn't do this. It's up to the client-side SPA or mobile app to detect these errors and handle them as appropriate.

> **TIP** The difference in authorization behavior is one of the reasons I generally recommend creating separate apps for your APIs and Razor pages apps—it's possible to have both in the same app, but the configuration is more complex.

The different behavior between traditional web apps and SPAs can be confusing initially, but you generally don't need to worry about that too much in practice. Whether you're building a

Web API or a traditional MVC web app, the authorization code in your app looks the same in both cases. Apply [Authorize] attributes to your endpoints, and let the framework take care of the differences for you.

> **NOTE** In chapter 14, you saw how to configure ASP.NET Core Identity in a Razor Pages app. This chapter assumes you're building a Razor Pages app too, but the chapter is equally applicable if you're building a web API. Authorization policies are applied in the same way, whichever style of app you're building. It's only the final response of unauthorized requests that differ.

You've seen how to apply the most basic authorization requirement—restricting an endpoint to authenticated users only—but most apps need something more subtle than this all-or-nothing approach.

Consider the airport scenario from section 15.1. Being authenticated (having a passport) isn't enough to get you through security. Instead, you also need a specific claim: BoardingPassNumber. In the next section, we'll look at how you can implement a similar requirement in ASP.NET Core.

15.3 Using policies for claims-based authorization

In the previous section, you saw how to require that users are logged in to access an endpoint. In this section, you'll see how to apply additional requirements. You'll learn to use authorization policies to perform claims-based authorization, to require that a logged in user has the required claims to execute a given endpoint.

In chapter 14, you saw that authentication in ASP.NET Core centers around a ClaimsPrincipal object, which represents the user. This object has a collection of claims that contain pieces of information about the user, such as their name, email, and date of birth.

You can use these to customize the app for each user, by displaying a welcome message addressing the user by name for example, but you can also use claims for authorization. For example, you might only authorize a user if they have a specific claim (such as BoardingPassNumber) or if a claim has a specific value (FrequentFlyerClass claim with the value Gold).

In ASP.NET Core, the rules that define whether a user is authorized are encapsulated in a *policy*.

> **DEFINITION** A *policy* defines the requirements you must meet for a request to be authorized.

Policies can be applied to an action using the [Authorize] attribute, similar to the way you saw in section 15.2.1. This listing shows a Razor Page PageModel that represents the first authorization step in the airport scenario. The AirportSecurity.cshtml Razor Page is protected by an [Authorize] attribute, but you've also provided a policy name: "CanEnterSecurity".

Listing 15.3 Applying an authorization policy to a Razor Page

```
[Authorize("CanEnterSecurity")]                    #A
public class AirportSecurityModel : PageModel
{
    public void OnGet()                           #B
    {

    }
}
```

#A Applying the "CanEnterSecurity" policy using [Authorize]
#B Only users that satisfy the "CanEnterSecurity" policy can execute the Razor Page.

If a user attempts to execute the AirportSecurity.cshtml Razor Page, the authorization middleware will verify whether the user satisfies the policy's requirements (we'll look at the policy itself shortly). This gives one of three possible outcomes:

- *The user satisfies the policy.*—The middleware pipeline continues, and the `EndpointMiddleware` executes the Razor Page as normal.
- *The user is unauthenticated.*—The user is redirected to the login page.
- *The user is authenticated but doesn't satisfy the policy.*—The user is redirected to a "Forbidden" or "Access Denied" page.

These three outcomes correlate with the real-life outcomes you might expect when trying to pass through security at the airport:

- *You have a valid boarding pass.*—You can enter security as normal.
- *You don't have a boarding pass.*—You're redirected to purchase a ticket.
- *Your boarding pass is invalid (you turned up a day late, for example).*—You're blocked from entering.

Listing 15.3 shows how you can apply a policy to a Razor Page using the `[Authorize]` attribute, but you still need to define the `CanEnterSecurity` policy.

You add policies to an ASP.NET Core application in the `ConfigureServices` method of Startup.cs, as shown in listing 15.4. First, you add the authorization services using `AddAuthorization()`, and then you can add policies by calling `AddPolicy()` on the `AuthorizationOptions` object. You define the policy itself by calling methods on a provided `AuthorizationPolicyBuilder` (called `policyBuilder` here).

Listing 15.4 Adding an authorization policy using `AuthorizationPolicyBuilder`

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddAuthorization(options =>                #A
    {
        options.AddPolicy(                              #B
            "CanEnterSecurity",                         #C
            policyBuilder => policyBuilder              #D
                .RequireClaim("BoardingPassNumber"));    #D
    });
    // Additional service configuration
}
```

#A Calls AddAuthorization to configure AuthorizationOptions.
#B Adds a new policy.
#C Provides a name for the policy.
#D Defines the policy requirements using AuthorizationPolicyBuilder.

When you call `AddPolicy` you provide a name for the policy, which should match the value you use in your `[Authorize]` attributes, and you define the requirements of the policy. In this example, you have a single simple requirement: the user must have a claim of type `BoardingPassNumber`. If a user has this claim, whatever its value, then the policy will be satisfied, and the user will be authorized.

> **REMEMBER** **A *claim* is information about the user, as a key-value pair. A policy defines the requirements for successful authorization. A policy can require that a user has a given claim, as well as more complex requirements, as you'll see shortly.**

`AuthorizationPolicyBuilder` contains several methods for creating simple policies like this, as shown in table 15.1. For example, an overload of the `RequireClaim()` method lets you specify a specific value that a claim must have. The following would let you create a policy where the `"BoardingPassNumber"` claim must have a value of `"A1234"`:

```
policyBuilder => policyBuilder.RequireClaim("BoardingPassNumber", "A1234");
```

Table 15.1 Simple policy builder methods on **`AuthorizationPolicyBuilder`**

Method	Policy behavior
`RequireAuthenticatedUser()`	**The required user must be authenticated. Creates a policy similar to the default `[Authorize]` attribute, where you don't set a policy.**
`RequireClaim(claim, values)`	**The user must have the specified claim. If provided, the claim must be one of the specified values.**
`RequireUsername(username)`	**The user must have the specified username.**
`RequireAssertion(function)`	**Executes the provided lambda function, which returns a `bool`, indicating whether the policy was satisfied.**

Role-based authorization vs. claims-based authorization

If you look at all of the methods available on the `AuthorizationPolicyBuilder` type using IntelliSense, you might notice that there's a method I didn't mention in table 15.1, `RequireRole()`. This is a remnant of the role-based approach to authorization used in previous versions of ASP.NET, and I don't recommend using it.

Before Microsoft adopted the claims-based authorization used by ASP.NET Core and recent versions of ASP.NET, role-based authorization was the norm. Users were assigned to one or more roles, such as `Administrator` or `Manager`, and authorization involved checking whether the current user was in the required role.

This role-based approach to authorization is possible in ASP.NET Core, but it's primarily for legacy compatibility reasons. Claims-based authorization is the suggested approach. Unless you're porting a legacy app that uses roles, I suggest you embrace claims-based authorization and leave those roles behind!

You can use these methods to build simple policies that can handle basic situations, but often you'll need something more complicated. What if you wanted to create a policy that enforces only users over the age of 18 can execute an endpoint?

The `DateOfBirth` claim provides the information you need, but there's not a *single* correct value, so you couldn't use the `RequireClaim()` method. You *could* use the `RequireAssertion()` method and provide a function that calculates the age from the `DateOfBirth` claim, but that could get messy pretty quickly.

For more complex policies that can't be easily defined using the `RequireClaim()` method, I recommend you take a different approach and create a custom policy, as you'll see in the following section.

15.4 Creating custom policies for authorization

You've already seen how to create a policy by requiring a specific claim, or requiring a specific claim with a specific value, but often the requirements will be more complex than that. In this section you'll learn how to create custom authorization requirements and handlers. You'll also see how to configure authorization requirements where there are multiple ways to satisfy a policy, any of which are valid.

Let's return to the airport example. You've already configured the policy for passing through security, and now you're going to configure the policy that controls whether you're authorized to enter the airline lounge.

As you saw in figure 15.1, you're allowed to enter the lounge if you have a `FrequentFlyerClass` claim with a value of `Gold`. If this was the only requirement, you could use `AuthorizationPolicyBuilder` to create a policy using:

```
options.AddPolicy("CanAccessLounge", policyBuilder =>
    policyBuilder.RequireClaim("FrequentFlyerClass", "Gold");
```

But what if the requirements are more complicated than this? For example, you can enter the lounge if

- You’re a gold-class frequent flyer (have a `FrequentFlyerClass` claim with value `"Gold"`)
- Or you’re an employee of the airline (have an `EmployeeNumber` claim)
- And you’re at least 18 years old (as calculated from the `DateOfBirth` claim)

If you’ve ever been banned from the lounge (you have an `IsBannedFromLounge` claim), then you won’t be allowed in, even if you satisfy the other requirements.

There’s no way of achieving this complex set of requirements with the basic usage of `AuthorizationPolicyBuilder` you’ve seen so far. Luckily, these methods are a wrapper around a set of building blocks that you can combine to achieve the desired policy.

15.4.1 Requirements and handlers: the building blocks of a policy

Every policy in ASP.NET Core consists of one or more *requirements*, and every requirement can have one or more *handlers*. For the airport lounge example, you have a single policy (`"CanAccessLounge"`), two requirements (`MinimumAgeRequirement` and `AllowedInLoungeRequirement`), and several handlers, as shown in figure 15.5.

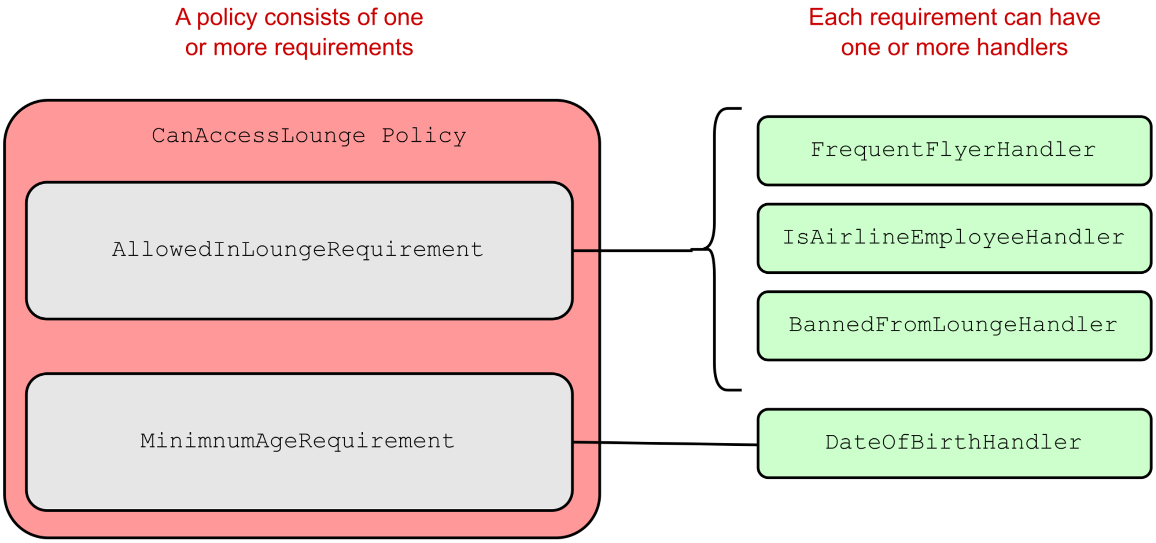


Figure 15.5 A policy can have many requirements, and every requirement can have many handlers. By combining multiple requirements in a policy, and by providing multiple handler implementations, you can create complex authorization policies that meet any of your business requirements.

For a policy to be satisfied, a user must fulfill *all* the requirements. If the user fails *any* of the requirements, the authorize middleware won’t allow the protected endpoint to be executed. In this example, a user must be allowed to access the lounge *and* must be over 18 years old.

Each requirement can have one or more handlers, which will confirm that the requirement has been satisfied. For example, as shown in figure 15.5, `AllowedInLoungeRequirement` has two handlers that can satisfy the requirement:

- `FrequentFlyerHandler`
- `IsAirlineEmployeeHandler`

If the user satisfies either of these handlers, then `AllowedInLoungeRequirement` is satisfied. You don’t need all handlers for a requirement to be satisfied, you just need one.

NOTE Figure 15.5 shows a third handler, `BannedFromLoungeHandler`, which I’ll cover in section 15.4.2. It’s slightly different, in that it can only *fail* a requirement, not *satisfy* it.

You can use requirements and handlers to achieve most any combination of behavior you need for a policy. By combining handlers for a requirement, you can validate conditions using a logical `OR`: if any of the handlers are satisfied, the requirement is satisfied. By combining requirements, you create a logical `AND`: all the requirements must be satisfied for the policy to be satisfied, as shown in figure 15.6.

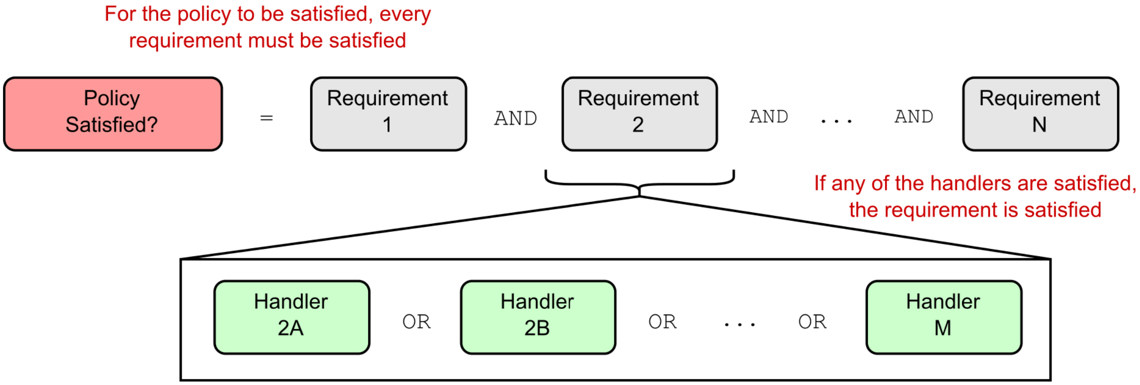

For the policy to be satisfied, every requirement must be satisfied
Policy Satisfied?
=
Requirement 1
AND
Requirement 2
AND
...
AND
Requirement N
If any of the handlers are satisfied, the requirement is satisfied
Handler 2A
OR
Handler 2B
OR
...
OR
Handler M

Figure 15.6 For a policy to be satisfied, every requirement must be satisfied. A requirement is satisfied if any of the handlers are satisfied.

TIP You can also add multiple policies to a Razor Page or action method by applying the `[Authorize]` attribute multiple times, for example `[Authorize("Policy1"), Authorize("Policy2")]`. All policies must be satisfied for the request to be authorized.

I’ve highlighted requirements and handlers that will make up your `"CanAccessLounge"` policy, so in the next section, you’ll build each of the components and apply them to the airport sample app.

15.4.2 Creating a policy with a custom requirement and handler

You've seen all the pieces that make up a custom authorization policy, so in this section, we'll explore the implementation of the "CanAccessLounge" policy.

CREATING AN IAUTHORIZATIONREQUIREMENT TO REPRESENT A REQUIREMENT

As you've seen, a custom policy can have multiple requirements, but what *is* a requirement in code terms? Authorization requirements in ASP.NET Core are any class that implements the IAuthorizationRequirement interface. This is a blank, marker interface, which you can apply to any class to indicate that it represents a requirement.

If the interface doesn't have any members, you might be wondering what the requirement class needs to look like. Typically, they're simple, POCO classes. The following listing shows AllowedInLoungeRequirement, which is about as simple as a requirement can get! It has no properties or methods; it implements the required IAuthorizationRequirement interface.

Listing 15.5 AllowedInLoungeRequirement

```
public class AllowedInLoungeRequirement
    : IAuthorizationRequirement { }                  #A
```

#A The interface identifies the class as an authorization requirement.

This is the simplest form of requirement, but it's also common for them to have one or two properties that make the requirement more generalized. For example, instead of creating the highly specific MustBe18YearsOldRequirement, you could instead create a parametrized MinimumAgeRequirement, as shown in the following listing. By providing the minimum age as a parameter to the requirement, you can reuse the requirement for other policies with different minimum age requirements.

Listing 15.6 The parameterized MinimumAgeRequirement

```
public class MinimumAgeRequirement : IAuthorizationRequirement    #A
{
    public MinimumAgeRequirement(int minimumAge)                  #B
    {
        MinimumAge = minimumAge;
    }
    public int MinimumAge { get; }                                #C
}
```

#A The interface identifies the class as an authorization requirement.
#B The minimum age is provided when the requirement is created.
#C Handlers can use the exposed minimum age to determine whether the requirement is satisfied.

The requirements are the easy part. They represent each of the components of the policy that must be satisfied for the policy to be satisfied overall.

CREATING A POLICY WITH MULTIPLE REQUIREMENTS

You've created the two requirements, so now you can configure the "`CanAccessLounge`" policy to use them. You configure your policies as you did before, in the `ConfigureServices` method of Startup.cs. Listing 15.7 shows how to do this by creating an instance of each requirement and passing them to `AuthorizationPolicyBuilder`. The authorization handlers will use these requirement objects when attempting to authorize the policy.

Listing 15.7 Creating an authorization policy with multiple requirements

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddAuthorization(options =>
    {                                                              #A
        options.AddPolicy(                                         #A
            "CanEnterSecurity",                                    #A
            policyBuilder => policyBuilder                         #A
                .RequireClaim(Claims.BoardingPassNumber));         #A
        options.AddPolicy(                                         #B
            "CanAccessLounge",                                     #B
            policyBuilder => policyBuilder.AddRequirements(        #C
                new MinimumAgeRequirement(18),                     #C
                new AllowedInLoungeRequirement()                   #C
            ));
    });
    // Additional service configuration
}
```

#A Adds the previous simple policy for passing through security
#B Adds a new policy for the airport lounge, called CanAccessLounge
#C Adds an instance of each IAuthorizationRequirement object

You now have a policy called "`CanAccessLounge`" with two requirements, so you can apply it to a Razor Page or action method using the `[Authorize]` attribute, in exactly the same way you did for the "`CanEnterSecurity`" policy:

```
[Authorize("CanAccessLounge")]
public class AirportLoungeModel : PageModel
{
    public void OnGet() { }
}
```

When a request is routed to the AirportLounge.cshtml Razor Page, the authorize middleware executes the authorization policy and each of the requirements are inspected. But you saw earlier that the requirements are purely data; they indicate what needs to be fulfilled, they don't describe how that has to happen. For that, you need to write some handlers.

CREATING AUTHORIZATION HANDLERS TO SATISFY YOUR REQUIREMENTS

Authorization handlers contain the logic of how a specific `IAuthorizationRequirement` can be satisfied. When executed, a handler can do one of three things:

- Mark the requirement handling as a success
- Not do anything
- Explicitly fail the requirement

Handlers should implement AuthorizationHandler<T>, where T is the type of requirement they handle. For example, the following listing shows a handler for AllowedInLoungeRequirement that checks whether the user has a claim called FrequentFlyerClass with a value of Gold.

Listing 15.8 FrequentFlyerHandler **for** AllowedInLoungeRequirement

```
public class FrequentFlyerHandler :
    AuthorizationHandler<AllowedInLoungeRequirement>           #A
{
    protected override Task HandleRequirementAsync(            #B
        AuthorizationHandlerContext context,                           #C
        AllowedInLoungeRequirement requirement)                        #D
    {
        if(context.User.HasClaim("FrequentFlyerClass", "Gold"))        #E
        {
            context.Succeed(requirement);                              #F
        }
        return Task.CompletedTask;                                     #G
    }
}
```

#A The handler implements AuthorizationHandler<T>.
#B You must override the abstract HandleRequirementAsync method.
#C The context contains details such as the ClaimsPrincipal user object.
#D The requirement instance to handle
#E Checks whether the user has the FrequentFlyerClass claim with the Gold value
#F If the user had the necessary claim, then mark the requirement as satisfied by calling Succeed.
#G If the requirement wasn't satisfied, do nothing.

This handler is functionally equivalent to the simple RequireClaim() handler you saw at the start of section 15.4, but using the requirement and handler approach instead.

When a request is routed to the AirportLounge.cshtml Razor Page, the authorization middleware sees the [Authorize] attribute on the endpoint with the "CanAccessLounge" policy. It loops through all the requirements in the policy, and all the handlers for each requirement, calling the HandleRequirementAsync method for each.

The authorization middleware passes the current AuthorizationHandlerContext and the requirement to be checked to each handler. The current ClaimsPrincipal being authorized is exposed on the context as the User property. In listing 15.8, FrequentFlyerHandler uses the context to check for a claim called FrequentFlyerClass with the Gold value, and if it exists, concludes that the user is allowed to enter the airline lounge, by calling Succeed().

> **NOTE** **Handlers mark a requirement as being successfully satisfied by calling** context.Succeed() **and passing the requirement as an argument.**

It’s important to note the behavior when the user *doesn’t* have the claim. `FrequentFlyerHandler` doesn’t do anything if this is the case (it returns a completed `Task` to satisfy the method signature).

> **NOTE** **Remember, if any of the handlers associated with a requirement pass, then the requirement is a success. Only *one* of the handlers must succeed for the requirement to be satisfied.**

This behavior, whereby you either call `context.Succeed()` or do nothing, is typical for authorization handlers. The following listing shows the implementation of `IsAirlineEmployeeHandler`, which uses a similar claim check to determine whether the requirement is satisfied.

Listing 15.9 `IsAirlineEmployeeHandler` **handler**

```
public class IsAirlineEmployeeHandler :
    AuthorizationHandler<AllowedInLoungeRequirement>                 #A
{
    protected override Task HandleRequirementAsync(                  #B
        AuthorizationHandlerContext context,                         #B
        AllowedInLoungeRequirement requirement)                      #B
    {
        if(context.User.HasClaim(c => c.Type == "EmployeeNumber"))   #C
        {
            context.Succeed(requirement);                            #D
        }
        return Task.CompletedTask;                                   #E
    }
}
```

#A The handler implements AuthorizationHandler<T>.
#B You must override the abstract HandleRequirementAsync method.
#C Checks whether the user has the EmployeeNumber claim
#D If the user has the necessary claim, then mark the requirement as satisfied by calling Succeed.
#E If the requirement wasn’t satisfied, do nothing.

> **TIP** **It’s possible to write very generic handlers that can be used with multiple requirements, but I suggest sticking to handling a single requirement only. If you need to extract some common functionality, move it to an external service and call that from both handlers.**

This pattern of authorization handler is common,[66] but in some cases, instead of checking for a *success* condition, you might want to check for a *failure* condition. In the airport example, you don’t want to authorize someone who was previously banned from the lounge, even if they would otherwise be allowed to enter.

[66] **I’ll leave the implementation of** `MinimumAgeHandler` **for** `MinimumAgeRequirement` **as an exercise for the reader. You can find an example in the code samples for the chapter.**

You can handle this scenario by using the `context.Fail()` method exposed on the context, as shown in the following listing. Calling `Fail()` in a handler will always cause the requirement, and hence the whole policy, to fail. You should only use it when you want to guarantee failure, even if other handlers indicate success.

Listing 15.10 Calling `context.Fail()` in a handler to fail the requirement

```
public class BannedFromLoungeHandler :
    AuthorizationHandler<AllowedInLoungeRequirement>          #A
{
    protected override Task HandleRequirementAsync(           #B
        AuthorizationHandlerContext context,                  #B
        AllowedInLoungeRequirement requirement)               #B
    {
        if(context.User.HasClaim(c => c.Type == "IsBanned"))    #C
        {
            context.Fail();                                   #D
        }

        return Task.CompletedTask;                            #E
    }
}
```

#A The handler implements AuthorizationHandler<T>.
#B You must override the abstract HandleRequirementAsync method.
#C Checks whether the user has the IsBanned claim
#D If the user has the claim, then fail the requirement by calling Fail. The whole policy will fail.
#E If the claim wasn't found, do nothing.

In most cases, your handlers will either call `Succeed()` or will do nothing, but the `Fail()` method is useful when you need this kill-switch to guarantee that a requirement won't be satisfied.

> **NOTE** **Whether a handler calls `Succeed()`, `Fail()`, or neither, the authorization system will always execute all of the handlers for a requirement, and all the requirements for a policy so you can be sure your handlers will always be called.**

The final step to complete your authorization implementation for the app is to register the authorization handlers with the DI container, as shown in listing 15.11.

Listing 15.11 Registering the authorization handlers with the DI container

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddAuthorization(options =>
    {
        options.AddPolicy(
            "CanEnterSecurity",
            policyBuilder => policyBuilder
                .RequireClaim(Claims.BoardingPassNumber));
        options.AddPolicy(
            "CanAccessLounge",
            policyBuilder => policyBuilder.AddRequirements(
                new MinimumAgeRequirement(18),
                new AllowedInLoungeRequirement()
            ));
    });
    services.AddSingleton<IAuthorizationHandler, MinimumAgeHandler>();
    services.AddSingleton<IAuthorizationHandler, FrequentFlyerHandler>();
    services
        .AddSingleton<IAuthorizationHandler, BannedFromLoungeHandler>();
    Services
        .AddSingleton<IAuthorizationHandler, IsAirlineEmployeeHandler>();
    // Additional service configuration
}
```

For this app, the handlers don't have any constructor dependencies, so I've registered them as singletons with the container. If your handlers have scoped or transient dependencies (the EF Core `DbContext`, for example), then you might want to register them as scoped instead, as appropriate.

> **REMINDER** Services are registered with a lifetime of either transient, scoped, or singleton, as discussed in chapter 10.

You can combine the concepts of policies, requirements, and handlers in many ways to achieve your goals for authorization in your application. The example in this section, although contrived, demonstrates each of the components you need to apply authorization declaratively at the action method or Razor Page level, by creating policies and applying the `[Authorize]` attribute as appropriate.

As well as applying the `[Authorize]` attribute explicitly to actions and Razor Pages, you can also configure it globally, so that a policy is applied to every Razor Page or controller in your application. Additionally, for Razor Pages, you can apply different authorization policies to different folders. You can read more about applying authorization policies using conventions here https://docs.microsoft.com/aspnet/core/security/authorization/razor-pages-authorization.

There's one area, however, where the `[Authorize]` attribute falls short: resource-based authorization. The `[Authorize]` attribute attaches metadata to an endpoint, so the authorization middleware can authorize the user *before* an endpoint is executed, but what if you need to authorize the action *during* the action method or Razor Page handler?

This is common when you're applying authorization at the document or resource level. If users are only allowed to edit documents they created, then you need to load the document before you can tell whether you're allowed to edit it! This isn't easy with the declarative `[Authorize]` attribute approach, so you must use an alternative, imperative approach. In the next section, you'll see how to apply this resource-based authorization in a Razor Page handler.

15.5 Controlling access with resource-based authorization

In this section you'll learn about resource-based authorization. This is used when you need to know details about the resource being protected to determine if a user is authorized. You'll learn how to apply authorization policies manually using the `IAuthorizationService`, and how to create resource-based `AuthorizationHandler`s.

Resource-based authorization is a common problem for applications, especially when you have users that can create or edit some sort of document. Consider the recipe application you built in the previous 3 chapters. This app lets users create, view, and edit recipes.

Up to this point, everyone can create new recipes, and anyone can edit any recipe, even if they haven't logged in. Now you want to add some additional behavior:

- Only authenticated users should be able to create new recipes.
- You can only edit the recipes you created.

You've already seen how to achieve the first of these requirements; decorate the Create.cshtml Razor Page with an `[Authorize]` attribute and don't specify a policy, as shown in this listing. This will force the user to authenticate before they can create a new recipe.

Listing 15.12 Adding `AuthorizeAttribute` to the Create.cshtml Razor Page

```
[Authorize]                                                 #A
public class CreateModel : PageModel
{
    [BindProperty]
    public CreateRecipeCommand Input { get; set; }

    public void OnGet()                                    #B
    {                                                      #B
        Input = new CreateRecipeCommand();                 #B
    }                                                      #B

    public async Task<IActionResult> OnPost()              #C
    {                                                      #C
        // Method body not shown for brevity               #C
    }                                                      #C
}
```

#A Users must be authenticated to execute the Create.cshtml Razor Page.
#B All page handlers are protected. You can only apply [Authorize] to the PageModel, not handlers
#C ...

> **TIP** **As with all filters, you can only apply the `[Authorize]` attribute to the Razor Page, not to individual page handlers. The attribute applies to all page handlers in the Razor Page.**

Adding the `[Authorize]` attribute fulfills your first requirement, but unfortunately, with the techniques you've seen so far, you have no way to fulfill the second. You could apply a policy that either permits or denies a user the ability to edit *all* recipes, but there's currently no easy way to restrict this so that a user can only edit *their own* recipes.

In order to find out who created the `Recipe`, you must first load it from the database. Only then can you attempt to authorize the user, taking the specific recipe (resource) into account. The following listing shows a partially implemented page handler for how this might look, where authorization occurs part way through the method, after the `Recipe` object has been loaded.

Listing 15.13 The Edit.cshtml page must load the `Recipe` before authorizing the request

```
public IActionResult OnGet(int id)                #A
{
    var recipe = _service.GetRecipe(id);         #B
    var createdById = recipe.CreatedById;        #B
    // Authorize user based on createdById       #C
    if(isAuthorized)                             #D
    {                                            #D
        return View(recipe);                     #D
    }                                            #D
}
```

#A The id of the recipe to edit is provided by model binding.
#B You must load the Recipe from the database before you know who created it.
#C You must authorize the current user, to verify they're allowed to edit this specific Recipe.
#D The action method can only continue if the user was authorized.

You need access to the resource (in this case, the `Recipe` entity) to perform the authorization, so the declarative `[Authorize]` attribute can't help you. In section 15.5.1, you'll see the approach you need to take to handle these situations and to apply authorization inside the action method or Razor Page.

> **WARNING** Be careful when exposing the integer ID of your entities in the URL, as in listing 15.13. Users will be able to edit every entity by modifying the ID in the URL to access a different entity. Be sure to apply authorization checks, otherwise you could expose a security vulnerability called Insecure Direct Object Reference.[67]

15.5.1 Manually authorizing requests with IAuthorizationService

All of the approaches to authorization so far have been *declarative*. You apply the `[Authorize]` attribute, with or without a policy name, and you let the framework take care of performing the authorization itself.

For this recipe-editing example, you need to use *imperative* authorization, so you can authorize the user after you've loaded the `Recipe` from the database. Instead of applying a

[67] You can read about this vulnerability and ways to counteract it on the Open Web Application Security Project (OWASP): www.owasp.org/index.php/Top_10_2007-Insecure_Direct_Object_Reference.

marker saying, "Authorize this method," you need to write some of the authorization code yourself.

> **DEFINITION** *Declarative* and *imperative* are two different styles of programming. Declarative programming describes *what* you're trying to achieve, and lets the framework figure out how to achieve it. Imperative programming describes *how* to achieve something by providing each of the steps needed.

ASP.NET Core exposes `IAuthorizationService`, which you can inject into your Razor Pages and controllers for imperative authorization. This listing shows how you can update the Edit.cshtml Razor Page (shown partially in listing 15.13) to use the `IAuthorizationService` and verify whether the action is allowed to continue execution.

Listing 15.14 Using `IAuthorizationService` for resource-based authorization

```
[Authorize]                                                  #A
public class EditModel : PageModel
{
    [BindProperty]
    public Recipe Recipe { get; set; }

    private readonly RecipeService _service;
    private readonly IAuthorizationService _authService;     #B

    public EditModel(
        RecipeService service,
        IAuthorizationService authService)                   #B
    {
        _service = service;
        _authService = authService;                          #B
    }

    public async Task<IActionResult> OnGet(int id)
    {
        Recipe = _service.GetRecipe(id);                         #C
        var authResult = await _authService                      #D
            .AuthorizeAsync(User, Recipe, "CanManageRecipe");    #D
        if (!authResult.Succeeded)                               #E
        {                                                        #E
            return new ForbidResult();                           #E
        }                                                        #E

        return Page();                                           #F
    }
}
```

#A Only authenticated users should be allowed to edit recipes.
#B IAuthorizationService is injected into the class constructor using DI.
#C Load the recipe from the database.
#D Calls IAuthorizationService, providing ClaimsPrinicipal, resource, and the policy name
#E If authorization failed, returns a Forbidden result
#F If authorization was successful, continues displaying the Razor Page

IAuthorizationService exposes an AuthorizeAsync method, which requires three things to authorize the request:

- The ClaimsPrincipal user object, exposed on the PageModel as User.
- The resource being authorized: Recipe.
- The policy to evaluate: "CanManageRecipe".

The authorization attempt returns an AuthorizationResult object, which indicates whether the attempt was successful via the Succeeded property. If the attempt wasn't successful, then you should return a new ForbidResult, which will be converted either into an HTTP 403 Forbidden response or will redirect the user to the "access denied" page, depending on if you're building a traditional web app with Razor Pages or a Web API.

> **NOTE** **As mentioned in section 15.2.2, which type of response is generated depends on which authentication services are configured. The default Identity configuration, used by Razor Pages, generates redirects. The JWT bearer token authentication typically used with Web APIs generates HTTP 401 and 403 responses instead.**

You've configured the imperative authorization in the Edit.cshtml Razor Page itself, but you still need to define the "CanManageRecipe" policy that you use to authorize the user. This is the same process as for declarative authorization, so you have to:

- Create a *policy* in ConfigureServices by calling AddAuthorization()
- Define one or more *requirements* for the policy
- Define one or more *handlers* for each requirement
- Register the handlers in the DI container

With the exception of the handler, these steps are all identical to the declarative authorization approach with the [Authorize] attribute, so I'll only run through them briefly here.

First, you can create a simple IAuthorizationRequirement. As with many requirements, this contains no data and simply implements the marker interface.

```
public class IsRecipeOwnerRequirement : IAuthorizationRequirement { }
```

Defining the policy in ConfigureServices is similarly simple, as you have only this single requirement. Note that there's nothing resource-specific in any of this code so far:

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddAuthorization(options => {
        options.AddPolicy("CanManageRecipe", policyBuilder =>
            policyBuilder.AddRequirements(new IsRecipeOwnerRequirement()));
    });
}
```

You're halfway there; all you need to do now is create an authorization handler for IsRecipeOwnerRequirement and register it with the DI container.

15.5.2 Creating a resource-based AuthorizationHandler

Resource-based authorization handlers are essentially the same as the authorization handler implementations you saw in section 15.4.2. The only difference is that the handler also has access to the resource being authorized.

To create a resource-based handler, you should derive from the `AuthorizationHandler<TRequirement, TResource>` base class, where `TRequirement` is the type of requirement to handle, and `TResource` is the type of resource that you provide when calling `IAuthorizationService`. Compare this to the `AuthorizationHandler<T>` class you implemented previously, where you only specified the requirement.

This listing shows the handler implementation for your recipe application. You can see that you've specified the requirement as `IsRecipeOwnerRequirement`, the resource as `Recipe`, and have implemented the `HandleRequirementAsync` method.

Listing 15.15 `IsRecipeOwnerHandler` **for resource-based authorization**

```
public class IsRecipeOwnerHandler :
        AuthorizationHandler<IsRecipeOwnerRequirement, Recipe>         #A
{
    private readonly UserManager<ApplicationUser> _userManager;    #B
    public IsRecipeOwnerHandler(                                   #B
        UserManager<ApplicationUser> userManager)                  #B
    {                                                              #B
        _userManager = userManager;                                #B
    }                                                              #B
    protected override async Task HandleRequirementAsync(
        AuthorizationHandlerContext context,
        IsRecipeOwnerRequirement requirement,
        Recipe resource)                                          #C
    {
        var appUser = await _userManager.GetUserAsync(context.User);
        if(appUser == null)                                         #D
        {
            return;
        }
        if(resource.CreatedById == appUser.Id)      #E
        {
            context.Succeed(requirement);           #F
        }
    }
}
```

#A Implements the necessary base class, specifying the requirement and resource type
#B Injects an instance of the UserManager<T> class using DI
#C As well as the context and requirement, you're also provided the resource instance.
#D If you aren't authenticated, then appUser will be null.
#E Checks whether the current user created the Recipe by checking the CreatedById property
#F If the user created the document, Succeed the requirement; otherwise, do nothing.

This handler is slightly more complicated than the examples you've seen previously, primarily because you're using an additional service, `UserManager<>`, to load the `ApplicationUser` entity based on `ClaimsPrincipal` from the request.

NOTE In practice, the `ClaimsPrincipal` will likely already have the `Id` added as a claim, making the extra step unnecessary in this case. This example shows the general pattern if you need to use dependency injected services.

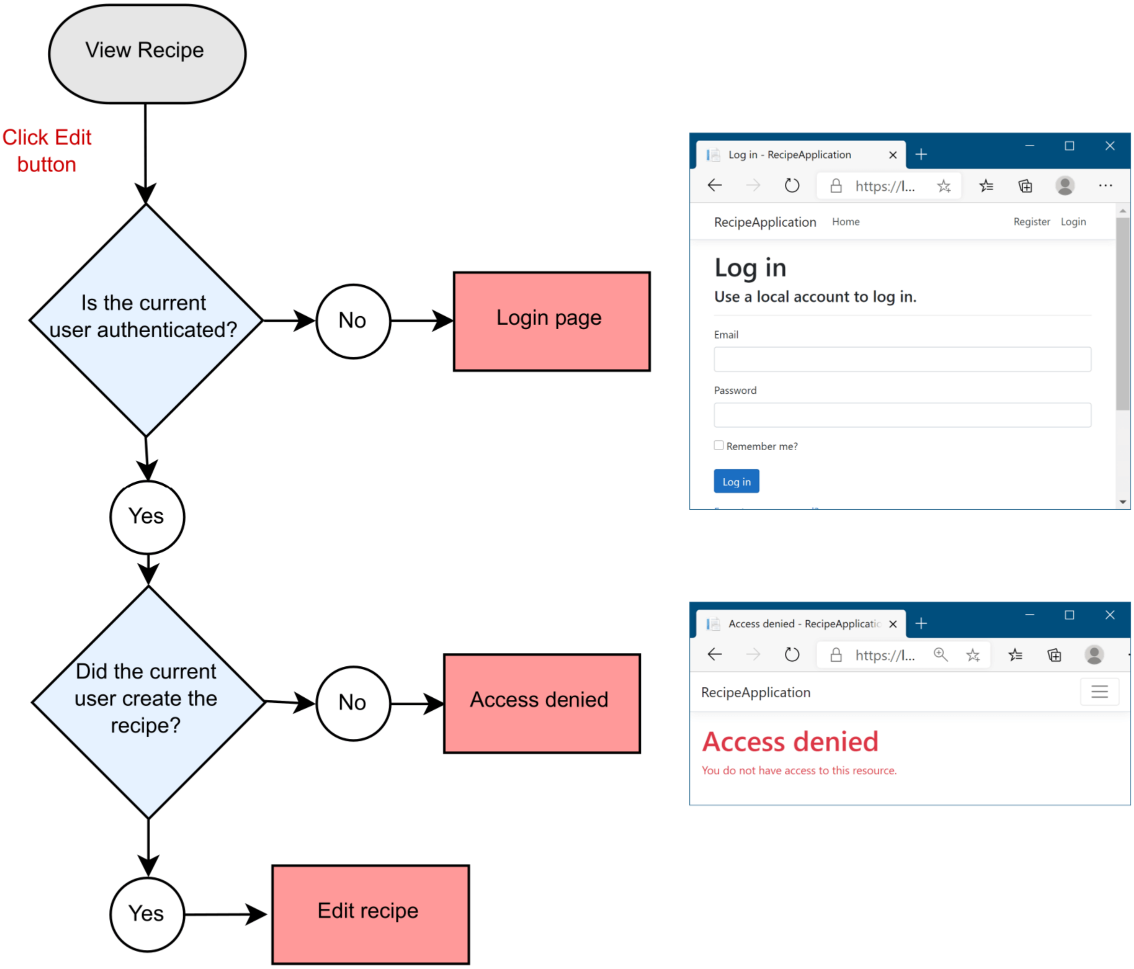
The other significant difference is that the `HandleRequirementAsync` method has provided the `Recipe` resource as a method argument. This is the same object that you provided when calling `AuthorizeAsync` on `IAuthorizationService`. You can use this resource to verify whether the current user created it. If so, you `Succeed()` the requirement, otherwise you do nothing.

The final task is to add `IsRecipeOwnerHandler` to the DI container. Your handler uses an additional dependency, `UserManager<>`, which uses EF Core, so you should register the handler as a scoped service:

```
services.AddScoped<IAuthorizationHandler, IsRecipeOwnerHandler>();
```

TIP If you're wondering how to know whether you register a handler as scoped or a singleton, think back to chapter 10. Essentially, if you have scoped dependencies, then you must register the handler as scoped; otherwise, singleton is fine.

With everything hooked up, you can take the application for a spin. If you try to edit a recipe you didn't create by clicking the Edit button on the recipe, you'll either be redirected to the login page (if you hadn't yet authenticated) or you'll be presented with an Access Denied page, as shown in figure 15.7.



Log in

Use a local account to log in.

Access denied

You do not have access to this resource.

Figure 15.7 If you’re logged in but not authorized to edit a recipe, you’ll be redirected to an Access Denied page. If you’re not logged in, you’ll be redirected to the login page.

By using resource-based authorization, you’re able to enact more fine-grained authorization requirements that you can apply at the level of an individual document or resource. Instead of only being able to authorize that a user can edit *any* recipe, you can authorize whether a user can edit *this* recipe.

All the authorization techniques you’ve seen so far have focused on server-side checks. Both the `[Authorize]` attribute and resource-based authorization approaches focus on stopping users from executing a protected action on the server. This is important from a security point of view, but there’s another aspect you should consider too: the user experience when they don’t have permission.

Now you’ve protected the code executing on the server, but arguably, the Edit button should never have been visible to the user if they weren’t going to be allowed to edit the recipe! In the next section, we’ll look at how you can conditionally hide the Edit button by using resource-based authorization in your view models.

15.6 Hiding elements in Razor templates from unauthorized users

All the authorization code you’ve seen so far has revolved around protecting action methods or Razor Pages on the server side, rather than modifying the UI for users. This is important and should be the starting point whenever you add authorization to an app.

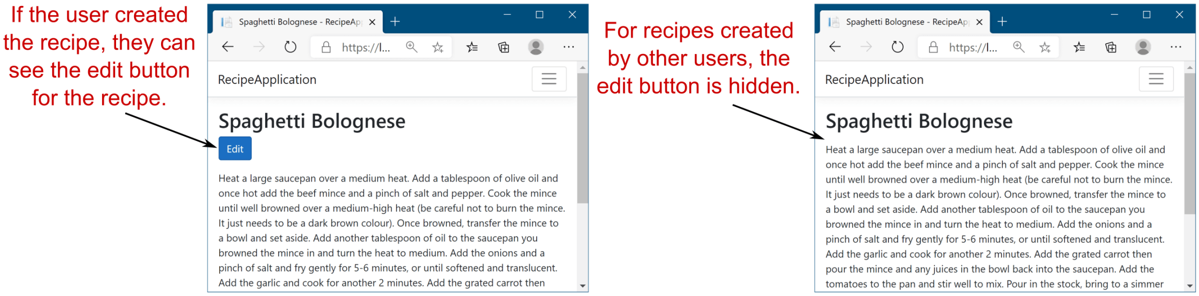
> **WARNING** **Malicious users can easily circumvent your UI, so it’s important to always authorize your actions and Razor Pages on the server, never on the client alone.**

From a user-experience point of view, however, it’s not friendly to have buttons or links that look like they’re available, but which present you with an Access Denied page when they’re clicked. A better experience would be for the links to be disabled, or not visible at all.

You can achieve this in several ways in your own Razor templates. In this section, I’m going to show you how to add an additional property to the `PageModel`, called `CanEditRecipe`, which the Razor view template will use to change the rendered HTML.

> **TIP** **An alternative approach would be to inject `IAuthorizationService` directly into the view template using the `@inject` directive, as you saw in chapter 10, but you should prefer to keep logic like this in the page handler.**

When you’re finished, the rendered HTML will look unchanged for recipes you created, but the Edit button will be hidden when viewing a recipe someone else created, as shown in figure 15.8.



If the user created the recipe, they can see the edit button for the recipe.

Spaghetti Bolognese

Heat a large saucepan over a medium heat. Add a tablespoon of olive oil and once hot add the beef mince and a pinch of salt and pepper. Cook the mince until well browned over a medium-high heat (be careful not to burn the mince. It just needs to be a dark brown colour). Once browned, transfer the mince to a bowl and set aside. Add another tablespoon of oil to the saucepan you browned the mince in and turn the heat to medium. Add the onions and a pinch of salt and fry gently for 5-6 minutes, or until softened and translucent. Add the garlic and cook for another 2 minutes. Add the grated carrot then

For recipes created by other users, the edit button is hidden.

Spaghetti Bolognese

Heat a large saucepan over a medium heat. Add a tablespoon of olive oil and once hot add the beef mince and a pinch of salt and pepper. Cook the mince until well browned over a medium-high heat (be careful not to burn the mince. It just needs to be a dark brown colour). Once browned, transfer the mince to a bowl and set aside. Add another tablespoon of oil to the saucepan you browned the mince in and turn the heat to medium. Add the onions and a pinch of salt and fry gently for 5-6 minutes, or until softened and translucent. Add the garlic and cook for another 2 minutes. Add the grated carrot then pour the mince and any juices in the bowl back into the saucepan. Add the tomatoes to the pan and stir well to mix. Pour in the stock, bring to a simmer

Figure 15.8 Although the HTML will appear unchanged for recipes you created, the Edit button is hidden when you view recipes created by a different user.

The following listing shows the PageModel for the View.cshtml Razor Page, which is used to render the recipe page shown in figure 15.8. As you've already seen for resource-based authorization, you can use the IAuthorizationService to determine whether the current user has permission to edit the Recipe by calling AuthorizeAsync, You can then set this value as an additional property on the PageModel, called CanEditRecipe.

Listing 15.16 Setting the CanEditRecipe property in the View.cshtml Razor Page

```
public class ViewModel : PageModel
{
    public Recipe Recipe { get; set; }
    public bool CanEditRecipe { get; set; }                 #A

    private readonly RecipeService _service;
    private readonly IAuthorizationService _authService;
    public ViewModel(
        RecipeService service,
        IAuthorizationService authService)
    {
        _service = service;
        _authService = authService;
    }

    public async Task<IActionResult> OnGetAsync(int id)
    {
        Recipe = _service.GetRecipe(id);                         #B
        var isAuthorised = await _authService                    #C
            .AuthorizeAsync(User, recipe, "CanManageRecipe");    #C
        CanEditRecipe = isAuthorised.Succeeded;                  #D
        return Page();
    }
}
```

#A The CanEditRecipe property will be used to control whether the Edit button is rendered.
#B Loads the Recipe resource for use with IAuthorizationService
#C Verifies whether the user is authorized to edit the Recipe
#D Sets the CanEditRecipe property on the PageModel as appropriate

Instead of blocking execution of the Razor Page (as you did previously in the Edit action), use the result of the call to AuthorizeAsync to set the CanEditRecipe value on the PageModel. You can then make a simple change to the View.chstml Razor template: add an if clause around the rendering of the edit link.

```
@if(Model.CanEditRecipe)
{
    <a asp-action="Edit" asp-route-id="@Model.Id"
        class="btn btn-primary">Edit</a>
}
```

This ensures that only users who will be able to execute the Edit.cshtml Razor Page can see the link to that page.

> **WARNING** Note that you *didn't* remove the server-side authorization check from the `Edit` action. This is important for preventing malicious users from circumventing your UI.

With that final change, you've finished adding authorization to the recipe application. Anonymous users can browse the recipes created by others, but they must log in to create new recipes. Additionally, authenticated users can only edit the recipes that they created and won't see an edit link for other people's recipes.

Authorization is a key aspect of most apps, so it's important to bear it in mind from an early point. Although it's possible to add authorization later, as you did with the recipe app, it's normally preferable to consider authorization sooner rather than later in the app's development.

In the next chapter, we're going to be looking at your ASP.NET Core application from a different point of view. Instead of focusing on the code and logic behind your app, we're going to look at how you prepare an app for production. You'll see how to specify the URLs your application uses, and how to publish an app so that it can be hosted in IIS. Finally, you'll learn about the bundling and minification of client-side assets, why you should care, and how to use `BundlerMinifier` in ASP.NET Core.

15.7 Summary

- Authentication is the process of determining who a user is. It's distinct from authorization, the process of determining what a user can do. Authentication typically occurs before authorization.
- You can use the authorization services in any part of your application, but it's typically applied using the `AuthorizationMiddleware` by calling `UseAuthorization()`. This should be placed after the calls to `UseRouting()` and `UseAuthentication()`, and before the call to `UseEndpoints()` for correct operation.
- You can protect Razor Pages and MVC actions by applying the `[Authorize]` attribute. The routing middleware records the presence of the attribute as metadata with the selected endpoint. The authorization middleware uses this metadata to determine how to authorize the request.
- The simplest form of authorization requires that a user is authenticated before executing an action. You can achieve this by applying the `[Authorize]` attribute to a Razor Page, action, controller, or globally. You can also apply attributes conventionally to a sub-set of Razor Pages.
- Claims-based authorization uses the current user's claims to determine whether they're authorized to execute an action. You define the claims needed to execute an action in a *policy*.
- Policies have a name and are configured in Startup.cs as part of the call to `AddAuthorization()` in `ConfigureServices`. You define the policy using `AddPolicy()`, passing in a name and a lambda that defines the claims needed.

- You can apply a policy to an action or Razor Page by specifying the policy in the authorize attribute, for example `[Authorize("CanAccessLounge")]`. This policy will be used by the `AuthorizationMiddleware` to determine if the user is allowed to execute the selected endpoint.
- In a Razor Pages app, if an unauthenticated user attempts to execute a protected action, they'll be redirected to the login page for your app. If they're already authenticated, but don't have the required claims, they'll be shown an Access Denied page instead.
- For complex authorization policies, you can build a custom policy. A custom policy consists of one or more requirements, and a requirement can have one or more handlers. You can combine requirements and handlers to create policies of arbitrary complexity.
- For a policy to be authorized, every requirement must be satisfied. For a requirement to be satisfied, one or more of the associated handlers must indicate success, and none must indicate explicit failure.
- `AuthorizationHandler<T>` contains the logic that determines whether a requirement is satisfied. For example, if a requirement requires that users be over 18, the handler could look for a `DateOfBirth` claim and calculate the user's age.
- Handlers can mark a requirement as satisfied by calling `context.Succeed(requirement)`. If a handler can't satisfy the requirement, then it shouldn't call anything on the context, as a different handler could call `Succeed()` and satisfy the requirement.
- If a handler calls `context.Fail()`, then the requirement will fail, even if a different handler marked it as a success using `Succeed()`. Only use this method if you want to override any calls to `Succeed()` from other handlers, to ensure the authorization policy will fail authorization.
- Resource-based authorization uses details of the resource being protected to determine whether the current user is authorized. For example, if a user is only allowed to edit their own documents, then you need to know the author of the document before you can determine whether they're authorized.
- Resource-based authorization uses the same policy, requirements, and handler system as before. Instead of applying authorization with the `[Authorize]` attribute, you must manually call `IAuthorizationService` and provide the resource you're protecting.
- You can modify the user interface to account for user authorization by adding additional properties to your `PageModel`. If a user isn't authorized to execute an action, you can remove or disable the link to that action method in the UI. You should always authorize on the server, even if you've removed links from the UI.

16

Publishing and deploying your application

This chapter covers

- **Publishing an ASP.NET Core application**
- **Hosting an ASP.NET Core application in IIS**
- **Customizing the URLs for an ASP.NET Core app**
- **Optimizing client-side assets with bundling and minification**

We've covered a vast amount of ground so far in this book. We've gone over the basic mechanics of building an ASP.NET Core application, such as configuring dependency injection, loading app settings, and building a middleware pipeline. We've looked at the UI side, using Razor templates and layouts to build an HTML response. And we've looked at higher-level abstractions, such as EF Core and ASP.NET Core Identity, that let you interact with a database and add users to your application.

In this chapter, we're taking a slightly different route. Instead of looking at ways to build bigger and better applications, we focus on what it means to deploy your application so that users can access it. You'll learn about

- The process of publishing an ASP.NET Core application so that it can be deployed to a server.
- How to prepare a reverse proxy (IIS) to host your application.
- How to optimize your app so that it's performant once deployed.

We start by looking again at the ASP.NET Core hosting model in section 16.1 and examining why you might want to host your application behind a reverse proxy instead of exposing your app directly to the internet. I show you the difference between running an ASP.NET Core app in development using `dotnet run` and publishing the app for use on a remote server. Finally, I describe some of the options available to you when deciding how and where to deploy your app.

In section 16.2, I show you how to deploy your app to one such option, a Windows server running IIS (Internet Information Services). This is a typical deployment scenario for many developers already familiar with ASP.NET, so it acts as a useful case study, but it's certainly not the only possibility. I won't go into all the technical details of configuring the venerable IIS system, but I'll show the bare minimum required to get it up and running. If your focus is cross-platform development, then don't worry, I don't dwell on IIS for too long!

In section 16.3, I provide an introduction to hosting on Linux. You'll see how it differs from hosting applications on Windows, learn the changes you need to make to your apps, and find out about some gotchas to look out for. I describe how reverse proxies on Linux differ from IIS and point you to some resources you can use to configure your environments, rather than giving exhaustive instructions in this book.

If you're *not* hosting your application using IIS, then you'll likely need to set the URL that your ASP.NET Core app is using when you deploy your application. In section 16.4, I show two approaches to this: using the special `ASPNETCORE_URLS` environment variable and using command line arguments. Although generally not an issue during development, setting the correct URLs for your app is critical when you need to deploy it.

In the final section of this chapter, we look at a common optimization step used when deploying your application. Bundling and minification are used to reduce the number and size of requests that browsers must make to your app to fully load a page. I show you how to use a simple tool to create bundles when you build your application, and how to conditionally load these when in production to optimize your app's page size.

This chapter covers a relatively wide array of topics, all related to deploying your app. But before we get into the nitty-gritty, I'll go over the hosting model for ASP.NET Core so that we're all on the same page. This is significantly different from the hosting model of the previous version of ASP.NET, so if you're coming from that background, it's best to try to forget what you know!

16.1 Understanding the ASP.NET Core hosting model

In this section I discuss the various ways to deploy your ASP.NET Core applications to production. I start by describing the role of a reverse proxy in deployments, and whether you should use one. I then describe the difference between running an app during development and publishing an app for production. Finally, I briefly discuss the various options available for deploying your application to a production server.

If you think back to chapter 1, you may remember that we discussed the hosting model of ASP.NET Core. ASP.NET Core applications are, essentially, console applications. They have a `static void Main` function that serves as the entry point for the application, like a standard .NET console app would.

What makes an app an ASP.NET Core app is that it runs a web server, typically Kestrel, inside the console app process. Kestrel provides the HTTP functionality to receive requests and return responses to clients. Kestrel passes any requests it receives to the body of your application to generate a response, as shown in figure 16.1. This hosting model decouples the server and reverse proxy from the application itself, so that the same application can run unchanged in multiple environments.

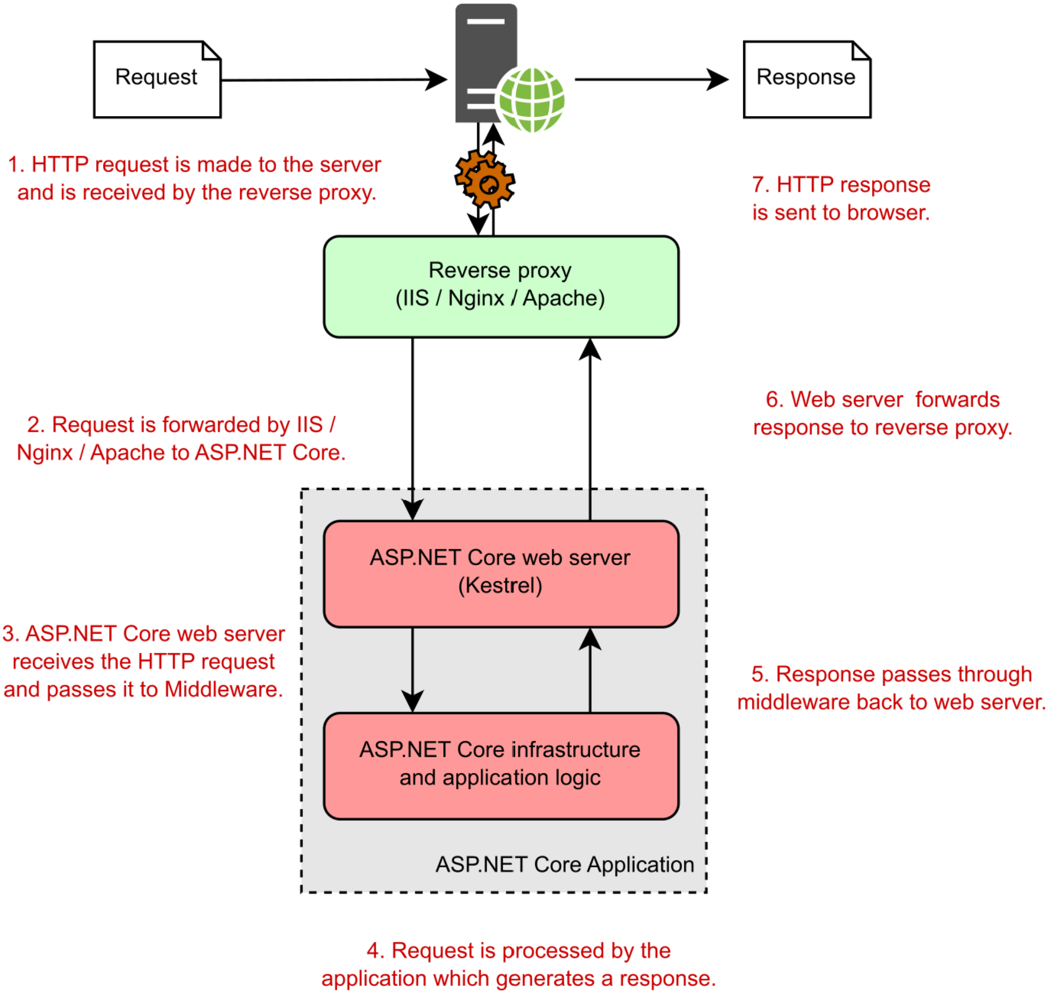

Request
Response
1. HTTP request is made to the server and is received by the reverse proxy.
7. HTTP response is sent to browser.
Reverse proxy (IIS / Nginx / Apache)
2. Request is forwarded by IIS / Nginx / Apache to ASP.NET Core.
6. Web server forwards response to reverse proxy.
ASP.NET Core web server (Kestrel)
3. ASP.NET Core web server receives the HTTP request and passes it to Middleware.
5. Response passes through middleware back to web server.
ASP.NET Core infrastructure and application logic
ASP.NET Core Application
4. Request is processed by the application which generates a response.

Figure 16.1 The hosting model for ASP.NET Core. Requests are received by the reverse proxy and are forwarded to the Kestrel web server. The same application can run behind various reverse proxies without modification.

In this book, we've focused on the lower half of figure 16.1—the ASP.NET Core application itself—but the reality is that you'll often want to place your ASP.NET Core apps behind a reverse proxy, such as IIS on Windows, or NGINX or Apache on Linux. The *reverse proxy* is the program that listens for HTTP requests from the internet and then makes requests to your app as though the request had come from the internet directly.

> **DEFINITION** A *reverse proxy* is software that's responsible for receiving requests and forwarding them to the appropriate web server. The reverse proxy is exposed directly to the internet, whereas the underlying web server is exposed only to the proxy.

If you're running your application using a Platform as a Service (PAAS) offering, such as Azure App Service, then you're using a reverse proxy there too, one that is managed by Azure. Using a reverse proxy has many benefits:

- *Security*—Reverse proxies are specifically designed to be exposed to malicious internet traffic, so they're typically well-tested and battle-hardened.
- *Performance*—You can configure reverse proxies to provide performance improvements by aggressively caching responses to requests.
- *Process management*—An unfortunate reality is that apps sometimes crash. Some reverse proxies can act as a monitor/scheduler to ensure that if an app crashes, the proxy can automatically restart it.
- *Support for multiple apps*—It's common to have multiple apps running on a single server. Using a reverse proxy makes it easier to support this scenario by using the host name of a request to decide which app should receive the request.

I don't want to make it seem like using a reverse proxy is all sunshine and roses. There are some downsides:

- *Complexity*— One of the biggest complaints is how complex reverse proxies can be. If you're managing the proxy yourself (as opposed to relying on a PaaS implementation) there can be lots of proxy-specific pitfalls to look out for.
- *Inter process communication*—Most reverse proxies require two processes: a reverse proxy and your web app. Communicating between the two is often slower than if you directly expose your web app to requests from the internet.
- *Restricted features*—Not all reverse proxies support all the same features as an ASP.NET Core app. For example, Kestrel supports HTTP/2, but if your reverse proxy doesn't, then you won't see the benefits.

Whether you choose to use a reverse proxy or not, when the time comes to host your app, you can't copy your code files directly on to the server. First, you need to *publish* your ASP.NET Core app, to optimize it for production. In section 16.1.1, we look at building an ASP.NET Core app so it can be run on your development machine, compared to publishing it so that it can be run on a server.

16.1.1 Running vs. publishing an ASP.NET Core app

One of the key changes in ASP.NET Core from previous versions of ASP.NET is making it easy to build apps using your favorite code editors and IDEs. Previously, Visual Studio was required for ASP.NET development, but with the .NET CLI and the OmniSharp plugin, you can now build apps with the tools you're comfortable with, on any platform.

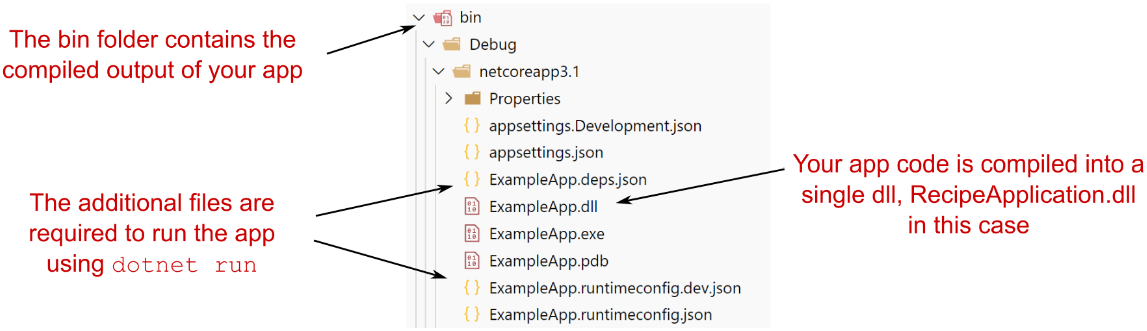
As a result, whether you build using Visual Studio or the .NET CLI, the same tools are being used under the hood. Visual Studio provides an additional GUI, functionality, and wrappers for building your app, but it executes the same commands as the .NET CLI behind the scenes.

As a refresher, you've used four main .NET CLI commands so far to build your apps:

- `dotnet new`—Creates an ASP.NET Core application from a template
- `dotnet restore`—Downloads and installs any referenced NuGet packages for your project
- `dotnet build`—Compiles and builds your project
- `dotnet run`—Executes your app, so you can send requests to it

If you've ever built a .NET application, whether it's an ASP.NET app or a .NET Framework Console app, then you'll know that the output of the build process is written to the bin folder. The same is true for ASP.NET Core applications.

If your project compiles successfully when you call `dotnet build`, then the .NET CLI will write its output to a bin folder in your project's directory. Inside this bin folder are several files required to run your app, including a dll file that contains the code for your application. Figure 16.2 shows part of the output of the bin folder for an ASP.NET Core application:



The bin folder contains the compiled output of your app

The additional files are required to run the app using `dotnet run`

Your app code is compiled into a single dll, RecipeApplication.dll in this case

Figure 16.2 The bin folder for an ASP.NET Core app after running `dotnet build`. The application is compiled into a single dll, ExampleApp.dll.

NOTE On Windows, you will also have an executable .exe file, ExampleApp.exe. This is a simple wrapper file for convenience that makes it easier to run the application contained in ExampleApp.dll.

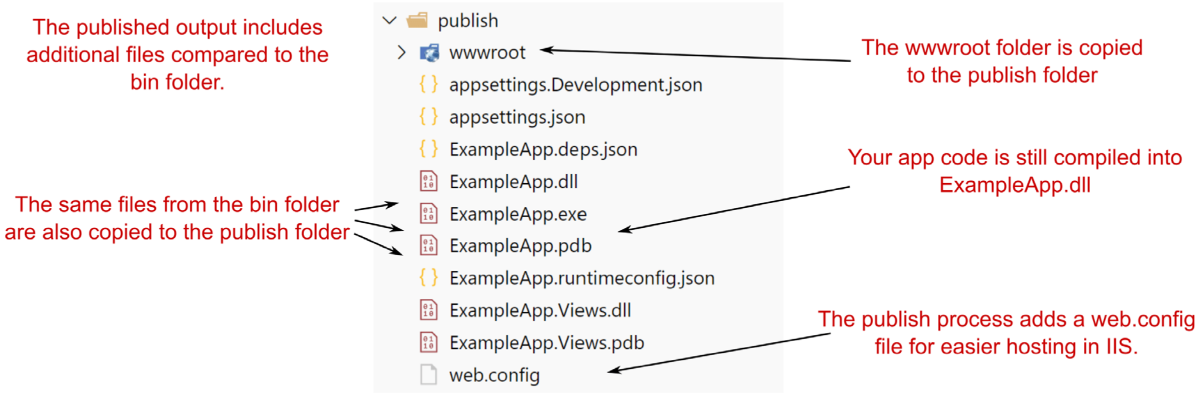
When you call `dotnet run` in your project folder (or run your application using Visual Studio), the .NET CLI uses the DLL to run your application. But this doesn't contain everything you need to deploy your app.

To host and deploy your app on a server, you first need to *publish* it. You can publish your ASP.NET Core app from the command line using the `dotnet publish` command. This builds and packages everything your app needs to run. The following command packages the app from the current directory and builds it to a subfolder called publish. I've used the `Release` configuration, instead of the default `Debug` configuration, so that the output will be fully optimized for running in production:

```
dotnet publish --output publish --configuration release
```

TIP Always use the release configuration when publishing your app for deployment. This ensures the compiler generates optimized code for your app.

Once the command completes, you'll find your published application in the publish folder, as shown in figure 16.3.



The published output includes additional files compared to the bin folder.

The wwwroot folder is copied to the publish folder

Your app code is still compiled into ExampleApp.dll

The same files from the bin folder are also copied to the publish folder

The publish process adds a web.config file for easier hosting in IIS.

Figure 16.3 The publish folder for the app after running `dotnet publish`. The app is still compiled into a single dll, but all the additional files, such as wwwroot and appsettings.json are also copied to the output.

As you can see, the ExampleApp.dll file is still there, along with some additional files. Most notably, the publish process has copied across the wwwroot folder of static files. When running your application locally with `dotnet run`, the .NET CLI uses these files from your application's project folder application directly. Running `dotnet publish` copies the files to the output directory, so they're included when you deploy your app to a server.

If your first instinct is to try running the application in the publish folder using the `dotnet run` command you already know and love, then you'll be disappointed. Instead of the application starting up, you're presented with a somewhat confusing message: "Couldn't find a project to run."

To run a published application, you need to use a slightly different command. Instead of calling `dotnet run`, you must pass the path to your application's dll file to the `dotnet` command. If you're running the command from the publish folder, then for the example app in figure 16.3, that would look something like

```
dotnet ExampleApp.dll
```

This is the command that your server will run when running your application in production. When you're developing, the `dotnet run` command does a whole load of work to make things easier on you: it makes sure your application is built, looks for a project file in the current folder, works out where the corresponding dlls will be (in the bin folder), and finally, runs your app.

In production, you don't need any of this extra work. Your app is already built, it only needs to be run. The `dotnet <dll>` syntax does this alone, so your app starts much faster.

> **NOTE** The `dotnet` command used to run your published application is part of the .NET Core Runtime, whereas the `dotnet` command used to build and run your application during development is part of the .NET Core SDK.

Framework-dependent deployments vs. self-contained deployments

.NET Core applications can be deployed in two different ways: runtime-dependent deployments (RDD) and self-contained deployments (SCD).

Most of the time, you'll use an RDD. This relies on the .NET Core runtime being installed on the target machine that runs your published app, but you can run your app on any platform—Windows, Linux, or macOS—without having to recompile.

In contrast, an SCD contains *all* the code required to run your app, so the target machine doesn't need to have .NET Core installed. Instead, publishing your app will package up the .NET Core runtime with your app's code and libraries.

Each approach has its pros and cons, but in most cases I tend to create RDDs. The final size of RDDs is much smaller, as they only contain your app code, instead of the whole .NET Core framework, as for SCDs. Also, you can deploy your RDD apps to any platform, whereas SCDs must be compiled specifically for the target machine's operating system, such as Windows 10 64-bit or Red Hat Enterprise Linux 64-bit.

In this book, I'll only discuss RDDs, but if you want to create an SCD, provide a runtime identifier, in this case Windows 10 64-bit, when you publish your app:

```
dotnet publish -c Release -r win10-x64 -o publish_folder
```

The output will contain an exe file, which is your application, and a *ton* of dlls (almost 100 MB of dlls for a sample app), which are the .NET Core framework. You need to deploy this whole folder to the target machine to run your app. For more details, see the documentation at https://docs.microsoft.com/dotnet/core/deploying/.

We’ve established that publishing your app is important for preparing it to run in production, but how do you go about deploying it? How do you get the files from your computer on to a server so that people can access your app? You have many, many options for this, so in the next section, I’ll give you a brief list of approaches to consider.

16.1.2 Choosing a deployment method for your application

To deploy any application to production, you generally have two fundamental requirements:

- A server that can run your app
- A means of loading your app on to the server

Historically, putting an app into production was a laborious, and error-prone, process. For many people, this is still true. If you’re working at a company that hasn’t changed practices in recent years, then you may need to request a server or virtual machine for your app and provide your application to an operations team who will install it for you. If that’s the case, you may have your hands tied regarding how you deploy.

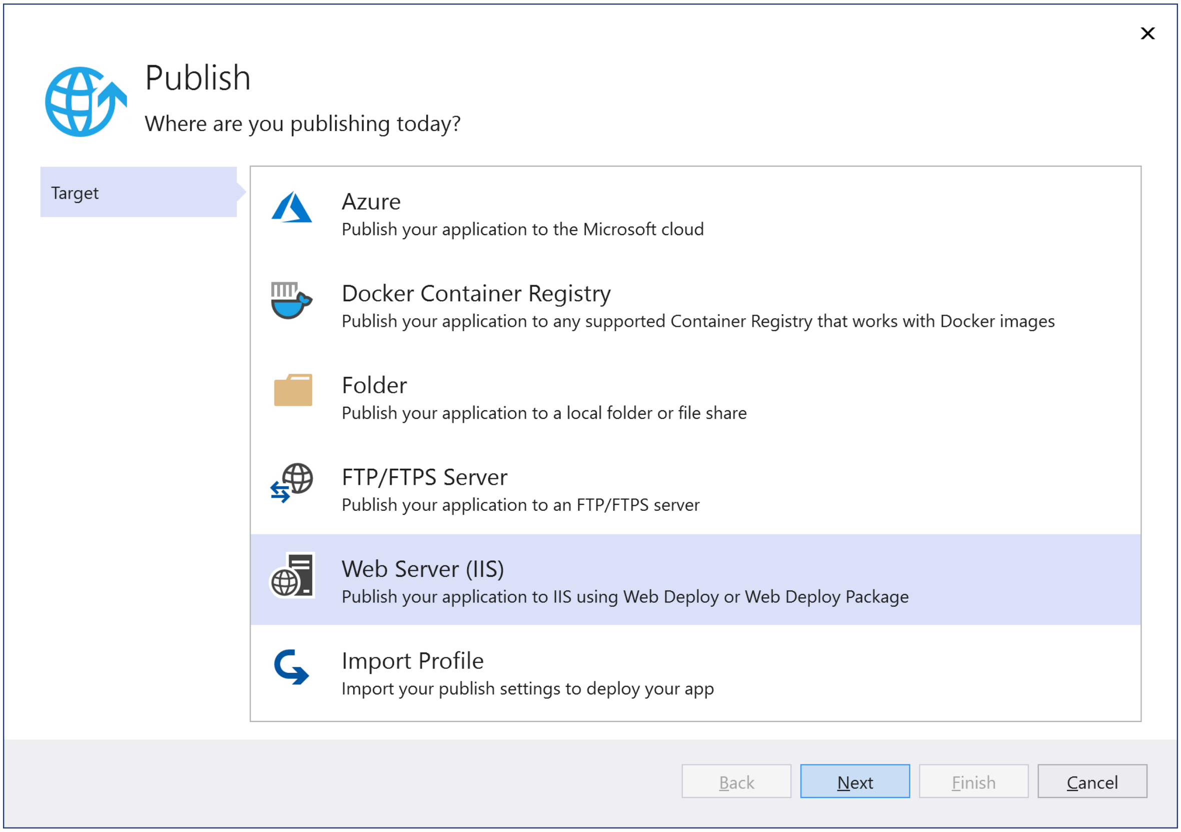
For those who have embraced continuous integration (CI) or continuous delivery/deployment (CD), there are many more possibilities. CI/CD is the process of detecting changes in your version control system (for example Git, SVN, Mercurial, Team Foundation Version Control) and automatically building, and potentially deploying, your application to a server, with little to no human intervention.[68]

You can find many different CI/CD systems out there: Azure DevOps, GitHub actions, Jenkins, TeamCity, AppVeyor, Travis, and Octopus Deploy, to name a few. Each can manage some or all of the CI/CD process and can integrate with many different systems.

Rather than pushing any particular system, I suggest trying out some of the services available and seeing which works best for you. Some are better suited to open source projects, some are better when you’re deploying to cloud services—it all depends on your particular situation.

If you’re getting started with ASP.NET Core and don’t want to have to go through the setup process of getting CI working, then you still have lots of options. The easiest way to get started with Visual Studio is to use the built-in deployment options. These are available from Visual Studio via the Build > Publish *AppName* menu option, which presents you with the screen shown in figure 16.4.

[68] There are important but subtle differences between these terms. You can find a good comparison here: https://www.atlassian.com/continuous-delivery/principles/continuous-integration-vs-delivery-vs-deployment



Publish

Where are you publishing today?

Azure

Publish your application to the Microsoft cloud

Docker Container Registry

Publish your application to any supported Container Registry that works with Docker images

Folder

Publish your application to a local folder or file share

FTP/FTPS Server

Publish your application to an FTP/FTPS server

Web Server (IIS)

Publish your application to IIS using Web Deploy or Web Deploy Package

Import Profile

Import your publish settings to deploy your app

Figure 16.4 The Publish application screen in Visual Studio 2019. This provides easy options for publishing your application directly to Azure App Service, to IIS, to an FTP site, or to a folder on the local machine.

From here, you can publish your application directly from Visual Studio to many different locations.[69] This is great when you're getting started, though I recommend looking at a more automated and controlled approach for larger applications, or when you have a whole team working on a single app.

Given the number of possibilities available in this space, and the speed with which these options change, I'm going to focus on one specific scenario in this chapter: you've built an ASP.NET Core application and you need to deploy it; you have access to a Windows server

[69] For guidance on choosing your Visual Studio publishing options, see https://docs.microsoft.com/visualstudio/deployment/deploying-applications-services-and-components-resources.

that’s already serving (previous version) ASP.NET applications using IIS and you want to run your ASP.NET Core app alongside them.

In the next section, you’ll see an overview of the steps required to run an ASP.NET Core application in production, using IIS as a reverse proxy. It won’t be a master class in configuring IIS (there’s so much depth to the 20-year-old product that I wouldn’t know where to start!), but I’ll cover the basics needed to get your application serving requests.

16.2 Publishing your app to IIS

In this section, I briefly show how to publish your first app to IIS. You’ll add an application pool and website to IIS, and ensure your app has the necessary configuration to work with IIS as a reverse proxy. The deployment itself will be as simple as copying your published app to IIS’s hosting folder.

In section 16.1, you learned about the need to publish an app before you deploy it, and the benefits of using a reverse proxy when you run an ASP.NET Core app in production. If you’re deploying your application to Windows, then IIS will be your reverse proxy, and will be responsible for managing your application.

IIS is an old and complex beast, and I can’t possibly cover everything related to configuring it in this book. Nor would you want me to—it would be very boring! Instead, in this section, I provide an overview of the basic requirements for running ASP.NET Core behind IIS, along with the changes you may need to make to your application to support IIS.

If you’re on Windows and want to try out these steps locally, then you’ll need to manually enable IIS on your development machine. If you’ve done this with older versions of Windows, nothing much has changed. You can find a step-by-step guide to configuring IIS and troubleshooting tips in the ASP.NET Core documentation at https://docs.microsoft.com/aspnet/core/publishing/iis.

16.2.1 Configuring IIS for ASP.NET Core

The first step in preparing IIS to host ASP.NET Core applications is to install the .NET Core Windows Hosting Bundle.[70] This includes several components needed to run .NET Core apps:

- *The .NET Core Runtime*—Runs your .NET Core application
- *The ASP.NET Core Runtime*—Required to run ASP.NET Core apps
- *The IIS AspNetCore Module*—Provides the link between IIS and your app, so that IIS can act as a reverse proxy

If you’re going to be running IIS on your development machine, then make sure to install the bundle as well, otherwise you’ll get strange errors from IIS.

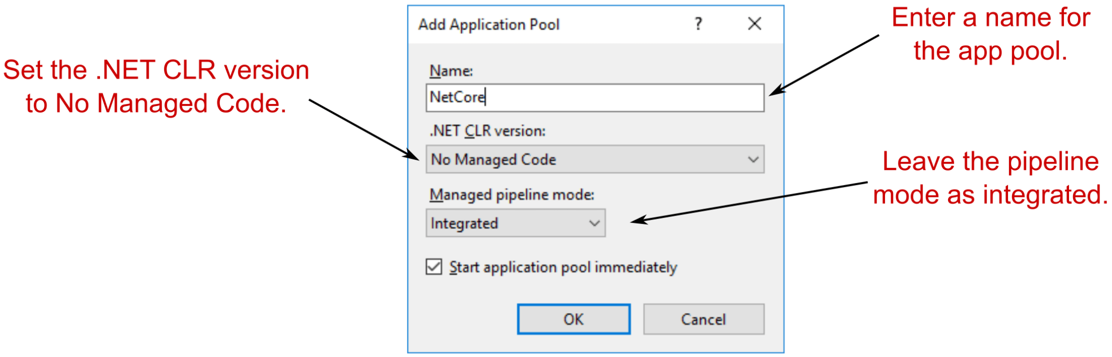
[70] You can download the bundle from https://dotnet.microsoft.com/permalink/dotnetcore-current-windows-runtime-bundle-installer.

TIP You only need the Windows Hosting Bundle for running ASP.NET Core behind IIS. However, wherever you're hosting your app, whether in IIS on Windows, or NGINX on Linux, you'll need to have the .NET Core Runtime and ASP.NET Core runtime installed to run runtime-dependent ASP.NET Core apps.

Once you've installed the bundle, you need to configure an *application pool* in IIS for your ASP.NET Core apps. Previous versions of ASP.NET would run in a *managed* app pool that used .NET Framework, but for ASP.NET Core you should create a *No Managed Code* pool. The native ASP.NET Core Module runs inside the pool, which boots the .NET Core runtime itself.

DEFINITION An *application pool* in IIS represents an application process. You can run each app in IIS in a separate application pool to keep them isolated from one another.

To create an unmanaged application pool, right-click Application Pools in IIS and choose Add Application Pool. Provide a name for the app pool in the resulting dialog, for example NetCore, and set the .NET CLR version to No Managed Code, as shown in figure 16.5.



Add Application Pool

Name: NetCore

.NET CLR version: No Managed Code

Managed pipeline mode: Integrated

☑ Start application pool immediately

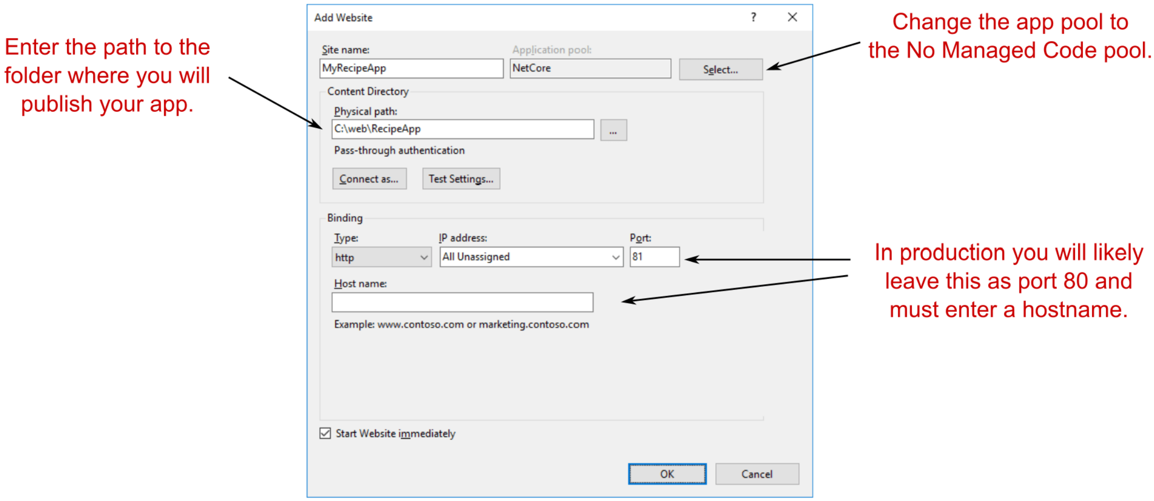
Set the .NET CLR version to No Managed Code.

Enter a name for the app pool.

Leave the pipeline mode as integrated.

Figure 16.5 Creating an app pool in IIS for your ASP.NET Core app. The .NET CLR version should be set to No Managed Code.

Now you have an app pool, you can add a new website to IIS. Right-click the Sites node and choose Add Website. In the Add Website dialog, shown in figure 16.6, you provide a name for the website and the path to the folder where you'll publish your website. I've created a folder that I'll use to deploy the Recipe app from previous chapters. It's important to change the Application pool for the app to the new NetCore app pool you created. In production, you'd also provide a hostname for the application, but I've left it blank for now and changed the port to 81, so the application will bind to the URL http://localhost:81.



Site name: MyRecipeApp

Application pool: NetCore

Content Directory

Physical path: C:\web\RecipeApp

Pass-through authentication

Binding

Type: http

IP address: All Unassigned

Port: 81

Host name:

Example: www.contoso.com or marketing.contoso.com

☑ Start Website immediately

Enter the path to the folder where you will publish your app.

Change the app pool to the No Managed Code pool.

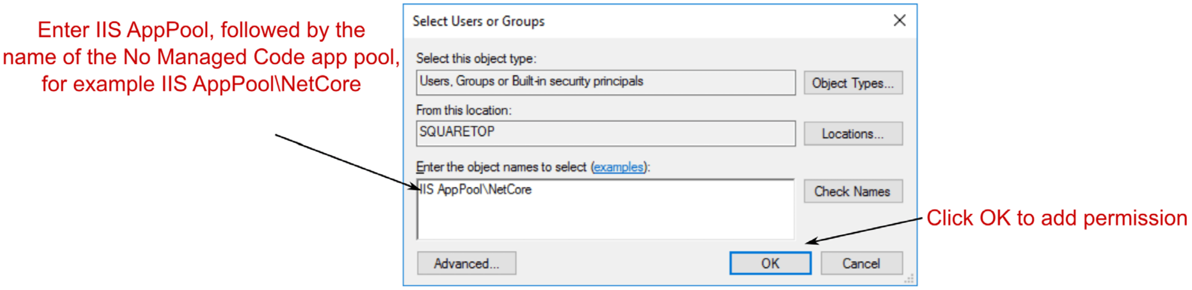
In production you will likely leave this as port 80 and must enter a hostname.

Figure 16.6 Adding a new website to IIS for your app. Be sure to change the Application pool to the No Managed Code pool created in the previous step. You also provide a name, the path where you'll publish your app files, and the URL IIS will use for your app.

> **NOTE** When you deploy an application to production, you need to register a host name with a domain registrar, so your site is accessible by people on the internet. Use that hostname when configuring your application in IIS, as shown in figure 16.6.

Once you click OK, IIS creates the application and attempts to start it. But you haven't published your app to the folder, so you won't be able view it in a browser yet.

You need to carry out one more critical setup step before you can publish and run your app: you must grant permissions for the NetCore app pool to access the path where you'll publish your app. To do this, right-click the folder that will host your app in Windows Explorer and choose Properties. In the Properties dialog, choose Security > Edit > Add… Enter `IIS AppPool\NetCore` in the textbox, as shown in figure 16.7, where NetCore is the name of your app pool, and click OK. Close all the dialog boxes by clicking OK and you're all set.



Enter IIS AppPool, followed by the name of the No Managed Code app pool, for example IIS AppPool\NetCore

Select Users or Groups

Select this object type:
Users, Groups or Built-in security principals

From this location:
SQUARETOP

Enter the object names to select (examples):
IIS AppPool\NetCore

Click OK to add permission

Figure 16.7 Adding permission for the NetCore app pool to the website publish folder.

Out of the box, the ASP.NET Core templates are configured to work seamlessly with IIS, but if you've created an app from scratch, then you may need to make a couple of changes. In the next section, I briefly show the changes you need to make and explain why they're necessary.

16.2.2 Preparing and publishing your application to IIS

As I discussed in section 16.1, IIS acts as a reverse proxy for your ASP.NET Core app. That means IIS needs to be able to communicate directly with your app to forward incoming requests and outgoing responses to and from your app.

IIS handles this with the ASP.NET Core Module, but there's a certain degree of negotiation required between IIS and your app. For this to work correctly, you need to configure your app to use IIS integration.

IIS integration is added by default when you use the `IHostBuilder.ConfigureWebHostDefaults()` helper method used in the default templates. If you're customizing your own `HostBuilder`, then you need to ensure you add IIS integration with the `UseIIS()` or `UseIISIntegration()` extension method.

Listing 16.1 Adding IIS Integration to a host builder

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();
    }
    public static IHostBuilder CreateHostBuilder(string[] args) =>
        Host.CreateDefaultBuilder(args)
            .ConfigureWebHost(webBuilder =>          #A
            {
                webBuilder.UseKestrel();
                webBuilder.UseStartup<Startup>();
                webBuilder.UseIIS();                 #B
                webBuilder.UseIISIntegration();      #C

            });
}
```

#A Using a custom builder, instead of the default ConfigureWebHostDefaults used in templates
#B Configures your application for use with IIS with an in-process hosting model
#C Configures your application for use with IIS with an out-of-process hosting model

> **NOTE** If you're not using your application with IIS, the `UseIIS()` and `UseIISIntegration()` methods will have no effect on your app, so it's safe to include them anyway.

In-process vs. out-of-process hosting in IIS

The reverse-proxy description I gave in section 16.1 assumes that your application is running in a separate process to the reverse proxy itself. That is the case if you're running on Linux and was the default for IIS up until ASP.NET Core 3.0. In ASP.NET Core 3.0, ASP.NET Core switched to using an *in-process* hosting model by default for applications deployed to IIS. In this model, IIS hosts your application directly in the IIS process, reducing inter-process communication, and boosting performance.

You can switch to the out-of-process hosting model with IIS if you wish, which can sometimes be useful for troubleshooting problems. Rick Strahl has an excellent post on the differences between the hosting models, how to switch between them, and the advantages of each: https://weblog.west-wind.com/posts/2019/Mar/16/ASPNET-Core-Hosting-on-IIS-with-ASPNET-Core-22.

In general, you shouldn't need to worry about the differences between the hosting models, but it's something to be aware of if you're deploying to IIS. If you choose to use the out-of-process hosting model then you should use the `UseIISIntegration()` extension method. If you use the in-process model, use `UseIIS()`. Alternatively, play it safe and use both—the correct extension method will be activated based on the hosting model used in production. And neither extension does anything if you don't use IIS!

When running behind IIS, these extension methods configure your app to pair with IIS so that it can seamlessly accept requests. Among other things, the extensions:

- Define the URL that IIS will use to forward requests to your app and configure your app to listen on this URL
- Configure your app to interpret requests coming from IIS as coming from the client by setting up header forwarding
- Enable Windows authentication if required

Adding the IIS extension methods is the only change you need to make to your application to be able to host in IIS, but there's one additional aspect to be aware of when you publish your app.

As with previous versions of ASP.NET, IIS relies on a web.config file to configure the applications it runs. It's important your application includes a web.config file when it's published to IIS, otherwise you could get broken behavior, or even expose files that shouldn't be exposed.[71]

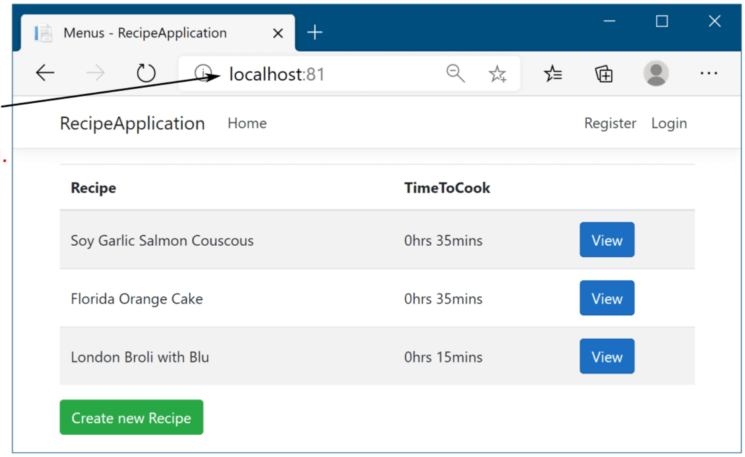
If your ASP.NET Core project already includes a web.config file, the .NET CLI or Visual Studio will copy it to the publish directory when you publish your app. If your app doesn't include a web.config file, the publish command will create the correct one for you. If you don't need to customize the web.config file, it's generally best not to include one in your project and let the CLI create the correct file for you.

With these changes, you're finally in a position to publish your application to IIS. Publish your ASP.NET Core app to a folder, either from Visual Studio, or with the .NET CLI by running

```
dotnet publish --output publish_folder --configuration release
```

This will publish your application to the publish_folder folder. You can then copy your application to the path specified in IIS as shown in figure 16.6. At this point, if all has gone smoothly, you should be able to navigate to the URL you specified for your app (http://localhost:81, in my case) and see it running, as shown in figure 16.8.

The app is served using IIS
as a reverse proxy, using the URL
sepecified in the Add Website dialog.



Recipe	TimeToCook	
Soy Garlic Salmon Couscous	0hrs 35mins	View
Florida Orange Cake	0hrs 35mins	View
London Broli with Blu	0hrs 15mins	View

Figure 16.8 The published application, using IIS as a reverse proxy listening at the URL http://localhost:81.

And there you have it, your first application running behind a reverse proxy. Even though ASP.NET Core uses a different hosting model to previous versions of ASP.NET, the process of configuring IIS is similar.

[71] For details on using web.config to customize the IIS AspNetCore Module, see https://docs.microsoft.com/aspnet/core/host-and-deploy/aspnet-core-module.

As is often the case when it comes to deployment, the success you have is highly dependent on your precise environment and your app itself. If, after following these steps, you find you can't get your application to start, I highly recommend checking out the documentation at https://docs.microsoft.com/aspnet/core/publishing/iis. This contains many troubleshooting steps to get you back on track if IIS decides to throw a hissy fit.

This section was deliberately tailored to deploying to IIS, as it provides a great segue for developers who are already used to deploying ASP.NET apps and want to deploy their first ASP.NET Core app. But that's not to say that IIS is the only, or best, place to host your application.

In the next section, I'll provide a brief introduction to hosting your app on Linux, behind a reverse proxy like NGINX or Apache. I won't go into configuration of the reverse proxy itself, but will provide an overview of things to consider, and resources you can use to run your applications on Linux.

16.3 Hosting an application on Linux

One of the great new features in ASP.NET Core is the ability to develop and deploy applications cross-platform, whether that be on Windows, Linux, or macOS. The ability to run on Linux, in particular, opens up the possibility of cheaper deployments to cloud hosting, deploying to small devices like a Raspberry Pi or to Docker containers.

One of the characteristics of Linux is that it's almost infinitely configurable. Although that's definitely a feature, it can also be extremely daunting, especially if coming from the Windows world of wizards and GUIs. This section provides an overview of what it takes to run an application on Linux. It focuses on the broad steps you need to take, rather than the somewhat tedious details of the configuration itself. Instead, I point to resources you can refer to as necessary.

16.3.1 Running an ASP.NET Core app behind a reverse proxy on Linux

You'll be glad to hear that running your application on Linux is broadly the same as running your application on Windows with IIS:

1. *Publish your app using* `dotnet publish`. If you're creating an RDD, the output is the same as you'd use with IIS. For an SCD, you must provide the target platform moniker, as described in section 16.1.1.
2. *Install the necessary prerequisites on the server.* For an RDD deployment, you must install the .NET Core Runtime and the necessary prerequisites. You can find details on this in the docs at https://docs.microsoft.com/dotnet/core/install/dependencies.
3. *Copy your app to the server.* You can use any mechanism you like, FTP, USB stick, whatever you need to get your files onto the server!
4. *Configure a reverse proxy and point it to your app.* As you know by now, you may want to run your app behind a reverse proxy, for the reasons described in section 16.1. On

Windows, you'd use IIS, but on Linux you have more options. NGINX, Apache, and HAProxy are all commonly used options.

5. *Configure a process-management tool for your app.* On Windows, IIS acts both as a reverse proxy and a process manager, restarting your app if it crashes or stops responding. On Linux, you typically need to configure a separate process manager to handle these duties; the reverse proxies won't do it for you.

The first three points are generally the same whether you're running on Windows with IIS or on Linux, but the last two points are more interesting. In contrast to the monolithic IIS, Linux has a philosophy of small applications with a single responsibility.

IIS runs on the same server as your app and takes on multiple duties—proxying traffic from the internet to your app, but also monitoring the app process itself. If your app crashes or stops responding, IIS will restart the process to ensure you can keep handling requests.

In Linux, the reverse proxy might be running on the same server as your app, but it's also common for it to be running on a different server entirely, as shown in figure 16.9. This is similarly true if you choose to deploy your app to Docker; your app would typically be deployed in a container without a reverse proxy, and a reverse proxy on a server would point to your Docker container.

As the reverse proxies aren't necessarily on the same server as your app, they can't be used to restart your app if it crashes. Instead, you need to use a process manager such as systemd to monitor your app. If you're using Docker, you'd typically use a container orchestrator such as Kubernetes (https://kubernetes.io) to monitor the health of your containers.

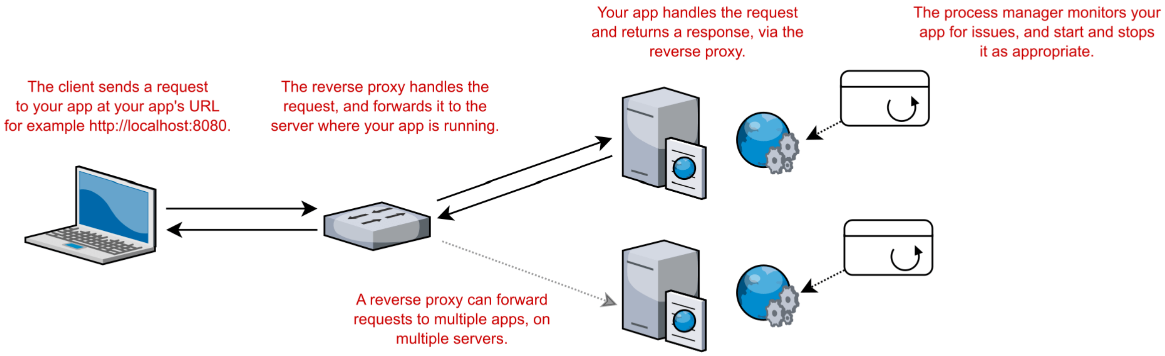

Your app handles the request and returns a response, via the reverse proxy.
The process manager monitors your app for issues, and start and stops it as appropriate.
The client sends a request to your app at your app's URL for example http://localhost:8080.
The reverse proxy handles the request, and forwards it to the server where your app is running.
A reverse proxy can forward requests to multiple apps, on multiple servers.

Figure 16.9 On Linux, it's common for a reverse proxy to be on a different server to your app. The reverse proxy forwards incoming requests to your app, while the process manager, for example systemd, monitors your apps for crashes and restarts it as appropriate.

Running ASP.NET Core applications in Docker

Docker is the most commonly used engine for *containerizing* your applications. A container is like a small, lightweight virtual machine, specific to your app. It contains an operating system, your app, and any dependencies for your app.

This container can then be run on any machine that runs Docker, and your app will run exactly the same, regardless of the host operating system and what's installed on it. This makes deployments highly repeatable: you can be confident that if the container runs on your machine, it will run on the server too.

ASP.NET Core is well-suited to container deployments, but moving to Docker involves a big shift in your deployment methodology, and may or may not be right for you and your apps. If you're interested in the possibilities afforded by Docker and want to learn more, I suggest checking out the following resources:

- *Docker in Practice, Second Edition* by Ian Miell and Aidan Hobson Sayers (Manning, 2017) provides a vast array of practical techniques to help you get the most out of Docker (https://livebook.manning.com/book/docker-in-practice-second-edition/).
- Even if you're not deploying to Linux, you can use Docker with Docker for Windows. Check out the free e-book, *Introduction to Windows Containers* by John McCabe and Michael Friis (Microsoft Press, 2017) from https://aka.ms/containersebook.
- You can find a lot of details on building and running your ASP.NET Core applications on Docker in the .NET documentation at https://docs.microsoft.com/aspnet/core/host-and-deploy/docker.
- Steve Gordon has an excellent blog post series on Docker for ASP.NET Core developers at https://www.stevejgordon.co.uk/docker-dotnet-developers.

Configuring these systems is a laborious task that makes for dry reading, so I won't detail them here. Instead, I recommend checking out the ASP.NET Core docs. They have a guide for NGINX and systemd (https://docs.microsoft.com/aspnet/core/host-and-deploy/linux-nginx), and a guide for configuring Apache with systemd (https://docs.microsoft.com/aspnet/core/host-and-deploy/linux-apache).

Both guides cover the basic configuration of the respective reverse proxy and systemd supervisor, but more importantly, they also show how to configure them *securely*. The reverse proxy sits between your app and the unfettered internet, so it's important to get it right!

Configuring the reverse proxy and the process manager is typically the most complex part of deploying to Linux, and isn't specific to .NET development: the same would be true if you were deploying a Node.js web app. But you need to consider a few things *inside* your application when you're going to be deploying to Linux, as you'll see in the next section.

16.3.2 Preparing your app for deployment to Linux

Generally speaking, your app doesn't care which reverse proxy it sits behind, whether it's NGINX, Apache, or IIS—your app receives requests and responds to them without the reverse proxy affecting things. Just as when you're hosting behind IIS, you need to add `UseIISIntegration()`; when you're hosting on Linux, you need to add a similar extension method to your app setup.

When a request arrives at the reverse proxy, it contains some information that is lost after the request is forwarded to your app. For example, the IP address of the client/browser connecting to your app: once the request is forwarded from the reverse proxy, the IP address is that of the *reverse proxy*, not the *browser*. Also, if the reverse proxy is used for SSL offloading (see chapter 18) then a request that was originally made using HTTPS may arrive at your app as an HTTP request.

The standard solution to these issues is for the reverse proxy to add additional headers before forwarding requests to your app. For example, the `X-Forwarded-For` header identifies the original client's IP address, while the `X-Forwarded-Proto` header indicates the original scheme of the request (`http` or `https`).

For your app to behave correctly, it needs to look for these headers in incoming requests and modify the request as appropriate. A request to http://localhost with the `X-Forwarded-Proto` header set to `https` should be treated the same as if the request was to https://localhost.

You can use `ForwardedHeadersMiddleware` in your middleware pipeline to achieve this. This middleware overrides `Request.Scheme` and other properties on `HttpContext` to correspond to the forwarded headers. If you're using the default `Host.CreateDefaultBuilder()` method in Program.cs, then this is partially handled for you—the middleware is automatically added to the pipeline in a disabled state. To enable it, set the environment variable ASPNETCORE_FORWARDEDHEADERS_ENABLED=true.

If you're using your own `HostBuilder` instance, instead of the default builder, you can add the middleware to the start of your middleware pipeline manually, as shown in listing 16.2, and configure it with the headers to look for.

> **WARNING** It's important that `ForwardedHeadersMiddleware` is placed early in the middleware pipeline to correct `Request.Scheme` before any middleware that depends on the scheme runs.

Listing 16.2 Configuring an app to use forwarded headers in Startup.cs

```
public class Startup
{
    public class Configure(IApplicationBuilder app)
    {
        app.UseForwardedHeaders(new ForwardedHeadersOptions         #A
        {
            ForwardedHeaders = ForwardedHeaders.XForwardedFor |     #B
                               ForwardedHeaders.XForwardedProto     #B
        });

        app.UseHttpsRedirection();   #C
        app.UseRouting();            #C

        app.UseAuthentication();      #C
        app.UseMvc();                 #C
    }
}
```

#A Adds ForwardedHeadersMiddleware early in your pipeline
#B Configures the headers the middleware should look for and use
#C The forwarded headers middleware must be placed before all other middleware.

> **NOTE** This behavior isn't specific to reverse proxies on Linux; the `UseIis()` extension adds `ForwardedHeadersMiddleware` under the hood as part of its configuration when your app is running behind IIS.

Aside from considering the forwarded headers, you need to consider a few minor things when deploying your app to Linux that may trip you up if you're used to deploying to Windows alone:

- *Line endings (*`LF` *on Linux versus* `CRLF` *on Windows).* Windows and Linux use different character codes in text to indicate the end of a line. This isn't often an issue for ASP.NET Core apps, but if you're writing text files on one platform and reading them on a different platform, then it's something to bear in mind.
- *Path directory separator (*`"\"` *on Windows,* `"/"` *on Linux).* This is one of the most common bugs I see when Windows developers move to Linux. Each platform uses a different separator in file paths, so while loading a file using the `"subdir\myfile.json"` path will work fine on Windows, it won't on Linux. Instead, you should use `Path.Combine` to create the appropriate separator for the current platform, for example `Path.Combine("subdir", "myfile.json")`.
- *Environment variables can't contain* `":"`. On some Linux distributions, the colon character, `":"`, isn't allowed in environment variables. As you saw in chapter 11, this character is typically used to denote different sections in ASP.NET Core configuration, so you often need to use it in environment variables. Instead, you can use a double underscore in your environment variables (`"__"`) and ASP.NET Core will treat it the same as if you'd used a colon.

As long as you set up `ForwardedHeadersMiddleware` and take care to use cross-platform constructs like `Path.Combine`, you shouldn't have any problems running your applications on Linux. But configuring a reverse proxy isn't the simplest of activities, so wherever you're planning on hosting your app, I suggest checking the documentation for guidance at https://docs.microsoft.com/aspnet/core/publishing.

16.4 Configuring the URLs for your application

At this point, you've deployed an application, but there's one aspect you haven't configured: the URLs for your application. When you're using IIS as a reverse proxy, you don't have to worry about this inside your app. IIS integration with the ASP.NET Core Module works by dynamically creating a URL that's used to forward requests between IIS and your app. The hostname you configure in IIS (in figure 16.6) is the URL that external users see for your app; the internal URL that IIS uses when forwarding requests is never exposed.

If you're not using IIS as a reverse proxy, maybe you're using NGINX or exposing your app directly to the internet, you may find you need to configure the URLs your application listens to directly.

By default, ASP.NET Core will listen for requests on the URL http://localhost:5000. There are lots of ways to set this URL, but in this section I'll describe two: using environment variables or using command line arguments. These are the two most common approaches I see (outside of IIS) to control which URLs your app uses.

TIP For further ways to set your application's URL, see https://andrewlock.net/5-ways-to-set-the-urls-for-an-aspnetcore-app/.

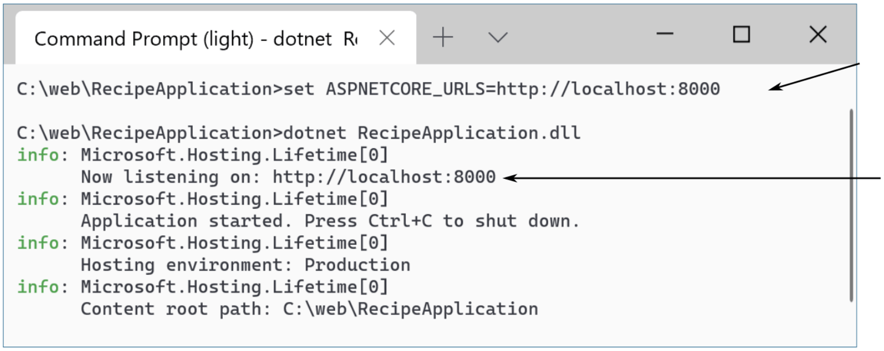
In chapter 10, you learned about configuration in ASP.NET Core, and in particular about the concept of hosting environments so that you can use different settings when running in development compared to production. You choose the hosting environment by setting an environment variable on your machine called `ASPNETCORE_ENVIRONMENT`. The ASP.NET Core framework magically picks up this variable when your app starts and uses it to set the hosting environment.

You can use a similar special environment variable to specify the URL that your app uses; this variable is called `ASPNETCORE_URLS`. When your app starts up, it looks for this value and uses it as the application's URL. By changing this value, you can change the default URL used by all ASP.NET Core apps on the machine.

For example, you could set a temporary environment variable in Windows from the command window using

```
set ASPNETCORE_URLS=http://localhost:8000
```

Running a published application using `dotnet <app.dll>` within the same command window, as shown in figure 16.10, shows that the app is now listening on the URL provided in the `ASPNETCORE_URLS` variable.



```
C:\web\RecipeApplication>set ASPNETCORE_URLS=http://localhost:8000

C:\web\RecipeApplication>dotnet RecipeApplication.dll
info: Microsoft.Hosting.Lifetime[0]
      Now listening on: http://localhost:8000
info: Microsoft.Hosting.Lifetime[0]
      Application started. Press Ctrl+C to shut down.
info: Microsoft.Hosting.Lifetime[0]
      Hosting environment: Production
info: Microsoft.Hosting.Lifetime[0]
      Content root path: C:\web\RecipeApplication
```

Set the ASPNETCORE_URLS environment variable. It applies for the lifetime of the console window.

Your app listens using the URL from the ASPETNCORE_URLS variable.

Figure 16.10 Change the `ASPNETCORE_URLS` environment variable to change the URL used by ASP.NET Core apps.

You can instruct an app to listen on multiple URLs by separating them with a semicolon, or you can listen to a specific port, without specifying the localhost hostname. If you set the `ASPNETCORE_URLS` environment variable to

```
http://localhost:5001;http://*:5002
```

then your ASP.NET Core apps would listen for requests to:

- http://localhost:5001. This address is only accessible on your local computer, so it will not accept requests from the wider internet.
- http://*:5002. Any URL on port 5002. External request from the internet can access the app on port 5002, using any URL that maps to your computer.

Note that you *can't* specify a different hostname, like tastyrecipes.com for example. ASP.NET Core will listen to all requests on a given port. The exception is the localhost hostname, which only allows requests that came from your own computer.

> **NOTE** If you find the ASPNETCORE_URLS variable isn't working properly, ensure you don't have a launchSettings.json file in the directory. When present, the values in this files takes presence. By default, launchSettings.json isn't included in the publish output, so this generally won't be an issue in production.

Setting the URL of an app using a single environment variable works great for some scenarios, most notably when you're running a single application in a virtual machine, or within a Docker container.[72]

If you're not using Docker containers, the chances are you're hosting multiple apps side-by-side on the same machine. A single environment variable is no good for setting URLs in this case, as it would change the URL of every app.

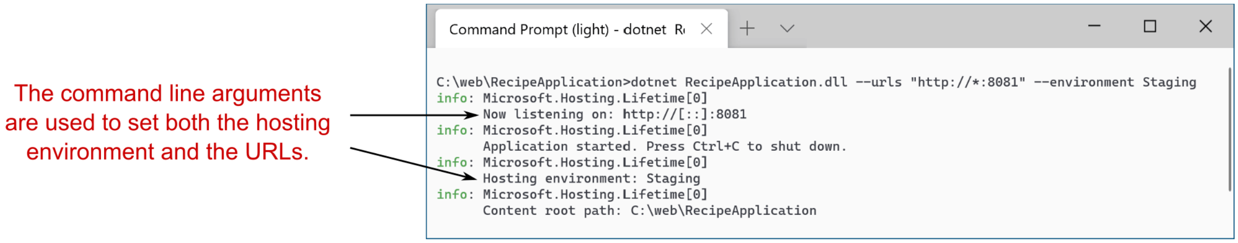
In chapter 11 you saw that you could set the hosting environment using the `ASPNETCORE_ENVIRONMENT` variable, but you could also set the environment using the `--environment` flag when calling `dotnet run`:

```
dotnet run --no-launch-profile --environment Staging
```

You can set the URLs for your application in a similar way, using the `--urls` parameter. Using command line arguments enables you to have multiple ASP.NET Core applications running on the same machine, listening to different ports. For example, the following command would run the recipe application, set it to listen on port 8081, and set the environment to Staging, as shown in figure 16.11:

```
dotnet RecipeApplication.dll --urls "http://*:8081" --environment Staging
```

[72] ASP.NET Core is well-suited to running in containers, but working with containers is a separate book in its own right. For details on hosting and publishing apps using Docker, see https://docs.microsoft.com/aspnet/core/host-and-deploy/docker/.



The command line arguments are used to set both the hosting environment and the URLs.

```
C:\web\RecipeApplication>dotnet RecipeApplication.dll --urls "http://*:8081" --environment Staging
info: Microsoft.Hosting.Lifetime[0]
      Now listening on: http://[::]:8081
info: Microsoft.Hosting.Lifetime[0]
      Application started. Press Ctrl+C to shut down.
info: Microsoft.Hosting.Lifetime[0]
      Hosting environment: Staging
info: Microsoft.Hosting.Lifetime[0]
      Content root path: C:\web\RecipeApplication
```

Figure 16.11 Setting the hosting environment and URLs for an application using command line arguments. The values passed at the command line override values provided from appSettings.json or environment variables.

Remember, you don't need to set your URLs in this way if you're using IIS as a reverse proxy; IIS integration handles this for you. Setting the URLs is only necessary when you're manually configuring the URL your app is listening on, for example if you're using NGINX or are exposing Kestrel directly to clients.

> **WARNING** If running your ASP.NET Core application without a reverse proxy, you should use *host filtering* for security reasons, to ensure your app only responds to requests for hostnames you expect. For more details, see https://andrewlock.net/adding-host-filtering-to-kestrel-in-aspnetcore/.

Continuing the theme of deployment-related tasks, in the next section, we take a look at optimizing some of your client-side assets for production. If you're building a Web API, then this isn't something you'll have to worry about in your ASP.NET Core app, but for traditional web apps it's worth considering.

16.5 Optimizing your client-side assets using BundlerMinifier

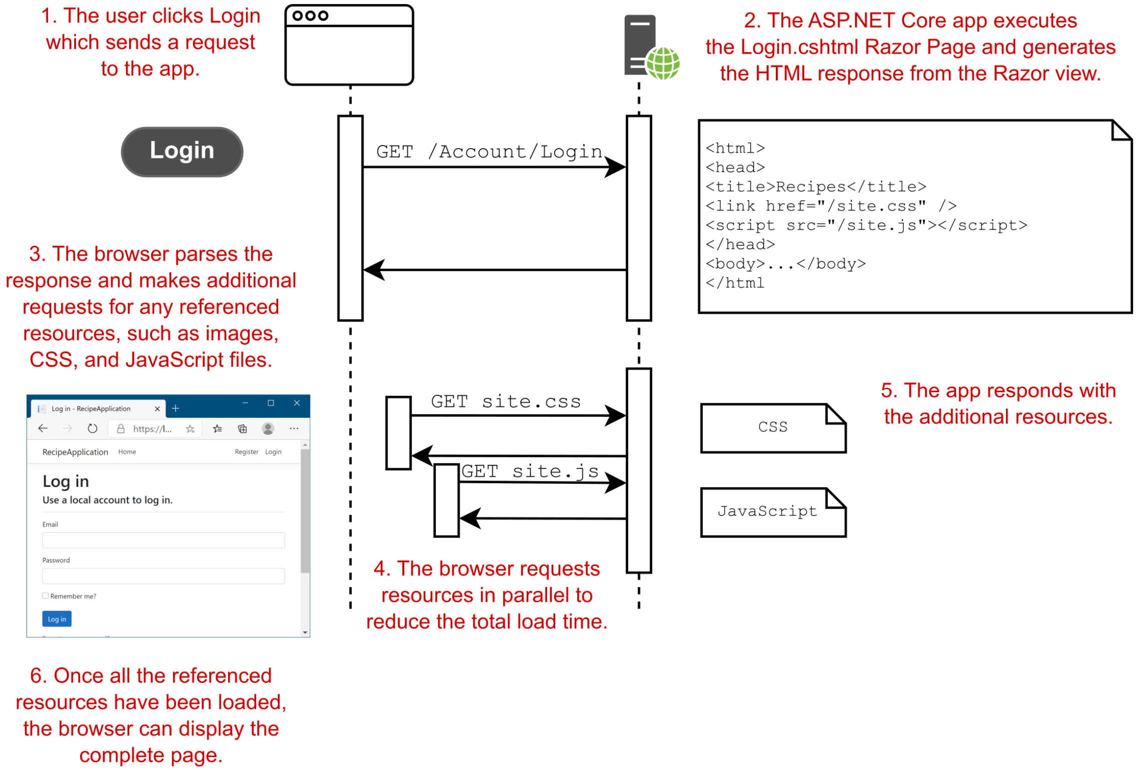
In this section, we'll explore the performance of your ASP.NET Core application in terms of the number and size of requests. You'll see how to improve the performance of your app using bundling and minification, but ensuring your app is still easy to debug while you're building it. Finally, we'll look at a common technique for improving app performance in production: using a content delivery network (CDN).

Have you ever used a web app or opened a web page that seemed to take forever to load? Once you stray off the beaten track of Amazon, Google, or Microsoft, it's only a matter of time before you're stuck twiddling your thumbs while the web page slowly pops into place.

Next time this happens to you, open the browser developer tools (for example, press F12 in Edge or Chrome) and take a look at the number, and size, of the requests the web app is making. In many cases, a high number of requests generating large responses will be responsible for the slow loading of a web page.

We'll start by exploring the problem of performance by looking at a single page from your recipe application: the login page. This is a simple page, and it isn't inherently slow, but even this is sufficient to investigate the impact of request size.

As a user, when you click the login button, the browser sends a request to `/Identity/Account/Login`. Your ASP.NET Core app executes the Login.cshtml Razor Page in the default UI, which executes a Razor template and returns the generated HTML in the response, as shown in figure 16.12. That's a single request-response; a single round-trip.



1. The user clicks Login which sends a request to the app.

2. The ASP.NET Core app executes the Login.cshtml Razor Page and generates the HTML response from the Razor view.

```
<html>
<head>
<title>Recipes</title>
<link href="/site.css" />
<script src="/site.js"></script>
</head>
<body>...</body>
</html
```

3. The browser parses the response and makes additional requests for any referenced resources, such as images, CSS, and JavaScript files.

4. The browser requests resources in parallel to reduce the total load time.

5. The app responds with the additional resources.

6. Once all the referenced resources have been loaded, the browser can display the complete page.

Figure 16.12 Loading a complete page for your app. The initial request returns the HTML for the page, but this may include links to other resources, such as CSS and JavaScript files. The browser must make additional requests to your app for all the outstanding resources before the page can be fully loaded.

But that's not it for the web page. The HTML returned by the page includes links to CSS files (for styling the page), JavaScript files (for client-side functionality—client-side form validation, in this case), and, potentially, images and other resources (though you don't have any others in this recipe app).

The browser must request each of these additional files and wait for the server to return them before the whole page is loaded. When you're developing locally, this all happens quickly, as the request doesn't have far to go at all, but once you deploy your app to production, it's a different matter.

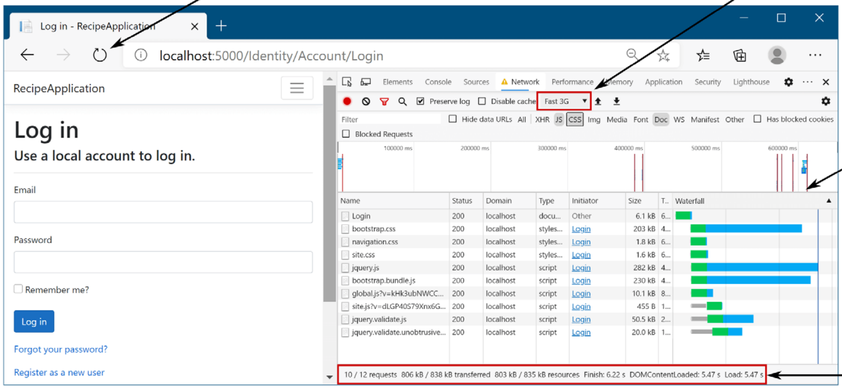
Users will be requesting pages from your app from a wide variety of distances from the server, and over a wide variety of network speeds. Suddenly, the number and size of the requests and responses for your app will have a massive impact on the overall perceived speed of your app. This, in turn, can have a significant impact on how users perceive your site and, for e-commerce sites, even how much money they spend.[73]

A great way to explore how your app will behave for non-optimal networks is to use the network-throttling feature in Chrome's developer tools. This simulates the delays and network speeds associated with different types of networks, so you can get an idea of how your app behaves in the wild. In figure 16.13, I've loaded the login page for the recipe app, but this time with the network set to a modest Fast 3G speed.

> **NOTE** I've added additional files to the template, navigation.css and global.js, to make the page more representative of a real app.

Right click the reload button and choose Empty Cache and Hard Refresh.

Throttling adds latency to each request and reduces the maximum data rate



A maximum of 6 requests can be made concurrently to a domain.

Loading the page fully takes 10 requests, 835kB, and 5.47s.

Log in - RecipeApplication

localhost:5000/Identity/Account/Login

RecipeApplication

Log in

Use a local account to log in.

Email

Password

□ Remember me?

Log in

Forgot your password?

Register as a new user

☑ Preserve log □ Disable cache Fast 3G

Filter □ Hide data URLs All XHR JS CSS Img Media Font Doc WS Manifest Other □ Has blocked cookies

□ Blocked Requests

Name	Status	Domain	Type	Initiator	Size	T..	Waterfall
Login	200	localhost	docu...	Other	6.1 kB	6...	
bootstrap.css	200	localhost	styles...	Login	203 kB	4...	
navigation.css	200	localhost	styles...	Login	1.8 kB	6...	
site.css	200	localhost	styles...	Login	1.6 kB	6...	
jquery.js	200	localhost	script	Login	282 kB	4...	
bootstrap.bundle.js	200	localhost	script	Login	230 kB	4...	
global.js?v=kHk3ubNWCC...	200	localhost	script	Login	10.1 kB	8...	
site.js?v=dLGP40S79Xnx6G...	200	localhost	script	Login	455 B	1...	
jquery.validate.js	200	localhost	script	Login	50.5 kB	2...	
jquery.validate.unobtrusive...	200	localhost	script	Login	20.0 kB	1...	

10 / 12 requests 806 kB / 838 kB transferred 803 kB / 835 kB resources Finish: 6.22 s DOMContentLoaded: 5.47 s Load: 5.47 s

Figure 16.13 Exploring the effect of network speed on application load times. Chrome and Edge let you simulate a slower network, so you can get an impression of the experience users will get when loading your application once it's in production.

Throttling the network doesn't change anything about the page or the data requested—there are 10 separate requests and 1MB loaded for this single page—but it dramatically impacts the time for the page to load. Without throttling, the login page loads locally in 200ms; with Fast 3G throttling, the login page takes 5.47 seconds to load!

[73] There has been a lot of research done on this, including stats such as "a 0.1-second delay in page load time equals 7% loss in conversions" from https://www.soasta.com/your-2017-guide-to-retail-performance-success/.

NOTE Don’t be too alarmed by these numbers. I’m making a point of reloading all the files with every request to emphasize the point, whereas in practice, browsers go to great lengths to cache files to avoid having to send this amount of data.

The time it takes to fully load a page of your app is based primarily on two things:

- *The total size of the responses*—This is straight-up math; you can only return data at a certain speed, so the more data you need to return, the longer it takes.
- *The number of requests*—In general, the more requests the browser must make, the longer it takes to fully load the page. In HTTP/1.0 and HTTP/1.1, you can only make six concurrent requests to a server, so any requests after the sixth must wait for an earlier request to *finish* before they can even *start*. HTTP/2.0, which is supported by Kestrel, doesn’t have this limit, but you can’t always rely on clients using it.

How can you improve your app speed, assuming all the files you’re serving are needed? In general, this is a big topic, with lots of possibilities, such as using a CDN to serve your static files. Two of the simplest ways to improve your site’s performance are to use *bundling* and *minification* to reduce the number and size of requests the browser must make to load your app.

16.5.1 Speeding up an app using bundling and minification

In figure 16.13 for the recipe app, you made a total of 10 requests to the server:

- One initial request for the HTML
- Three requests for CSS files
- Six requests for JavaScript files

Some of the CSS and JavaScript files are standard vendor libraries, like Bootstrap and jQuery, that are included as part of the default Razor templates, and some (navigation.css, site.css, global.js, and site.js) are files specific to your app. In this section, we’re going to look at optimizing your custom CSS and JavaScript files.

If you’re trying to reduce the number of requests for your app, then an obvious first thought is to avoid creating multiple files in the first place! For example, instead of creating a navigation.css file and a site.css file, you could use a single file that contains all the CSS, instead of separating it out.

That’s a valid solution but putting all your code into one file may make it harder to manage and debug. As developers, we generally try to avoid this sort of monster file. A better solution is to let you split your code into as many files as you want, and then *bundle* the files when you come to deploy your code.

DEFINITION *Bundling* is the process of concatenating multiple files into a single file, to reduce the number of requests.

Similarly, when you write JavaScript, you should use descriptive variables names, comments where necessary, and whitespace to create easily readable and debuggable code. When you come to deploy your scripts, you can process and optimize them for size, instead of readability. This process is called *minification*.

> **DEFINITION** *Minification* involves processing code to reduce its size, without changing the behavior of the code. Processing has many different levels, which typically includes removing comments and whitespace, and can extend to renaming variables to give them shorter names or removing whole sections of code entirely if they're unused.

As an example, look at the JavaScript in the following listing. This (very contrived) function adds up some numbers and returns them. It includes (excessively) descriptive variable names, comments, and plenty of use of whitespace, but is representative of the JavaScript you might find in your own app.

Listing 16.3 Example JavaScript function before minification

```
function myFunc() {
    // this function doesn't really do anything,
    // it's just here so that we can show off minifying!
    function innerFunctionToAddTwoNumbers(
        thefirstnumber, theSecondNumber) {
        // i'm nested inside myFunc
        return thefirstnumber + theSecondNumber;
    }
    var shouldAddNumbers = true;
    var totalOfAllTheNumbers = 0;

    if (shouldAddNumbers == true) {
        for (var index = 0; i < 10; i++) {
            totalOfAllTheNumbers =
                innerFunctionToAddTwoNumbers(totalOfAllTheNumbers, index);
        }
    }
    return totalOfAllTheNumbers;
}
```

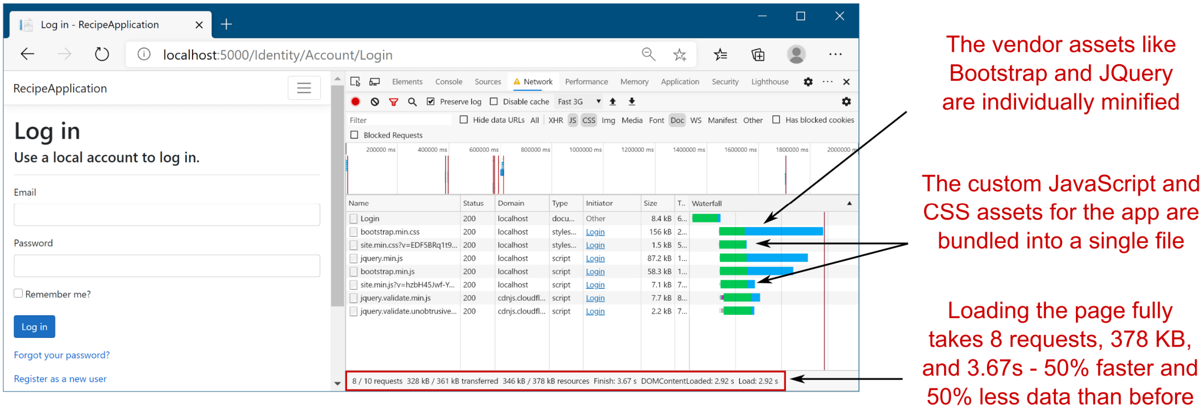
This function takes a total of 588 bytes as it's currently written, but after minification, that's reduced to 95 bytes—16% of its original size. The behavior of the code is identical, but the output, shown in the following listing, is optimized to reduce its size. It's clearly not something you'd want to debug, but you'd only use minified versions of your file in production; you'd use the original source files when developing.

Listing 16.4 Example JavaScript function after minification

```
function myFunc(){function r(n,t){return n+t}var
n=0,t;if(1)for(t=0;i<10;i++)n=r(n,t);return n}
```

Optimizing your static files using bundling and minification can provide a free boost to your app's performance when you deploy your app to production, while letting you develop using easy-to-read and separated files.

Figure 16.14 shows the impact of bundling and minifying the files for the login page of your recipe app. Each of the vendor files has been minified to reduce its size, and your custom assets have been bundled and minified to reduce both their size and the number of requests. This reduced the number of requests from 10 to 8, the total amount of data from 580 KB to 270 KB, and the load time from 6.45 s to 3.15 s.



Name	Status	Domain	Type	Initiator	Size	T..	Waterfall
Login	200	localhost	docu...	Other	8.4 kB	6...	
bootstrap.min.css	200	localhost	styles...	Login	156 kB	2...	
site.min.css?v=EDF5BRq1t9...	200	localhost	styles...	Login	1.5 kB	5...	
jquery.min.js	200	localhost	script	Login	87.2 kB	1...	
bootstrap.min.js	200	localhost	script	Login	58.3 kB	1...	
site.min.js?v=hzbH45Jwf-Y...	200	localhost	script	Login	7.1 kB	7...	
jquery.validate.min.js	200	cdnjs.cloudfl...	script	Login	7.7 kB	8...	
jquery.validate.unobtrusive...	200	cdnjs.cloudfl...	script	Login	2.2 kB	7...	

8 / 10 requests 328 kB / 361 kB transferred 346 kB / 378 kB resources Finish: 3.67 s DOMContentLoaded: 2.92 s Load: 2.92 s

The vendor assets like Bootstrap and JQuery are individually minified

The custom JavaScript and CSS assets for the app are bundled into a single file

Loading the page fully takes 8 requests, 378 KB, and 3.67s - 50% faster and 50% less data than before

Figure 16.14 By bundling and minifying your client-side resources, you can reduce both the number of requests required and the total data to transfer, which can significantly improve performance. In this example, bundling and minification cut the time to fully load in half.

> **NOTE** The vendor assets, such as jQuery and Bootstrap, aren't bundled with your custom scripts in figure 16.16. This lets you load those files from a CDN, as I'll touch on in section 16.5.4.

This performance improvement can be achieved with little effort on your part, and no impact on your development process. In the next section, I'll show how you can include bundling and minification as part of your ASP.NET Core build process, and how to customize the bundling and minification processes for your app.

16.5.2 Adding BundlerMinifier to your application

Bundling and minification isn't a new idea, so you have many ways to achieve the same result. The previous version of ASP.NET performed bundling and minification in managed code, whereas JavaScript task runners such as gulp, grunt, and webpack are commonly used for these sorts of tasks. In fact, if you're writing a SPA, then you're almost certainly already performing bundling and minification as a matter of course.

ASP.NET Core includes support for bundling and minification via a NuGet package called BuildBundlerMinifier or a Visual Studio extension version called Bundler & Minifier. You don’t have to use either of these, and if you’re already using other tools such as gulp or webpack, then I suggest you continue to use them instead. But if you’re getting started with a new project, then I suggest considering BundlerMinifier; you can always switch to a different tool later.

You have two options for adding BundlerMinifier to your project:

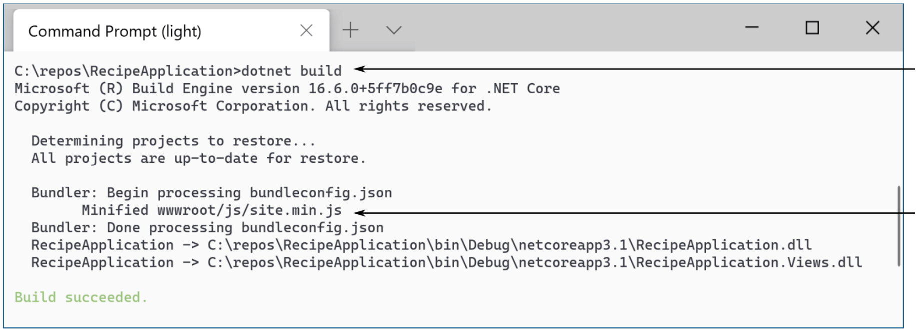
- You can install the Bundler & Minifier Visual Studio extension from Tools > Extensions and Updates.
- You can add the BuildBundlerMinifier NuGet package to your project.

Whichever approach you use, they both use the same underlying BundlerMinifier library.[74] I prefer to use the NuGet package approach as it’s cross-platform and will automatically bundle your resources for you, but the extension is useful for performing ad-hoc bundling. If you do use the Visual Studio extension, make sure to enable Bundle on build, as you’ll see shortly.

You can install the BuildBundlerMinifier NuGet package in your project with this command:

```
dotnet add package BuildBundlerMinifier
```

With the BuildBundlerMinifier package installed, whenever you build your project the BundlerMinifier will check your CSS and JavaScript files for changes. If something has changed, new bundled and minified files are created, as shown in figure 16.15, where I modified a JavaScript file.



```
C:\repos\RecipeApplication>dotnet build
Microsoft (R) Build Engine version 16.6.0+5ff7b0c9e for .NET Core
Copyright (C) Microsoft Corporation. All rights reserved.

  Determining projects to restore...
  All projects are up-to-date for restore.

  Bundler: Begin processing bundleconfig.json
        Minified wwwroot/js/site.min.js
  Bundler: Done processing bundleconfig.json
  RecipeApplication -> C:\repos\RecipeApplication\bin\Debug\netcoreapp3.1\RecipeApplication.dll
  RecipeApplication -> C:\repos\RecipeApplication\bin\Debug\netcoreapp3.1\RecipeApplication.Views.dll

Build succeeded.
```

Building the project will run the BundlerMinifier process.

If a file has changed, the BundlerMinifier will rebuild and minify the bundle.

Figure 16.15 Whenever the project is built, the BuildBundlerMinifier tool looks for changes in the input files and builds new bundles as necessary.

[74] The library and extension are open source on GitHub https://github.com/madskristensen/BundlerMinifier/.

As you can see in figure 16.15, the bundler minified your JavaScript code and created a new file at wwwroot/js/site.min.js. But why did it pick this name? Well, because you told it to in bundleconfig.json. You add this JSON file to the root folder of your project, and it controls the BundlerMinifier process.

Listing 16.5 shows a typical bundleconfig.json configuration for a small app. This defines which files to include in each bundle, where to write each bundle, and what minification options to use. Two bundles are configured here: one for CSS and one for JavaScript. You can add bundles to the JSON array, or you can customize the existing provided bundles.

Listing 16.5 A typical bundleconfig.json file

```
[
  {
    "outputFileName": "wwwroot/css/site.min.css",   #A
    "inputFiles": [                                  #B
      "wwwroot/css/site.css"                        #B
      "wwwroot/css/navigation.css"                  #B
    ]                                               #B
  },
  {
    "outputFileName": "wwwroot/js/site.min.js",     #C
    "inputFiles": [                                  #D
      "wwwroot/js/site.js"
      "wwwroot/js/*.js",                                 #E
      "!wwwroot/js/site.min.js"                          #F
    ],
    "minify": {                 #G
      "enabled": true,          #G
      "renameLocals": true      #G
    },
    "sourceMap": false          #H
  }
]
```

#A The bundler will create a file with this name.
#B The files listed in inputFiles are minified and concatenated into outputFileName.
#C You can specify multiple bundles, each with an output filename.
#D You should create separate bundles for CSS and JavaScript.
#E You can use globbing patterns to specify files to include.
#F The ! symbol excludes the matching file from the bundle.
#G The JavaScript bundler has some additional options.
#H You can optionally create a source map for the bundled JavaScript file.

For each bundle you can list a specific set of files to include, as specified in the `inputFiles` property. If you add a new CSS or JavaScript file to your project, you have to remember to come back to bundleconfig.json and add it to the list.

Alternatively, you can use *globbing* patterns to automatically include new files by default. This isn't always possible, for example when you need to ensure that files are concatenated in a given order, but I find it preferable in many cases. The example in the previous listing uses globbing for the JavaScript bundle: the pattern includes all .js files in the wwwroot/js folder but excludes the minified output file itself.

DEFINITION *Globbing* patterns use wildcards to represent many different characters. For example, *.css would match all files with a .css extension, whatever the filename.

When you build your project, the BundlerMinifier optimizes your css files into a single wwwroot/css/site.min.css file, and your JavaScript into a single wwwroot/js/ site.min.js file, based on the settings in bundleconfig.json. In the next section, we'll look at how to include these files when you run in production, continuing to use the original files when developing locally.

NOTE The BundlerMinifier package is great for optimizing your CSS and JavaScript resources. But images are another important resource to consider for optimization and can easily constitute the bulk of your page's size. Unfortunately, there aren't any built-in tools for this, so you'll need to look at other options; https://tinypng.com is one.

16.5.3 Using minified files in production with the environment tag helper

Optimizing files using bundling and minification is great for performance, but you want to use the original files during development. The easiest way to achieve this split in ASP.NET Core is to use the Environment Tag Helper to conditionally include the original files when running in the Development hosting environment, and to use the optimized files in other environments.

You learned about the Environment Tag Helper in chapter 8, in which we used it to show a banner on the homepage when the app was running in the Testing environment. Listing 16.6 shows how you can achieve a similar approach in the _Layout .cshtml page for the CSS files of your Recipe app by using two Environment Tag Helpers: one for when you're in Development, and one for when you aren't in Development (you're in Production or Staging, for example). You can use similar Tag Helpers for the JavaScript files in the app.

Listing 16.6 Using Environment Tag Helpers to conditionally render optimized files

```
<environment include="Development">                         #A
    <link rel="stylesheet"                                  #B
        href="~/lib/bootstrap/dist/css/bootstrap.css" />    #B
    <link rel="stylesheet" href="~/css/navigation.css" />   #C
    <link rel="stylesheet" href="~/css/site.css" />         #C
</environment>
<environment exclude="Development">                            #D
    <link rel="stylesheet"                                     #E
        href="~/lib/bootstrap/dist/css/bootstrap.min.css" />   #E
    <link rel="stylesheet" href="~/css/site.min.css" />        #F
</environment>
```

#A Only render these links when running in Development environment.
#B The development version of Bootstrap
#C The development version of your styles
#D Only render these links when not in Development, such as in Staging or Production.
#E The minified version of Bootstrap
#F The bundled and minified version of your styles

When the app detects it isn't running in the Development hosting environment (as you learned in chapter 11), it will switch to rendering links for the optimized files. This gives you the best of both worlds: performance in production and ease of development.

The example in listing 16.6 also included a minified version of Bootstrap, even though you didn't configure this as part of the BundlerMinifier. It's common for CSS and JavaScript libraries like Bootstrap to include a pre-minified version of the file for you to use in Production. For those that do, it's often better to exclude them from your bundling process, as this allows you to potentially serve the file from a public CDN.

16.5.4 Serving common files from a CDN

A public CDN is a website that hosts commonly used files, such as Bootstrap or jQuery, which you can reference from your own apps. They have several advantages:

- They're normally fast.
- They save your server having to serve the file, saving bandwidth.
- Because the file is served from a different server, it doesn't count toward the six concurrent requests allowed to your server in HTTP/1.0 and HTTP/1.1.[75]
- Many different apps can reference the same file, so a user visiting your app may have already cached the file by visiting a different website, and may not need to download it at all.

It's easy to use a CDN in principle: reference the CDN file instead of the file on your own server. Unfortunately, you need to cater for the fact that, like any server, CDNs can sometimes fail. If you don't have a fallback mechanism to load the file from a different location, such as your server, then this can result in your app looking broken.

Luckily, ASP.NET Core includes several tag helpers to make working with CDNs and fallbacks easier. Listing 16.7 shows how you could update your CSS Environment Tag Helper to serve Bootstrap from a CDN when running in production, and to include a fallback. The fallback test creates a temporary HTML element and applies a Bootstrap style to it. If the element has the expected CSS properties, then the fallback test passes, because Bootstrap must be loaded. If it doesn't have the required properties, Bootstrap will be loaded from the alternative, local link instead.

Listing 16.7 Serving Bootstrap CSS styles from a CDN with a local fallback

```
<environment include="Development">
    <link rel="stylesheet" href="~/lib/bootstrap/dist/css/bootstrap.css" />
    <link rel="stylesheet" href="~/css/navigation.css" />
    <link rel="stylesheet" href="~/css/site.css" />
</environment>
```

[75] This limit is not fixed in stone but modern browsers all use the same limit: https://docs.pushtechnology.com/cloud/latest/manual/html/designguide/solution/support/connection_limitations.html

```
<environment exclude="Development">
    <link rel="stylesheet"  href="https://stackpath.bootstrapcdn.com/    #A
[CA] bootstrap/4.3.1/css/bootstrap.min.css"                             #A
    asp-fallback-test-class="sr-only"                                   #B
    asp-fallback-test-property="position"                               #C
    asp-fallback-test-value="absolute"                                  #C
    asp-fallback-href="~/lib/bootstrap/dist/css/bootstrap.min.css" />   #D

    <link rel="stylesheet" href="~/css/site.min.css" />
</environment>
```

#A By default, Bootstrap is loaded from a CDN.
#B The fallback test applies the sr-only class to an element …
#C … and checks the element has a CSS position of absolute. This indicates Bootstrap was loaded.
#D If the fallback check fails, the CDN must have failed, so Bootstrap is loaded from the local link.

Optimizing your static files is an important step to consider before you put your app into production, as it can have a significant impact on performance. Luckily, the BuildBundlerMinifier package makes it easy to optimize your CSS and JavaScript files. If you couple that with serving common files from a CDN, your app will be as speedy as possible for users in production.

That brings us to the end of this chapter on publishing your app. This last mile of app development, deploying an application to a server where users can access it, is a notoriously thorny issue. Publishing an ASP.NET Core application is easy enough, but the multitude of hosting options available makes providing concise steps for every situation difficult.

Whichever hosting option you choose, there's one critical topic which is often overlooked, but is crucial for resolving issues quickly: logging. In the next chapter, you'll learn about the logging abstractions in ASP.NET Core, and how you can use them to keep tabs on your app once it's in production.

16.6 Summary

- ASP.NET Core apps are console applications that self-host a web server. In production, you typically use a reverse proxy which handles the initial request and passes it to your app. Reverse proxies can provide additional security, operations, and performance benefits, but can also add complexity to your deployments.
- .NET Core has two parts: the .NET Core SDK (also known as the .NET CLI) and the .NET Core Runtime. When you're developing an application, you use the .NET CLI to restore, build, and run your application. Visual Studio uses the same .NET CLI commands from the IDE.
- When you want to deploy your app to production, you need to publish your application, using `dotnet publish`. This creates a folder containing your application as a DLL, along with all its dependencies.
- To run a published application, you don't need the .NET CLI as you won't be building the app. You only need the .NET Core Runtime to run a published app. You can run a

published application using the `dotnet app.dll` command, where app.dll is the application dll created by the `dotnet publish` command.

- To host ASP.NET Core applications in IIS, you must install the ASP.NET Core Module. This allows IIS to act as a reverse proxy for your ASP.NET Core app.
- IIS can host ASP.NET Core applications using one of two modes: in-process and out-of-process. The out-of-process mode runs your application as a separate process, as is typical for most reverse proxies. The in-process mode runs your application as part of the IIS process. This has performance benefits, as no inter-process communication is required.
- To prepare your application for publishing to IIS with ASP.NET Core, ensure you call `UseIISIntegration()` and `UseIIS()` on `WebHostBuilder`. The `ConfigureWebHostDefaults` static helper method does this automatically.
- When you publish your application using the .NET CLI, a web.config file will be added to the output folder. It's important that this file is deployed with your application when publishing to IIS, as it defines how your application should be run.
- The URL that your app will listen on is specified by default using the environment variable `ASPNETCORE_URLS`. Setting this value will change the URL for all the apps on your machine. Alternatively, pass the `--urls` command line argument when running your app, for example `dotnet app.dll --urls http://localhost:80`.
- It's important to optimize your client-side assets to reduce the size and number of files that must be downloaded by a client's web browser when a page loads. You can achieve this by bundling and minifying your assets.
- You can use the BuildBundlerMinifier package to combine multiple JavaScript or CSS files together in a process called bundling. You can reduce the size of the files in a process called minification, in which unnecessary whitespace is removed and variables are renamed while preserving the function of the file.
- You can install a Visual Studio extension to control bundling and minification, or you can install the BuildBundlerMinifier package to automatically perform bundling and minification on each build of the project. Using the extension allows you to minify on an ad-hoc basis, but using the NuGet package allows you to automate the process.
- The settings for bundling and minification are stored in the bundleconfig.json file, where you can define the different output bundle files and choose which files to include in the bundle. You can explicitly specify files, or you can use globbing patterns to include multiple files using wildcard characters. Globbing is typically easier and less error prone, but you will need to specify files explicitly if they must be bundled in a specific order.
- Use the Environment Tag Helper to conditionally render your bundles in production only. This lets you optimize for performance in production and readability in development.

- For common files shared by multiple apps, such as jQuery or Bootstrap, you can serve files from a CDN. These are websites that host the common files, so your app doesn’t need to serve them itself.
- Use Link and Script Tag Helpers to check that the file has loaded correctly from the CDN. These can test that a file has been downloaded by a client and ensures that your server is used as a fallback should the CDN fail.

Part 3

Extending your applications

We covered a huge amount of content in parts 1 and 2: we looked at all the main functional components you'll use to build both traditional server-rendered Razor Pages apps, as well as Web APIs. In part 3, we look at six different topics that build on what you've learned so far: logging, security, custom components, interacting with third-party HTTP APIs, background services, and testing.

Adding logging to your application is one of those activities that's often left until after you discover a problem in production. Adding sensible logging from the get-go will help you quickly diagnose and fix errors as they arise. Chapter 17 introduces the logging framework built in to ASP.NET Core. You'll see how you can use it to write log messages to a wide variety of locations, whether it's the console, a file, or a third-party remote-logging service.

Correctly securing your app is an important part of web development these days. Even if you don't feel you have any sensitive data in your application, you have to make sure you protect your users from attacks by adhering to security best practices. In chapter 18, I describe some common vulnerabilities, how attackers can exploit them, and what you can do to protect your applications.

In part 1, you learned about the middleware pipeline, and how it is fundamental to all ASP.NET Core applications. In chapter 19 you'll learn how to create your own custom middleware, as well as simple endpoints, for when you don't need the full power of Razor Pages or a Web API controller. You'll also learn how to handle some complex chicken-and-egg configuration issues that often arise in real-life applications. Finally, you'll learn how to replace the built-in dependency injection container with a third-party alternative.

In chapter 20 you'll learn how to create custom components for working with Razor Pages and API controllers. You'll learn how to create custom Tag Helpers and validation attributes, and I introduce a new component—view components—for encapsulating logic with Razor view rendering. You'll also learn how to replace the attribute-based validation framework used by default in ASP.NET Core with an alternative.

Most apps you build aren’t designed to stand on their own. It’s very common for your app to need to interact with third-party APIs, whether that’s APIs for sending emails, fetching exchange rates, or taking payments. In chapter 21 you’ll learn how to interact with third-party APIs using the `IHttpClientFactory` abstraction to simplify configuration, to add transient fault handling, and to avoid common pitfalls.

This book deals primarily with serving HTTP traffic, both server-rendered web pages using Razor Pages, and Web APIs commonly used by mobile and single-page applications. However, many apps require long-running background tasks that execute jobs on a schedule or process items from a queue. In chapter 22 I show how you can create these long background tasks in your ASP.NET Core applications. I also show how to create standalone services that *only* have background tasks, without any HTTP handling, and how to install them as a Windows Service or as a Linux systemd daemon.

Chapter 23, the final chapter, covers testing your application. The exact role of testing in application development can sometimes lead to philosophical arguments, but in chapter 23, I stick to the practicalities of testing your app using the xUnit test framework. You’ll see how to create unit tests for your apps, how to test code that’s dependent on EF Core using an in-memory database provider, and how to write integration tests that can test multiple aspects of your application at once.

17

Monitoring and troubleshooting errors with logging

This chapter covers

- **Understanding the components of a log message**
- **Writing logs to multiple output locations**
- **Controlling log verbosity in different environments using filtering**
- **Using structured logging to make logs searchable**

Logging is one of those topics that seems unnecessary, right up until the point when you desperately need it! There's nothing more frustrating than finding an issue that you can only reproduce in production, and then discovering there are no logs to help you debug it.

Logging is the process of recording events or activities in an app and often involves writing a record to a console, a file, the Windows Event Log, or some other system. You can record anything in a log message, though there are generally two different types of message:

- *Informational messages*—A standard event occurred: a user logged in, a product was placed in a shopping cart, or a new post was created on a blogging app.
- *Warnings and errors*—An error or unexpected condition occurred: a user had a negative total in the shopping cart, or an exception occurred.

Historically, a common problem with logging in larger applications was that each library and framework would generate logs in a slightly different format, if at all. When an error occurred in your app and you were trying to diagnose it, this inconsistency made it harder to connect the dots in your app to get the full picture and understand the problem.

Luckily, ASP.NET Core includes a new, generic logging interface that you can plug into. It's used throughout the ASP.NET Core framework code itself, as well as by third-party libraries, and you can easily use it to create logs in your own code. With the ASP.NET Core logging framework, you can control the verbosity of logs coming from each part of your code, including the framework and libraries, and you can write the log output to any destination that plugs into the framework.

In this chapter, I cover the ASP.NET Core logging framework in detail and explain how you can use it to record events and diagnose errors in your own apps. In section 17.1, I describe the architecture of the logging framework. You'll learn how DI makes it easy for both libraries and apps to create log messages, as well as to write those logs to multiple destinations.

In section 17.2, you'll learn how to write your own log messages in your apps with the `ILogger` interface. We'll break down the anatomy of a typical log record and look at its properties, such as the log level, category, and message.

Writing logs is only useful if you can read them, so in section 17.3, you'll learn how to add *logging providers* to your application. Logging providers control where your app writes your log messages. This could be to the console, to a file, or even an external service. I'll show you how to add a logging provider that writes logs to a file, and how to configure a popular third-party logging provider called Serilog in your app.

Logging is an important part of any application, but determining *how much* logging is enough can be a tricky question. On the one hand, you want to provide sufficient information to be able to diagnose any problems. On the other, you don't want to fill your logs with data that makes it hard to find the important information when you need it. Even worse, what is sufficient in development might be far too much once you're running in production.

In section 17.4, I explain how you can filter log messages from various sections of your app, such as the ASP.NET Core infrastructure libraries, so that your logging providers only write the important messages. This lets you keep that balance between extensive logging in development and only writing important logs in production.

In the final section of this chapter, I touch on some of the benefits of *structured logging*, an approach to logging that you can use with some providers for the ASP.NET Core logging framework. Structured logging involves attaching data to log messages as key-value pairs to make logs more easily searched and queried. You might attach a unique customer ID to every log message generated by your app, for example. Finding all the log messages associated with a user is much simpler with this approach, compared to recording the customer ID in an inconsistent manner as part of the log message.

We'll start this chapter by digging into what logging involves, and why your future self will thank you for using logging effectively in your application. Then we'll look at the pieces of the ASP.NET Core logging framework you'll use directly in your apps, and how they fit together.

17.1 Using logging effectively in a production app

In this section I discuss the concept of logging at a high level. You'll see why writing custom log messages can help you diagnose problems in production applications and get a taste for the logging built into the ASP.NET Core framework libraries. Finally, you'll learn about the logging abstractions built into .NET Core that you can use in your own applications.

Imagine you've just deployed a new app to production, when a customer calls saying that they're getting an error message using your app.

How would you identify what caused the problem? You could ask the customer what steps they were taking, and potentially try to recreate the error yourself, but if that doesn't work then you're left trawling through the code, trying to spot errors with nothing else to go on.

Logging can provide the extra context you need to quickly diagnose a problem. Arguably, the most important logs capture the details about the error itself, but the events that led to the error can be just as useful in diagnosing the cause of an error.

There are many reasons for adding logging to an application, but typically, the reasons fall into one of two categories:

- Logging for auditing or analytics reasons, to trace when events have occurred
- Logging errors, or to provide a breadcrumb trail of events when an error does occur

The first of these reasons is simple. You may be required to keep a record of every time a user logs in, for example, or you may want to keep track of how many times a particular API method is called. Logging is an easy way to record the behavior of your app, by writing a message to the log every time an interesting event occurs.

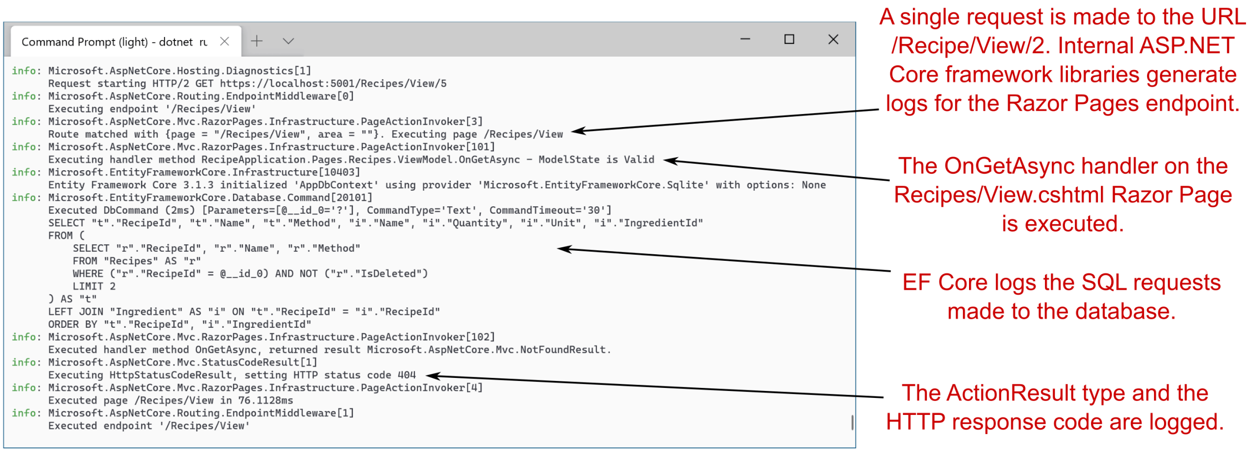
I find the second reason for logging to be the most common. When an app is working perfectly, logs often go completely untouched. It's when there's an issue and a customer comes calling that logs become invaluable. A good set of logs can help you understand the conditions in your app that caused an error, including the context of the error itself, but also the context in previous requests.

TIP **Even with extensive logging in place, you may not realize you have an issue in your app unless you look through your logs regularly! For any medium to large app this becomes impractical, so monitoring services such as https://raygun.io or https://sentry.io can be invaluable for notifying you of issues quickly.**

If this sounds like a lot of work, then you're in luck. ASP.NET Core does a ton of the "breadcrumb" logging for you so that you can focus on creating high-quality log messages that provide the most value when diagnosing problems.

17.1.1 Highlighting problems using custom log messages

ASP.NET Core uses logging throughout its libraries. Depending on how you configure your app, you'll have access to the details of each request and EF Core query, even without adding additional logging messages to your own code. In figure 17.1 you can see the log messages created when you view a single recipe in the recipe application.



```
info: Microsoft.AspNetCore.Hosting.Diagnostics[1]
      Request starting HTTP/2 GET https://localhost:5001/Recipes/View/5
info: Microsoft.AspNetCore.Routing.EndpointMiddleware[0]
      Executing endpoint '/Recipes/View'
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[3]
      Route matched with {page = "/Recipes/View", area = ""}. Executing page /Recipes/View
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[101]
      Executing handler method RecipeApplication.Pages.Recipes.ViewModel.OnGetAsync - ModelState is Valid
info: Microsoft.EntityFrameworkCore.Infrastructure[10403]
      Entity Framework Core 3.1.3 initialized 'AppDbContext' using provider 'Microsoft.EntityFrameworkCore.Sqlite' with options: None
info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand (2ms) [Parameters=[@__id_0='?'], CommandType='Text', CommandTimeout='30']
      SELECT "t"."RecipeId", "t"."Name", "t"."Method", "i"."Name", "i"."Quantity", "i"."Unit", "i"."IngredientId"
      FROM (
          SELECT "r"."RecipeId", "r"."Name", "r"."Method"
          FROM "Recipes" AS "r"
          WHERE ("r"."RecipeId" = @__id_0) AND NOT ("r"."IsDeleted")
          LIMIT 2
      ) AS "t"
      LEFT JOIN "Ingredient" AS "i" ON "t"."RecipeId" = "i"."RecipeId"
      ORDER BY "t"."RecipeId", "i"."IngredientId"
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[102]
      Executed handler method OnGetAsync, returned result Microsoft.AspNetCore.Mvc.NotFoundResult.
info: Microsoft.AspNetCore.Mvc.StatusCodeResult[1]
      Executing HttpStatusCodeResult, setting HTTP status code 404
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[4]
      Executed page /Recipes/View in 76.1128ms
info: Microsoft.AspNetCore.Routing.EndpointMiddleware[1]
      Executed endpoint '/Recipes/View'
```

A single request is made to the URL /Recipe/View/2. Internal ASP.NET Core framework libraries generate logs for the Razor Pages endpoint.

The OnGetAsync handler on the Recipes/View.cshtml Razor Page is executed.

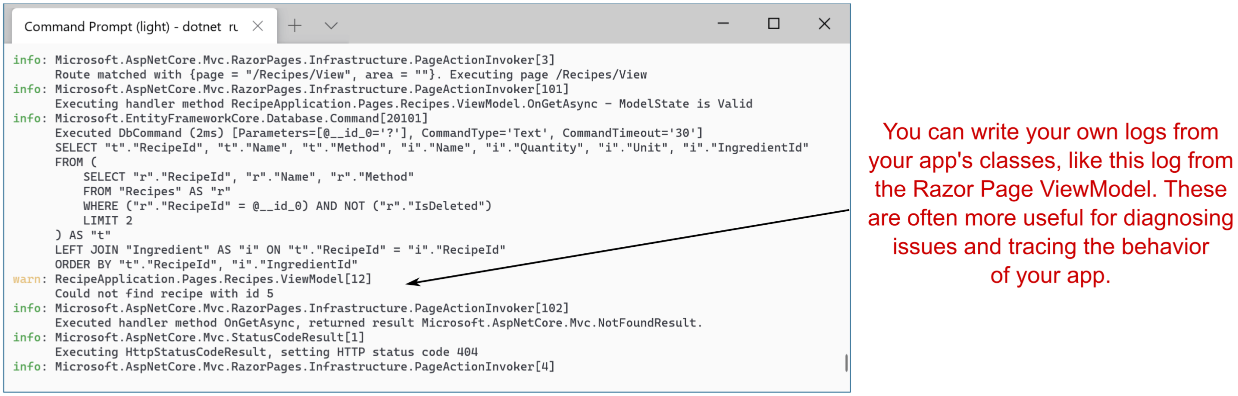
EF Core logs the SQL requests made to the database.

The ActionResult type and the HTTP response code are logged.

Figure 17.1 The ASP.NET Core Framework libraries use logging throughout. A single request generates multiple log messages that describe the flow of the request through your application.

This gives you a lot of useful information. You can see which URL was requested, the Razor Page and page handler that was invoked, the EF Core database command, the action result invoked, and the response. This information can be invaluable when trying to isolate a problem, whether a bug in a production app or a feature in development when you're working locally.

This infrastructure logging can be useful, but log messages that you create yourself can have even greater value. For example, you may be able to spot the cause of the error from the log messages in figure 17.1—we're attempting to view a recipe with an unknown `RecipeId` of `5`, but it's far from obvious. If you explicitly add a log message to your app when this happens, as in figure 17.2, then the problem is much more apparent.



```
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[3]
      Route matched with {page = "/Recipes/View", area = ""}. Executing page /Recipes/View
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[101]
      Executing handler method RecipeApplication.Pages.Recipes.ViewModel.OnGetAsync - ModelState is Valid
info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand (2ms) [Parameters=[@__id_0='?'], CommandType='Text', CommandTimeout='30']
      SELECT "t"."RecipeId", "t"."Name", "t"."Method", "i"."Name", "i"."Quantity", "i"."Unit", "i"."IngredientId"
      FROM (
          SELECT "r"."RecipeId", "r"."Name", "r"."Method"
          FROM "Recipes" AS "r"
          WHERE ("r"."RecipeId" = @__id_0) AND NOT ("r"."IsDeleted")
          LIMIT 2
      ) AS "t"
      LEFT JOIN "Ingredient" AS "i" ON "t"."RecipeId" = "i"."RecipeId"
      ORDER BY "t"."RecipeId", "i"."IngredientId"
warn: RecipeApplication.Pages.Recipes.ViewModel[12]
      Could not find recipe with id 5
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[102]
      Executed handler method OnGetAsync, returned result Microsoft.AspNetCore.Mvc.NotFoundResult.
info: Microsoft.AspNetCore.Mvc.StatusCodeResult[1]
      Executing HttpStatusCodeResult, setting HTTP status code 404
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[4]
```

You can write your own logs from your app's classes, like this log from the Razor Page ViewModel. These are often more useful for diagnosing issues and tracing the behavior of your app.

Figure 17.2 You can write your own logs. These are often more useful for identifying issues and interesting events in your apps.

This custom log message easily stands out, and clearly states both the problem (the recipe with the requested ID doesn't exist) and the parameters/variables that led to the issue (the ID value of `5`). Adding similar log messages to your own applications will make it easier for you to diagnose problems, track important events, and generally give you an idea of what your app is doing.

Hopefully, you're now motivated to add logging to your apps, so we'll dig into the details of what that involves. In section 17.1.2, you'll see how to create a log message, and how to define where the log messages are written. We'll look in detail at these two aspects in section 17.2 and 17.3; for now, we'll only look at where they fit in terms of the ASP.NET Core logging framework as a whole.

17.1.2 The ASP.NET Core logging abstractions

The ASP.NET Core logging framework consists of a number of logging abstractions (interfaces, implementations, and helper classes), the most important of which are shown in figure 17.3:

- `ILogger`—This is the interface you'll interact with in your code. It has a `Log()` method, which is used to write a log message.
- `ILoggerProvider`—This is used to create a custom instance of an `ILogger`, depending on the provider. A "console" `ILoggerProvider` would create an `ILogger` that writes to the console, whereas a "file" `ILoggerProvider` would create an `ILogger` that writes to a file.
- `ILoggerFactory`—The glue between the `ILoggerProvider` instances and the `ILogger` you use in your code. You register `ILoggerProvider` instances with an `ILoggerFactory` and call `CreateLogger()` on the `ILoggerFactory` when you need an `ILogger`. The factory creates an `ILogger` that wraps each of the providers, so when you call the `Log()` method, the log is written to every provider.

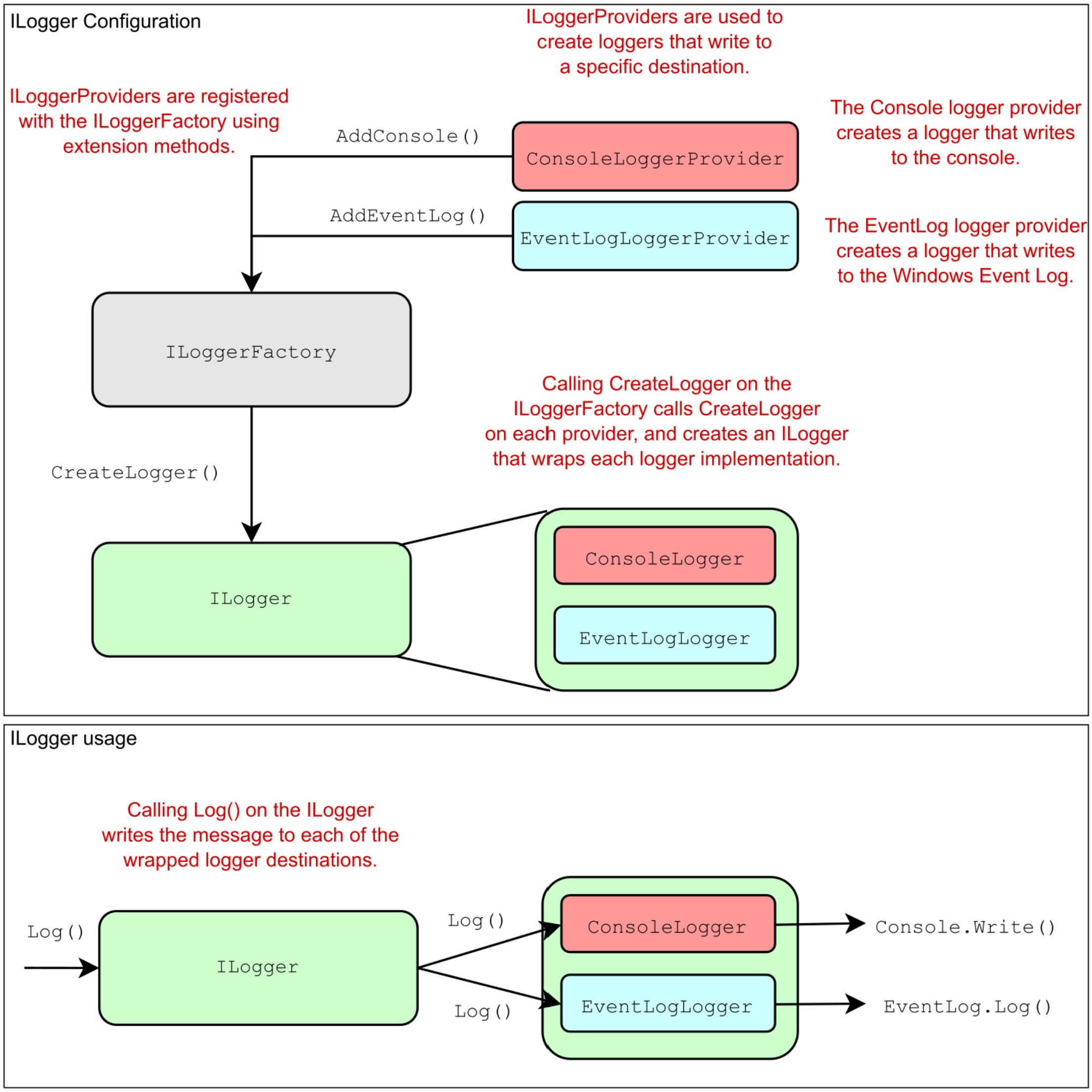

ILogger Configuration
ILoggerProviders are used to create loggers that write to a specific destination.
ILoggerProviders are registered with the ILoggerFactory using extension methods.
AddConsole()
ConsoleLoggerProvider
The Console logger provider creates a logger that writes to the console.
AddEventLog()
EventLogLoggerProvider
The EventLog logger provider creates a logger that writes to the Windows Event Log.
ILoggerFactory
Calling CreateLogger on the ILoggerFactory calls CreateLogger on each provider, and creates an ILogger that wraps each logger implementation.
CreateLogger()
ILogger
ConsoleLogger
EventLogLogger
ILogger usage
Calling Log() on the ILogger writes the message to each of the wrapped logger destinations.
Log()
ILogger
Log()
ConsoleLogger
Console.Write()
Log()
EventLogLogger
EventLog.Log()

Figure 17.3 The components of the ASP.NET Core logging framework. You register logging providers with an `ILoggerFactory`, which are used to create implementations of `ILogger`. You write logs to the `ILogger`, which uses the `ILogger` implementations to output logs to the console or a file. This design allows you to send logs to multiple locations, without having to configure those locations when you create a log message.

This design in figure 17.3 makes it easy to add or change where your application writes the log messages, without having to change your application code. This listing shows all the code required to add an `ILoggerProvider` that writes logs to the console.

Listing 17.1 Adding a console log provider to `IHost` in Program.cs

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();
    }
    public static IHostBuilder CreateHostBuilder(string[] args) =>
        new HostBuilder()
            .ConfigureLogging(builder =>builder.AddConsole())     #A
            .ConfigureWebHostDefaults(webBuilder =>
            {
                webBuilder.UseStartup<Startup>();
            });
}
```

#A Add new providers with the ConfigureLogging extension method on HostBuilder.

> **NOTE** The console logger is added by default in the `CreateDefaultBuilder` method, as you'll see in section 17.3.

Other than this configuration on `IHostBuilder`, you don't interact with `ILoggerProvider` instances directly. Instead, you write logs using an instance of `ILogger`, as you'll see in the next section.

17.2 Adding log messages to your application

In this section, we'll look in detail at how to create log messages in your own application. You'll learn how to create an instance of `ILogger`, and how to use it to add logging to an existing application. Finally, we'll look at the properties that make up a logging record, what they mean, and what you can use them for.

Logging, like almost everything in ASP.NET Core, is available through DI. To add logging to your own services, you only need to inject an instance of `ILogger<T>`, where `T` is the type of your service.

> **NOTE** When you inject `ILogger<T>`, the DI container indirectly calls `ILoggerFactory.CreateLogger<T>()` to create the wrapped `ILogger` of figure 17.3. In section 17.2.2, you'll see how to work directly with `ILoggerFactory` if you prefer. The `ILogger<T>` interface also implements the non-generic `ILogger` interface but also adds additional convenience methods.

You can use the injected `ILogger` instance to create log messages, which writes the log to each configured `ILoggerProvider`. The following listing shows how to inject an `ILogger<>` instance into the `PageModel` of the Index.cshtml Razor Page for the recipe application from previous chapters and write a log message indicating how many recipes were found.

Listing 17.2 Injecting `ILogger` into a class and writing a log message

```
public class IndexModel : PageModel
```

```
{
    private readonly RecipeService _service;
    private readonly ILogger<IndexModel> _log;    #A

    public ICollection<RecipeSummaryViewModel> Recipes { get; set; }

    public IndexModel(
        RecipeService service,
        ILogger<IndexModel> log)                  #A
    {
        _service = service;
        _log = log;                               #A
    }

    public void OnGet()
    {
        Recipes = _service.GetRecipes();
        _log.LogInformation(                                    #B
            "Loaded {RecipeCount} recipes", Recipes.Count);     #B
    }
}
```

#A Injects the generic ILogger<T> using DI, which implements ILogger
#B This writes an Information-level log. The RecipeCount variable is substituted in the message.

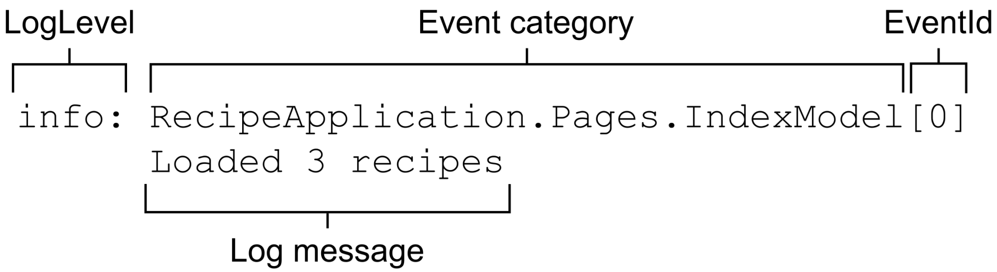
In this example, you're using one of the many extension methods on `ILogger` to create the log message, `LogInformation()`. There are many extension methods on `ILogger` that let you easily specify a `LogLevel` for the message.

DEFINITION The *log level* of a log is how important it is and is defined by the `LogLevel` enum. Every log message has a log level.

You can also see that the message you pass to the `LogInformation` method has a placeholder indicated by braces, `{RecipeCount}`, and you pass an additional parameter, `Recipes.Count`, to the logger. The logger will replace the placeholder with the parameter at runtime. Placeholders are matched with parameters by position, so if you include two placeholders for example, the second placeholder is matched with the second parameter.

TIP You could have used normal string interpolation to create the log message, for example, `$"Loaded {Recipes.Count} recipes"`. But I recommend always using placeholders, as they provide additional information for the logger that can be used for structured logging, as you'll see in section 17.5.

When the `OnGet` page handler in the `IndexModel` executes, `ILogger` writes a message to any configured logging providers. The exact format of the log message will vary from provider to provider, but figure 17.4 shows how the console provider would display the log message from listing 17.2.



```
info: RecipeApplication.Pages.IndexModel[0]
      Loaded 3 recipes
```

Figure 17.4 An example log message, as it's written to the default console provider. The Log Level category provides information about how important the message is and where it was generated. The EventId provides a way to identify similar log messages.

The exact presentation of the message will vary depending on where the log is written, but each log record includes up to six common elements:

- *Log level*—The log level of the log is how important it is and is defined by the `LogLevel` enum.
- *Event category*—The category may be any string value, but it’s typically set to the name of the class creating the log. For `ILogger<T>`, the full name of the type `T` is the category.
- *Message*—This is the content of the log message. It can be a static string, or it can contain placeholders for variables, as shown in listing 17.2. Placeholders are indicated by braces, `{}`, and are substituted with the provided parameter values.
- *Parameters*—If the message contains placeholders, then they’re associated with the provided parameters. For the example in listing 17.2, the value of `Recipes.Count` is assigned to the placeholder called `RecipeCount`. Some loggers can extract these values and expose them in your logs, as you’ll see in section 17.5.
- *Exception*—If an exception occurs, you can pass the exception object to the logging function along with the message and other parameters. The logger will log the exception, in addition to the message itself.
- *EventId*—This is an optional integer identifier for the error, which can be used to quickly find all similar logs in a series of log messages. You might use an `EventId` of `1000` when a user attempts to load a non-existent recipe, and an `EventId` of `1001` when a user attempts to access a recipe they don’t have permission to access. If you don’t provide an `EventId`, the value `0` will be used.

Not every log message will have all these elements—you won’t always have an `Exception` or parameters for example. There are various overloads to the logging methods that take these as additional method parameters. Besides these, each message will have, at the very least, a level, category, and message. These are the key features of the log, so we’ll look at each in turn.

17.2.1 Log level: how important is the log message?

Whenever you create a log using ILogger, you must specify the *log level*. This indicates how serious or important the log message is and is an important factor when it comes to filtering which logs get written by a provider, as well as finding the important log messages after the fact.

You might create an Information level log when a user starts to edit a recipe. This is useful for tracing the application’s flow and behavior, but it’s not important, because everything is normal. But if an exception is thrown when the user attempts to save the recipe, you might create a Warning or Error level log.

The log level is typically set by using one of several extension methods on the ILogger interface, as shown in listing 17.3. This example creates an Information level log when the View method executes, and a Warning level error if the requested recipe isn’t found.

Listing 17.3 Specifying the log level using extension methods on ILogger

```
private readonly ILogger _log;                          #A
public async IActionResult OnGet(int id)
{
    _log.LogInformation(                              #B
        "Loading recipe with id {RecipeId}", id);     #B

    Recipe = _service.GetRecipeDetail(id);
    if (Recipe is null)
    {
        _log.LogWarning(                                        #C
            "Could not find recipe with id {RecipeId}", id);    #C
        return NotFound();
    }
    return Page();
}
```

#A An ILogger instance is injected into the controller using constructor injection.
#B Writes an Information level log message
#C Writes a warning level log message

The LogInformation and LogWarning extension methods create log messages with a log level of Information and Warning, respectively. There are six log levels to choose from, ordered here from most to least serious:

- Critical—For disastrous failures that may leave the app unable to function correctly, such as out of memory exceptions, if the hard drive is out of disk space, or the server is on fire.
- Error—For errors and exceptions that you can’t handle gracefully, for example, exceptions thrown when saving an edited entity in EF Core. The operation failed, but the app can continue to function for other requests and users.
- Warning—For when an unexpected or error condition arises that you can work around. You might log a Warning for handled exceptions, or when an entity isn't found, as in listing 17.3.

- `Information`—For tracking normal application flow, for example, logging when a user logs in, or when they view a specific page in your app. Typically, these log messages provide context when you need to understand the steps leading up to an error message.
- `Debug`—For tracking detailed information that's particularly useful during development. Generally, this only has short-term usefulness.
- `Trace`—For tracking very detailed information, which may contain sensitive information like passwords or keys. It's rarely used, and not used at all by the framework libraries.

Think of these log levels in terms of a pyramid, as shown in figure 17.5. As you progress down the log levels, the importance of the messages goes down, but the frequency goes up. Generally, you'll find many `Debug` level log messages in your application, but (hopefully) few `Critical` or `Error` level messages.

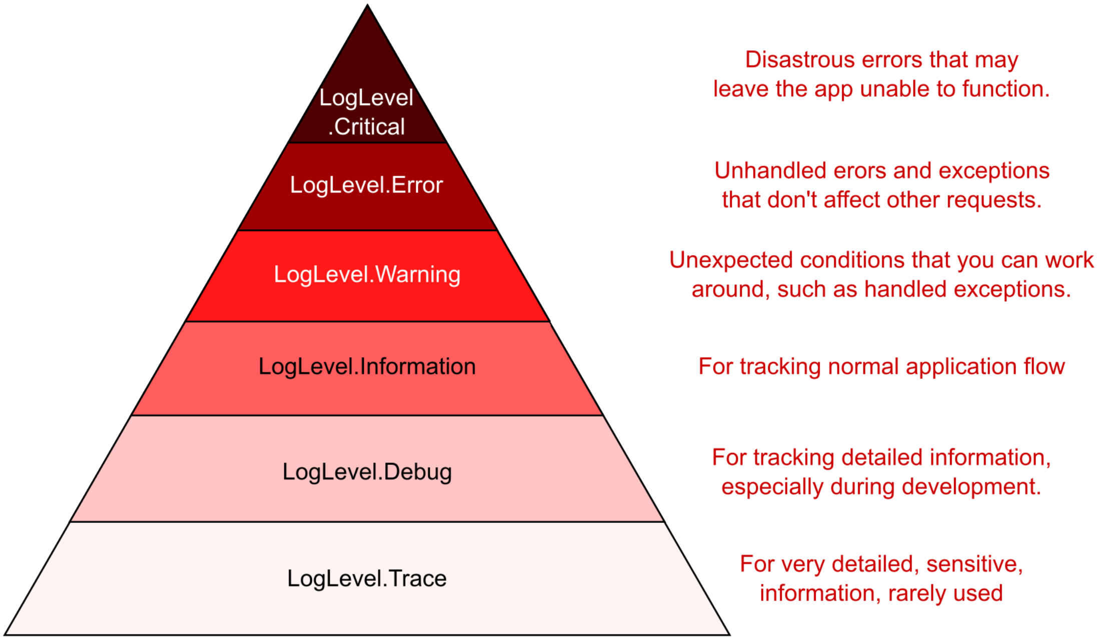

LogLevel
.Critical
Disastrous errors that may
leave the app unable to function.
LogLevel.Error
Unhandled erors and exceptions
that don't affect other requests.
LogLevel.Warning
Unexpected conditions that you can work
around, such as handled exceptions.
LogLevel.Information
For tracking normal application flow
LogLevel.Debug
For tracking detailed information,
especially during development.
LogLevel.Trace
For very detailed, sensitive,
information, rarely used

Figure 17.5 The pyramid of log levels. Logs with a level near the base of the pyramid are used more frequently but are less important. Logs with a level near the top should be rare but are important.

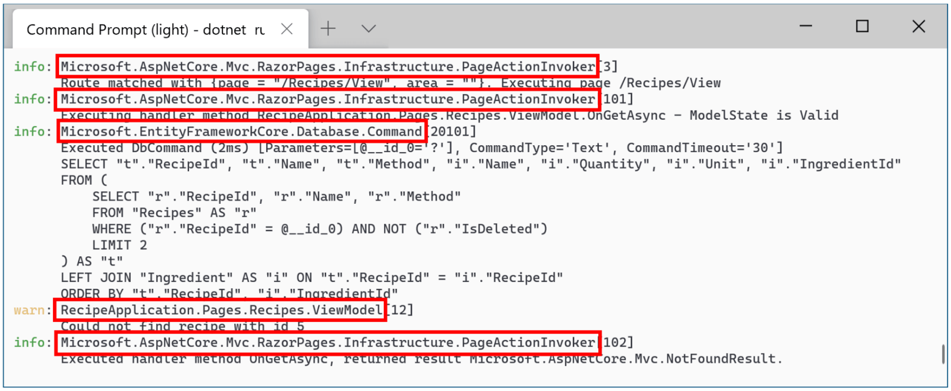
This pyramid shape will become more meaningful when we look at filtering in section 17.4. When an app is in production, you typically don't want to record all the `Debug` level messages generated by your application. The sheer volume of messages would be overwhelming to sort through and could end up filling your disk with messages that say, "Everything's OK!"

Additionally, `Trace` messages shouldn't be enabled in production, as they may leak sensitive data. By filtering out the lower log levels, you can ensure that you generate a sane number of logs in production, while still having access to all the log levels in development.

In general, logs of a higher level are more important than lower-level logs, so a `Warning` log is more important than an `Information` log, but there's another aspect to consider. Where the log came from, or who created the log, is a key piece of information that's recorded with each log message and is called the *category*.

17.2.2 Log category: which component created the log

As well as a log level, every log message also has a *category*. You set the log level independently for every log message, but the category is set when you create the `ILogger` instance. Like log levels, the category is particularly useful for filtering, as you'll see in section 17.4, but it's also written to every log message, as shown in figure 17.6



```
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[3]
      Route matched with {page = "/Recipes/View", area = ""}. Executing page /Recipes/View
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[101]
      Executing handler method RecipeApplication.Pages.Recipes.ViewModel.OnGetAsync - ModelState is Valid
info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand (2ms) [Parameters=[@__id_0='?'], CommandType='Text', CommandTimeout='30']
      SELECT "t"."RecipeId", "t"."Name", "t"."Method", "i"."Name", "i"."Quantity", "i"."Unit", "i"."IngredientId"
      FROM (
          SELECT "r"."RecipeId", "r"."Name", "r"."Method"
          FROM "Recipes" AS "r"
          WHERE ("r"."RecipeId" = @__id_0) AND NOT ("r"."IsDeleted")
          LIMIT 2
      ) AS "t"
      LEFT JOIN "Ingredient" AS "i" ON "t"."RecipeId" = "i"."RecipeId"
      ORDER BY "t"."RecipeId", "i"."IngredientId"
warn: RecipeApplication.Pages.Recipes.ViewModel[12]
      Could not find recipe with id 5
info: Microsoft.AspNetCore.Mvc.RazorPages.Infrastructure.PageActionInvoker[102]
      Executed handler method OnGetAsync, returned result Microsoft.AspNetCore.Mvc.NotFoundResult.
```

Every log message has an associated category

The category is typically set to the name of the class creating the log message

Figure 17.6 Every log message has an associated category, which is typically the class name of the component creating the log. The default console logging provider outputs the log category for every log.

The category is a `string`, so you can set it to anything, but the convention is to set it to the fully qualified name of the type that's using `ILogger`. In section 17.2, I achieved this by injecting `ILogger<T>` into `RecipeController`; the generic parameter `T` is used to set it to the category of the `ILogger`.

Alternatively, you can inject `ILoggerFactory` into your methods and pass an explicit category when creating an `ILogger` instance. This lets you change the category to an arbitrary string.

Listing 17.4 Injecting `ILoggerFactory` to use a custom category

```
public class RecipeService
{
    private readonly ILogger _log;
    public RecipeService(ILoggerFactory factory)                #A
    {
        _log = factory.CreateLogger("RecipeApp.RecipeService");  #B
    }
}
```

#A Injects an ILoggerFactory instead of an ILogger directly
#B Passes a category as a string when calling CreateLogger

There is also an overload of `CreateLogger()` with a generic parameter that uses the provided class to set the category. If the `RecipeService` in listing 17.4 was in the `RecipeApp` namespace, then the `CreateLogger` call could be written equivalently as

```
_log = factory.CreateLogger<RecipeService>();.
```

Similarly, the final `ILogger` instance created by this call would be the same as if you'd directly injected `ILogger<RecipeService>` instead of `ILoggerFactory`.

> **TIP** **Unless you're using heavily customized categories for some reason, favor injecting** `ILogger<T>` **into your methods over** `ILoggerFactory`.

The final compulsory part of every log entry is fairly obvious: the *log message*. At the simplest level, this can be any string, but it's worth thinking carefully about what information would be useful to record—anything that will help you diagnose issues later on!

17.2.3 Formatting messages and capturing parameter values

Whenever you create a log entry, you must provide a *message*. This can be any string you like, but as you saw in listing 17.2, you can also include placeholders indicated by braces, `{}`, in the message string:

```
_log.LogInformation("Loaded {RecipeCount} recipes", Recipes.Count);
```

Including a placeholder and a parameter value in your log message effectively creates a key-value pair, which some logging providers can store as additional information associated with the log. The previous log message would assign the value of `Recipes.Count` to a key, `RecipeCount`, and the log message itself is generated by replacing the placeholder with the parameter value, to give (if `Recipes.Count=3`):

```
"Loaded 3 recipes"
```

You can include multiple placeholders in a log message, and they'll be associated with the additional parameters passed to the log method. The order of the placeholders in the format string must match the order of the parameters you provide.

> **WARNING** **You must pass at least as many parameters to the log method as there are placeholders in the message. If you don't pass enough parameters, you'll get an exception at runtime.**

For example, the log message

```
_log.LogInformation("User {UserId} loaded recipe {RecipeId}", 123, 456)
```

would create the parameters `UserId=123` and `RecipeId=456`. *Structured logging* providers could store these values, in addition to the formatted log message `"User 123 loaded recipe 456"`. This makes it easier to search the logs for a particular `UserId` or `RecipeId`.

> **DEFINITION** ***Structured or semantic logging*** **attaches additional structure to log messages to make them more easily searchable and filterable. Rather than storing only text, it stores additional contextual information, typically as key-value pairs. JSON is a comment format used for structured log messages, as it has all of these properties.**

Not all logging providers use semantic logging. The default console logging provider doesn't, for example—the message is formatted to replace the placeholders, but there's no way of searching the console by key-value.

But even if you're not using structured logging initially, I recommend writing your log messages as though you are, with explicit placeholders and parameters. That way, if you decide to add a structured logging provider later, then you'll immediately see the benefits. Additionally, I find that thinking about the parameters that you can log in this way prompts you to record more parameter values, instead of only a log message. There's nothing more frustrating than seeing a message like `"Cannot insert record due to duplicate key"` but not having the key value logged!

> **TIP** **Generally speaking, I'm a fan of C# 6's interpolated strings, but don't use them for your log messages when a placeholder and parameter would also make sense. Using placeholders instead of interpolated strings will give you the same output message but will also create key-value pairs that can be searched later.**

We've looked a lot at how you can create log messages in your app, but we haven't focused on where those logs are written. In the next section, we'll look at the built-in ASP.NET Core logging providers, how they're configured, and how you can replace the defaults with a third-party provider.

17.3 Controlling where logs are written using logging providers

In this section you'll learn how to control where your log messages are written by adding additional `ILoggerProvider`s to your application. As an example, you'll see how to add a simple file logger provider that writes your log messages to a file, in addition to the existing console logger provider. In section 17.3.2 you'll learn how to swap out the default logging infrastructure entirely for an alternative implementation using the open source Serilog library.

Up to this point, we've been writing all our log messages to the console. If you've run any ASP.NET Core sample apps locally, you'll have probably already seen the log messages written to the console window.

NOTE If you're using Visual Studio and debugging using the IIS Express option (the default), then you won't see the console window (though the log messages are written to the Debug Output window instead). For that reason, I normally ensure I select the app name from the dropdown in the debug toolbar, instead of IIS Express.

Writing log messages to the console is great when you're debugging, but it's not much use for production. No one's going to be monitoring a console window on a server, and the logs wouldn't be saved anywhere or be searchable. Clearly, you'll need to write your production logs somewhere else when in production.

As you saw in section 17.1, *logging providers* control the destination of your log messages in ASP.NET Core. They take the messages you create using the `ILogger` interface and write them to an output location, which varies depending on the provider.

NOTE This name always gets to me—the log *provider* effectively *consumes* the log messages you create and outputs them to a destination. You can probably see the origin of the name from figure 17.3, but I still find it somewhat counterintuitive!

Microsoft have written several first-party log providers for ASP.NET Core, which are available out-of-the-box in ASP.NET Core. These include

- *Console provider*—Writes messages to the console, as you've already seen.
- *Debug provider*—Writes messages to the debug window when you're debugging an app in Visual Studio or Visual Studio Code, for example.
- *EventLog provider*—Writes messages to the Windows Event Log. Only outputs log messages when running on Windows, as it requires Windows-specific APIs.
- *EventSource provider*—Writes messages using Event Tracing for Windows (ETW) or LTTng tracing on Linux.

There are also many third-party logging provider implementations, such as an Azure App Service provider, an elmah.io provider, and an ElasticSearch provider. On top of that, there are integrations with other pre-existing logging frameworks like NLog and Serilog. It's always worth looking to see whether your favorite .NET logging library or service has a provider for ASP.NET Core, as most do.

You configure the logging providers for your app in Program.cs using `HostBuilder`. The `CreateDefaultBuilder` helper method configures the console and debug providers for your application automatically, but it's likely you'll want to change or add to these.

You have two options when you need to customize logging for your app:

- Use your own `HostBuilder` instance, instead of `Host.CreateDefaultBuilder` and configure it explicitly.
- Add an additional `ConfigureLogging` call after `CreateDefaultBuilder`.

If you only need to customize logging, then the latter approach is simpler. But if you find you also want to customize the other aspects of the `HostBuilder` created by

`CreateDefaultBuilder` (such as your app configuration settings), then it may be worth ditching the `CreateDefaultBuilder` method and creating your own instance instead.

In section 17.3.1, I show how to add a simple third-party logging provider to your application that writes log messages to a file, so that your logs are persisted. In section 17.3.2, I'll show how to go one step further and replace the default `ILoggerFactory` in ASP.NET Core with an alternative implementation using the popular open source Serilog library.

17.3.1 Adding a new logging provider to your application

In this section, we're going to add a logging provider that writes to a rolling file, so our application writes logs to a new file each day. We'll continue to log using the console and debug providers as well, because they will be more useful than the file provider when developing locally.

To add a third-party logging provider in ASP.NET Core, you must

1. Add the logging provider NuGet package to the solution. I'm going to be using a provider called NetEscapades.Extensions.Logging.RollingFile, which is available on NuGet and GitHub. You can add it to your solution using the NuGet Package Manager in Visual Studio, or using the .NET CLI by running

   ```
   dotnet add package NetEscapades.Extensions.Logging.RollingFile
   ```

   from your application's project folder.

   NOTE This package is a simple file logging provider, available at https://github.com/andrewlock/NetEscapades.Extensions.Logging which is based on the Azure App Service logging provider. If you would like more control over your logs, such as the file format, consider using Serilog instead, as described in section 17.3.2.

2. Add the logging provider using the `IHostBuilder.ConfigureLogging()` extension method. You can add the file provider by calling `AddFile()`, as shown in the next listing. This is an extension method, provided by the logging provider package, to simplify adding the provider to your app.

Listing 17.5 Adding a third-party logging provider to `IHostBuilder`

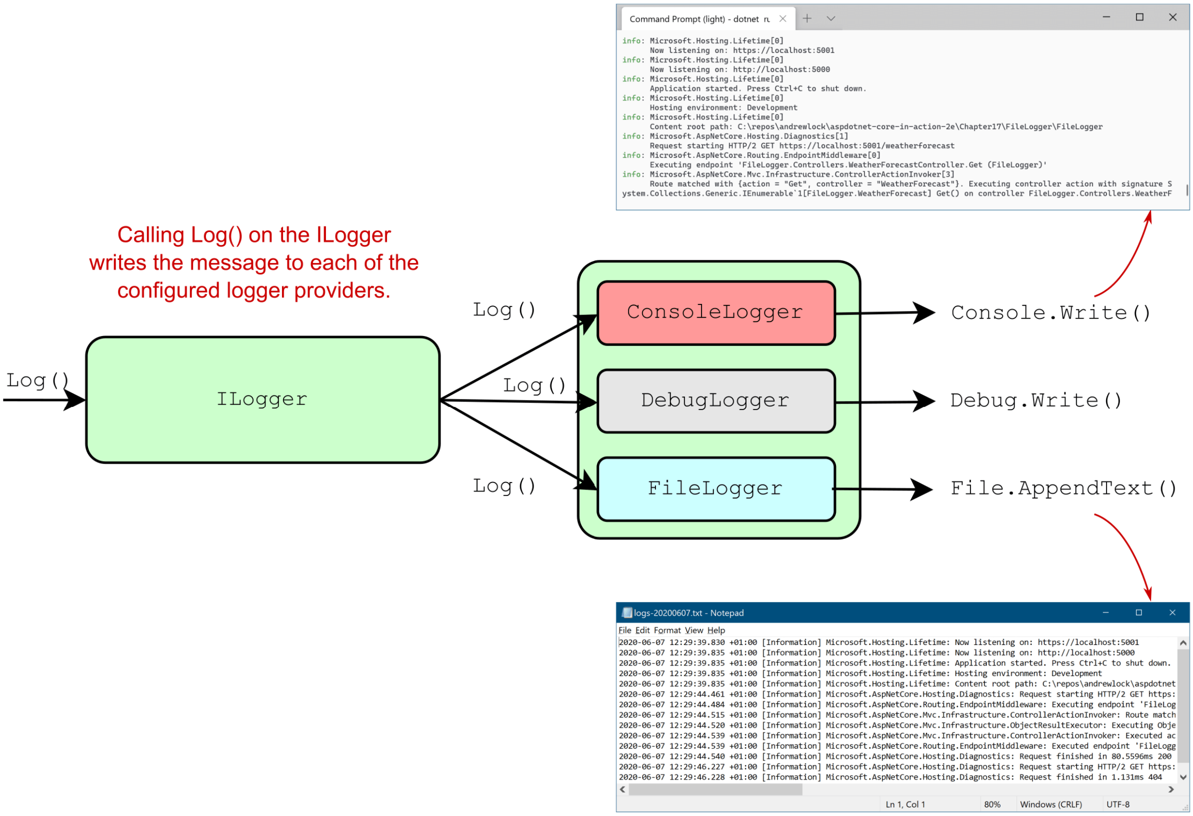
```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>
        Host.CreateDefaultBuilder(args)                        #A
            .ConfigureLogging(builder => builder.AddFile())    #B
            .ConfigureWebHostDefaults(webBuilder =>
```

```
            {
                webBuilder.UseStartup<Startup>();
            });
}
```

#A The CreateDefaultBuilder method configures the console and debug providers as normal.
#B Adds the new file logging provider to the logger factory.

> **NOTE** Adding a new provider doesn't replace existing providers. Listing 17.5 uses the `CreateDefaultBuilder` helper method, so the console and debug logging providers have already been added. To remove them, call `builder.ClearProviders()` at the start of the `ConfigureLogging` method, or use a custom `HostBuilder`.

With the file logging provider configured, you can run the application and generate logs. Every time your application writes a log using an `ILogger` instance, `ILogger` writes the message to all configured providers, as shown in figure 17.7. The console messages are conveniently available, but you also have a persistent record of the logs stored in a file.


Command Prompt (light) - dotnet ru
Calling Log() on the ILogger
writes the message to each of the
configured logger providers.
Log()
ILogger
Log()
Log()
Log()
ConsoleLogger
DebugLogger
FileLogger
Console.Write()
Debug.Write()
File.AppendText()
logs-20200607.txt - Notepad
File Edit Format View Help
Ln 1, Col 1
80%
Windows (CRLF)
UTF-8

```
info: Microsoft.Hosting.Lifetime[0]
      Now listening on: https://localhost:5001
info: Microsoft.Hosting.Lifetime[0]
      Now listening on: http://localhost:5000
info: Microsoft.Hosting.Lifetime[0]
      Application started. Press Ctrl+C to shut down.
info: Microsoft.Hosting.Lifetime[0]
      Hosting environment: Development
info: Microsoft.Hosting.Lifetime[0]
      Content root path: C:\repos\andrewlock\aspdotnet-core-in-action-2e\Chapter17\FileLogger\FileLogger
info: Microsoft.AspNetCore.Hosting.Diagnostics[1]
      Request starting HTTP/2 GET https://localhost:5001/weatherforecast
info: Microsoft.AspNetCore.Routing.EndpointMiddleware[0]
      Executing endpoint 'FileLogger.Controllers.WeatherForecastController.Get (FileLogger)'
info: Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker[3]
      Route matched with {action = "Get", controller = "WeatherForecast"}. Executing controller action with signature S
ystem.Collections.Generic.IEnumerable`1[FileLogger.WeatherForecast] Get() on controller FileLogger.Controllers.WeatherF
```

```
2020-06-07 12:29:39.830 +01:00 [Information] Microsoft.Hosting.Lifetime: Now listening on: https://localhost:5001
2020-06-07 12:29:39.835 +01:00 [Information] Microsoft.Hosting.Lifetime: Now listening on: http://localhost:5000
2020-06-07 12:29:39.835 +01:00 [Information] Microsoft.Hosting.Lifetime: Application started. Press Ctrl+C to shut down.
2020-06-07 12:29:39.835 +01:00 [Information] Microsoft.Hosting.Lifetime: Hosting environment: Development
2020-06-07 12:29:39.835 +01:00 [Information] Microsoft.Hosting.Lifetime: Content root path: C:\repos\andrewlock\aspdotnet
2020-06-07 12:29:44.461 +01:00 [Information] Microsoft.AspNetCore.Hosting.Diagnostics: Request starting HTTP/2 GET https:
2020-06-07 12:29:44.484 +01:00 [Information] Microsoft.AspNetCore.Routing.EndpointMiddleware: Executing endpoint 'FileLog
2020-06-07 12:29:44.515 +01:00 [Information] Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Route match
2020-06-07 12:29:44.520 +01:00 [Information] Microsoft.AspNetCore.Mvc.Infrastructure.ObjectResultExecutor: Executing Obje
2020-06-07 12:29:44.539 +01:00 [Information] Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Executed ac
2020-06-07 12:29:44.539 +01:00 [Information] Microsoft.AspNetCore.Routing.EndpointMiddleware: Executed endpoint 'FileLogg
2020-06-07 12:29:44.540 +01:00 [Information] Microsoft.AspNetCore.Hosting.Diagnostics: Request finished in 80.5596ms 200
2020-06-07 12:29:46.227 +01:00 [Information] Microsoft.AspNetCore.Hosting.Diagnostics: Request starting HTTP/2 GET https:
2020-06-07 12:29:46.228 +01:00 [Information] Microsoft.AspNetCore.Hosting.Diagnostics: Request finished in 1.131ms 404
```

Figure 17.7 Logging a message with `ILogger` writes the log using all of the configured providers. This lets you, for example, log a convenient message to the console while also persisting the logs to a file.

> **TIP** By default, the rolling file provider will write logs to a subdirectory of your application. You can specify additional options such as filenames and file size limits using overloads of `AddFile()`. For production, I recommend using a more established logging provider, such as Serilog.

The key takeaway from this listing is that the provider system makes it easy to integrate existing logging frameworks and providers with the ASP.NET Core logging abstractions. Whichever logging provider you choose to use in your application, the principles are the same: call `ConfigureLogging` on `IHostBuilder` and add a new logging provider using extension methods like `AddConsole()`, or `AddFile()` in this case.

Logging your application messages to a file can be useful in some scenarios, and it’s certainly better than logging to a non-existent console window in production, but it may still not be the best option.

If you discovered a bug in production and you needed to quickly look at the logs to see what happened, for example, you'd need to log on to the remote server, find the log files on disk, and trawl through them to find the problem. If you have multiple web servers, then suddenly you'd have a mammoth job to fetch all the logs before you could even start to tackle the bug. Not fun. Add to that the possibility of file permission or drive space issues and file logging seems less attractive.

Instead, it's often better to send your logs to a centralized location, separate from your application. Exactly where this location may be is up to you; the key is that each instance of your app sends its logs to the same location, separate from the app itself.

If you're running your app on Azure, then you get centralized logging for free because you can collect logs using the Azure App Service provider. Alternatively, you could send your logs to a third-party log aggregator service such as Loggr (http://loggr.net/), elmah.io (https://elmah.io/), or Seq (https://getseq.net/). You can find ASP.NET Core logging providers for each of these services on NuGet, so adding them is the same process as adding the file provider you've seen already.

Another popular option is to use the open source Serilog library to simultaneously write to a variety of different locations. In the next section, I'll show how you can replace the default `ILoggerFactory` implementation with Serilog in your application, opening up a wide range of possible options for where your logs are written.

17.3.2 Replacing the default ILoggerFactory with Serilog

In this section, we'll replace the default `ILoggerFactory` in the Recipe app with an implementation that uses Serilog. Serilog (https://serilog.net) is an open source project that can write logs to many different locations, such as files, the console, an Elasticsearch cluster,[76] or a database. This is similar to the functionality you get with the default `ILoggerFactory`, but due to the maturity of Serilog, you may find you can write to more places.

Serilog predates ASP.NET Core, but thanks to the logging abstractions around `ILoggerFactory` and `ILoggerProvider`, you can easily integrate with Serilog while still using the `ILogger` abstractions in your application code.

Serilog uses a similar design philosophy to the ASP.NET Core logging abstractions—you write logs to a central logging object and the log messages are written to multiple locations, such as the console or a file. Serilog calls each of these locations a *sink*.[77]

When you use Serilog with ASP.NET Core, you'll typically replace the default `ILoggerFactory` with a custom factory that contains a single logging provider, `SerilogLoggerProvider`. This provider can write to multiple locations, as shown in figure

[76] Elasticsearch is a REST-based search engine that's often used for aggregating logs. You can find out more at www.elastic.co/elasticsearch/.

[77] For a full list of available sinks, see https://github.com/serilog/serilog/wiki/Provided-Sinks. There are 93 different sinks at the time of writing!

17.8. This configuration is a bit of a departure from the standard ASP.NET Core logging setup, but it prevents Serilog's features from conflicting with equivalent features of the default `LoggerFactory`, such as filtering (see section 17.4).

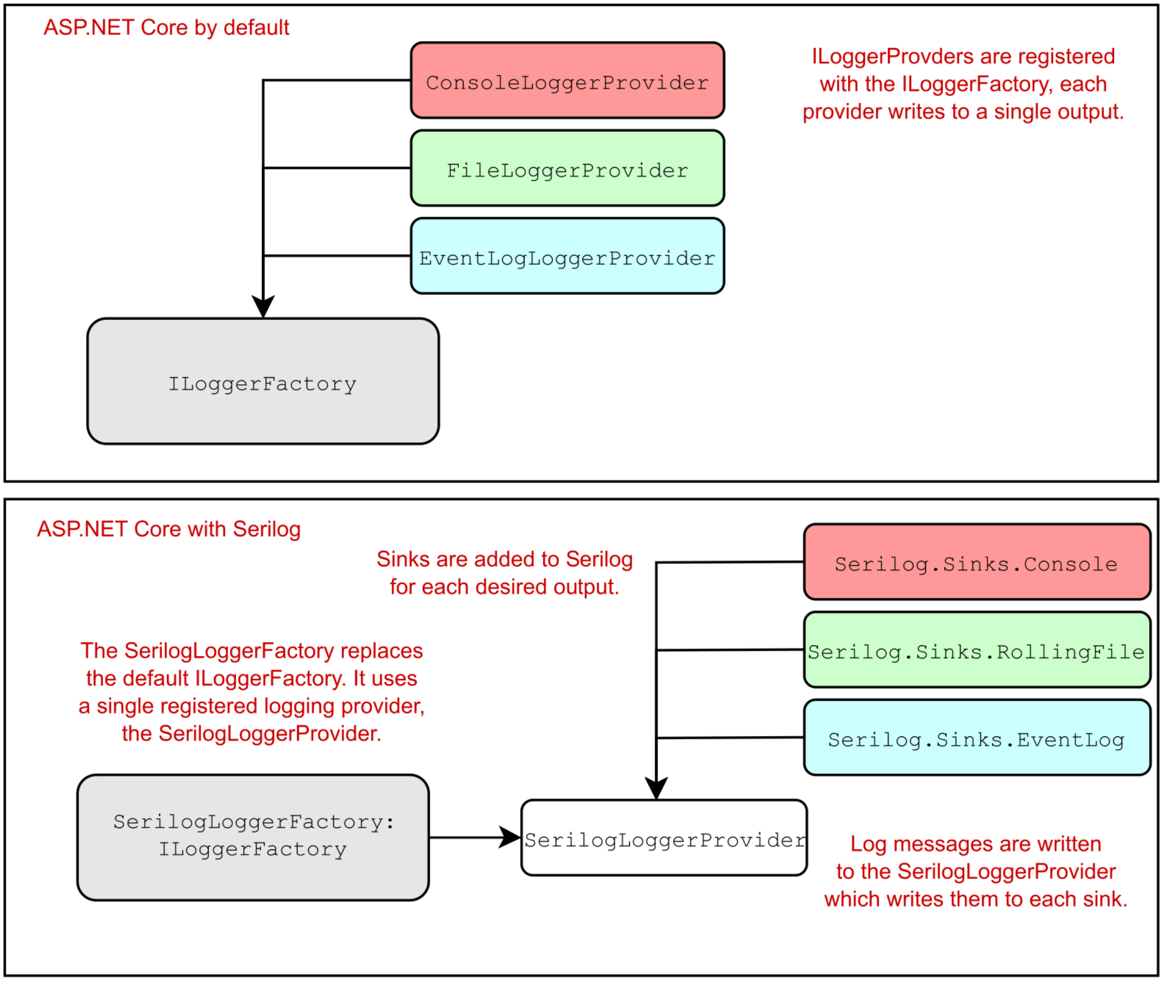

ASP.NET Core by default
ConsoleLoggerProvider
FileLoggerProvider
EventLogLoggerProvider
ILoggerFactory
ILoggerProvders are registered with the ILoggerFactory, each provider writes to a single output.
ASP.NET Core with Serilog
Sinks are added to Serilog for each desired output.
Serilog.Sinks.Console
Serilog.Sinks.RollingFile
Serilog.Sinks.EventLog
The SerilogLoggerFactory replaces the default ILoggerFactory. It uses a single registered logging provider, the SerilogLoggerProvider.
SerilogLoggerFactory: ILoggerFactory
SerilogLoggerProvider
Log messages are written to the SerilogLoggerProvider which writes them to each sink.

Figure 17.8 Configuration differences when using Serilog with ASP.NET Core compared to the default logging configuration. You can achieve the same functionality with both approaches, but you may find Serilog provides additional libraries for adding extra features.

TIP If you're familiar with Serilog, you can use the examples in this section to easily integrate a working Serilog configuration with the ASP.NET Core logging infrastructure.

In this section, we'll add a single sink to write the log messages to the console, but using the Serilog logging provider instead of the built-in console provider. Once you've set this up, adding additional sinks to write to other locations is trivial. Adding the Serilog logging provider to an application involves three steps:

1. Add the required Serilog NuGet packages to the solution.
2. Create a Serilog logger and configure it with the required sinks.
3. Call `UseSerilog()` on `IHostBuilder` to replace the default `ILoggerFactory` implementation with `SerilogLoggerFactory`. This configures the Serilog provider automatically and hooks up the already-configured Serilog logger.

To install Serilog into your ASP.NET Core app, you need to add the base NuGet package and the NuGet packages for any sinks you need. You can do this through the Visual Studio NuGet GUI, using the PMC, or using the .NET CLI. To add the Serilog ASP.NET Core package and a sink for writing to the console, run

```
dotnet add package Serilog.AspNetCore
dotnet add package Serilog.Sinks.Console
```

This adds the necessary NuGet packages to your project file and restores them. Next, create a Serilog logger and configure it to write to the console by adding the console sink, as shown in listing 17.6. This is the most basic of Serilog configurations, but you can add extra sinks and configuration here too.[78] I've also added a `try-catch-finally` block around our call to `CreateHostBuilder`, to ensure that logs are still written if there's an error starting up the web host or there's a fatal exception. Finally, the Serilog logger factory is configured by calling `UseSerilog()` on the `IHostBuilder`.

Listing 17.6 Configuring a Serilog logging provider to use a console sink

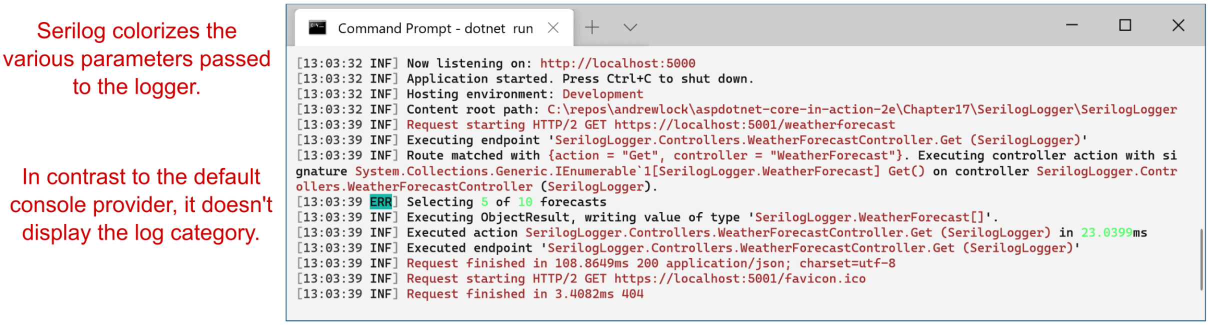
```
public class Program
{
    public static void Main(string[] args)
    {
        Log.Logger = new LoggerConfiguration()     #A
            .WriteTo.Console()                     #B
            .CreateLogger();                       #C
        try
        {
            CreateHostBuilder(args).Build().Run();
        }
        catch (Exception ex)
        {
            Log.Fatal(ex, "Host terminated unexpectedly");
        }
        finally
```

[78] You can customize Serilog until the cows come home, so it's worth consulting the documentation to see what's possible. The wiki is particularly useful: https://github.com/serilog/serilog/wiki/Configuration-Basics.

```
        {
            Log.CloseAndFlush();
        }
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>
        Host.CreateDefaultBuilder(args)
            .UseSerilog()                          #D
            .ConfigureWebHostDefaults(webBuilder =>
            {
                webBuilder.UseStartup<Startup>();
            });
}
```

#A Creates a LoggerConfiguration for configuring the Serilog logger.
#B Serilog will write logs to the console.
#C This creates a Serilog logger instance on the static Log.Logger property.
#D Registers the SerilogLoggerFactory and connects the Log.Logger as the sole logging provider.

With the Serilog logging provider configured, you can run the application and generate some logs. Every time the app generates a log, `ILogger` writes the message to the Serilog provider, which writes it to every sink. In the example, you've only configured the console sink, so the output will look something like figure 17.9. The Serilog console sink colorizes the logs more than the built-in console provider, so I find it's somewhat easier to parse the logs visually.



Serilog colorizes the various parameters passed to the logger.

In contrast to the default console provider, it doesn't display the log category.

```
[13:03:32 INF] Now listening on: http://localhost:5000
[13:03:32 INF] Application started. Press Ctrl+C to shut down.
[13:03:32 INF] Hosting environment: Development
[13:03:32 INF] Content root path: C:\repos\andrewlock\aspdotnet-core-in-action-2e\Chapter17\SerilogLogger\SerilogLogger
[13:03:39 INF] Request starting HTTP/2 GET https://localhost:5001/weatherforecast
[13:03:39 INF] Executing endpoint 'SerilogLogger.Controllers.WeatherForecastController.Get (SerilogLogger)'
[13:03:39 INF] Route matched with {action = "Get", controller = "WeatherForecast"}. Executing controller action with si
gnature System.Collections.Generic.IEnumerable`1[SerilogLogger.WeatherForecast] Get() on controller SerilogLogger.Contr
ollers.WeatherForecastController (SerilogLogger).
[13:03:39 ERR] Selecting 5 of 10 forecasts
[13:03:39 INF] Executing ObjectResult, writing value of type 'SerilogLogger.WeatherForecast[]'.
[13:03:39 INF] Executed action SerilogLogger.Controllers.WeatherForecastController.Get (SerilogLogger) in 23.0399ms
[13:03:39 INF] Executed endpoint 'SerilogLogger.Controllers.WeatherForecastController.Get (SerilogLogger)'
[13:03:39 INF] Request finished in 108.8649ms 200 application/json; charset=utf-8
[13:03:39 INF] Request starting HTTP/2 GET https://localhost:5001/favicon.ico
[13:03:39 INF] Request finished in 3.4082ms 404
```

Figure 17.9 Example output using the Serilog provider and a console sink. The output has more colorization than the built-in console provider, though by default it doesn't display the log category for each log.[79]

> **TIP** Serilog has many great features in addition to this. One of my favorites is the ability to add *enrichers*. These automatically add additional information to all your log messages, such as the process ID or environment variables, which can be useful when diagnosing problems. For an in-depth look at the

[79] **If you wish to display the log category in the console sink, you can customize the** `outputTemplate` **and add** `{SourceContext}`**. For details, see** **https://github.com/serilog/serilog-sinks-console#output-templates**.

recommended way to configure Serilog for ASP.NET Core apps, see this post by Nicholas Blumhardt, the creator of Serilog: https://nblumhardt.com/2019/10/serilog-in-aspnetcore-3/.

Serilog lets you easily plug in additional sinks to your application, in much the same way as you do with the default ASP.NET Core abstractions. Whether you choose to use Serilog or stick to other providers is up to you; the feature sets are quite similar, though Serilog is more mature. Whichever you choose, once you start running your apps in production, you'll quickly discover a different issue: the sheer number of log messages your app generates!

17.4 Changing log verbosity with filtering

In this section you'll see how to reduce the number of log messages written to the logger providers. You'll learn how to apply a base level filter, filter out messages from specific namespaces, and use logging provider-specific filters.

If you've been playing around with the logging samples, then you'll probably have noticed that you get a lot of log messages, even for a single request like the one in figure 17.2: messages from the Kestrel server, messages from EF Core, not to mention your own custom messages. When you're debugging locally, having access to all that detailed information is extremely useful, but in production you'll be so swamped by noise that it'll make picking out the important messages difficult.

ASP.NET Core includes the ability to filter out log messages *before* they're written based on a combination of three things:

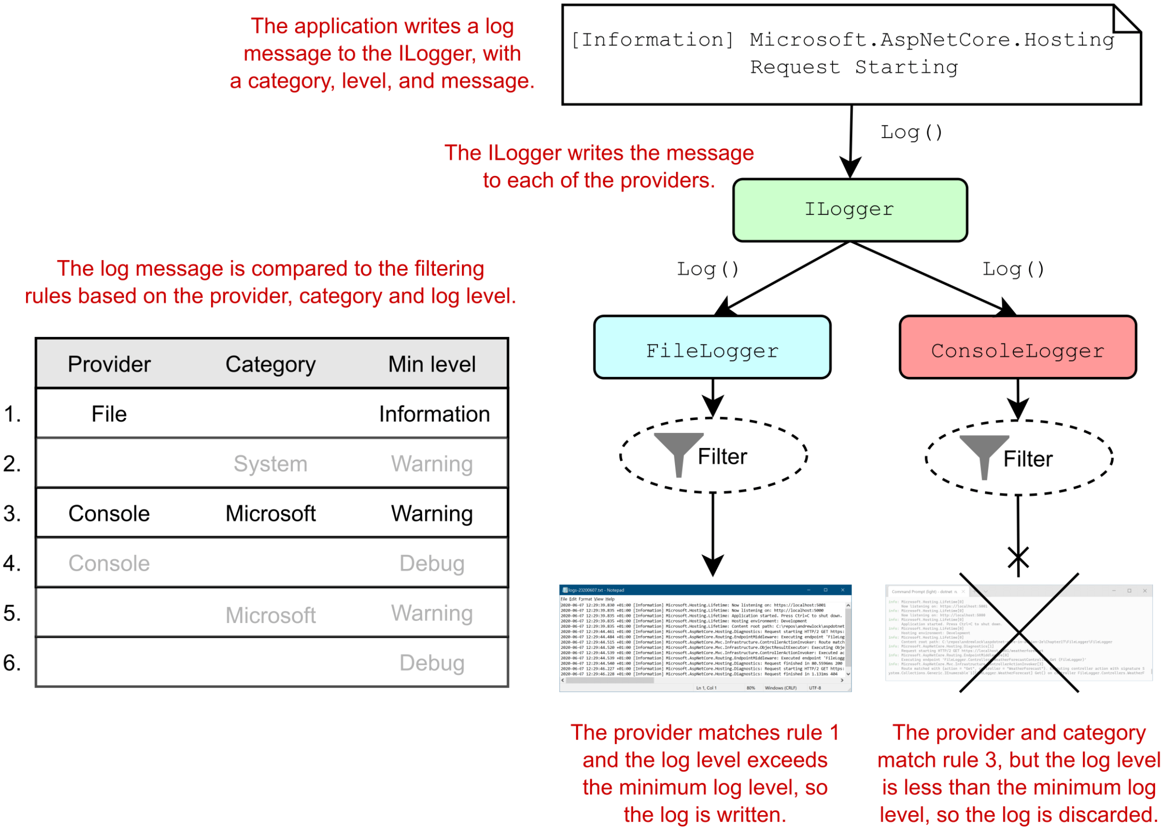
- The log level of the message
- The category of the logger (who created the log)
- The logger provider (where the log will be written)

You can create multiple rules using these properties, and for each log that's created, the most specific rule will be applied to determine whether the log should be written to the output. You could create the following three rules:

- *The default minimum log level is* `Information`. If no other rules apply, only logs with a log level of `Information` or above will be written to providers.
- *For categories that start with* `Microsoft`, *the minimum log level is* `Warning`. Any logger created in a namespace that starts with `Microsoft` will only write logs that have a log level of `Warning` or above. This would filter out the "noisy" framework messages you saw in figure 17.6.
- *For the console provider, the minimum log level is* `Error`. Logs written to the console provider must have a minimum log level of `Error`. Logs with a lower level won't be written to the console, though they might be written using other providers.

Typically, the goal with log filtering is to reduce the number of logs written to certain providers, or from certain namespaces (based on the log category). Figure 17.10 shows a possible set of filtering rules that apply filtering rules to the console and file logging providers.

In this example, the console logger explicitly restricts logs written in the `Microsoft` namespace to `Warning` or above, so the console logger ignores the log message shown. Conversely, the file logger doesn't have a rule that explicitly restricts the `Microsoft` namespace, so it uses the configured minimum level of `Information` and writes the log to the output.



The application writes a log message to the ILogger, with a category, level, and message.

```
[Information] Microsoft.AspNetCore.Hosting
              Request Starting
```

The ILogger writes the message to each of the providers.

The log message is compared to the filtering rules based on the provider, category and log level.

	Provider	Category	Min level
1.	File		Information
2.		System	Warning
3.	Console	Microsoft	Warning
4.	Console		Debug
5.		Microsoft	Warning
6.			Debug

The provider matches rule 1 and the log level exceeds the minimum log level, so the log is written.

The provider and category match rule 3, but the log level is less than the minimum log level, so the log is discarded.

Figure 17.10 Applying filtering rules to a log message to determine whether a log should be written. For each provider, the most specific rule is selected. If the log exceeds the rule's required minimum level, the provider writes the log, otherwise it discards it.

> **TIP** Only a single rule is chosen when deciding whether a log message should be written; they aren't combined. In figure 17.10, rule 1 is considered more specific than rule 5, so the log is written to the file provider, even though both could technically apply.

You typically define your app's set of logging rules using the layered configuration approach discussed in chapter 11, because this lets you easily have different rules when running in development and production. You do this by calling `AddConfiguration` when configuring logging in Program.cs, but `CreateDefaultBuilder()` also does this for you automatically.

This listing shows how you'd add configuration rules to your application when configuring your own `HostBuilder`, instead of using the `CreateDefaultBuilder` helper method.

Listing 17.7 Loading logging configuration in `ConfigureLogging`

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>
        new HostBuilder()
            .UseContentRoot(Directory.GetCurrentDirectory())
            .ConfigureAppConfiguration(config =>               #A
                config.AddJsonFile("appsettings.json"))        #A
            .ConfigureLogging((ctx, builder) =>
            {
                builder.AddConfiguration(                      #B
                    ctx.Configuration.GetSection("Logging"));  #B
                builder.AddConsole();                          #C
            })
            .ConfigureWebHostDefaults(webBuilder =>
            {
                webBuilder.UseStartup<Startup>();
            });
}
```

#A Loads configuration values from appsettings.json
#B Loads the log filtering configuration from the Logging section and adds to ILoggingBuilder
#C Adds a console provider to the app

In this example, I've loaded the configuration from a single file, appsettings.json, which contains all of our app configuration. The logging configuration is specifically contained in the `"Logging"` section of the `IConfiguration` object, which is available when you call `Configurelogging()`.

> **TIP** As you saw in chapter 11, you can load configuration settings from multiple sources, like JSON files and environment variables, and can load them conditionally based on the `IHostingEnvironment`. A common practice is to include logging settings for your production environment in appsettings.json, and overrides for your local development environment in appsettings.Development.json.

The logging section of your configuration should look similar to the following listing, which shows how you could define the rules shown in figure 17.10.

Listing 17.8 The log filtering configuration section of appsettings.json

```
{
  "Logging": {
    "LogLevel": {                #A
      "Default": "Debug",        #A
      "System": "Warning",       #A
      "Microsoft": "Warning"     #A
    },
    "File": {                       #B
      "LogLevel": {                 #B
        "Default": "Information"    #B
      }
    },
    "Console": {                   #C
      "LogLevel": {                #C
        "Default": "Debug",        #C
        "Microsoft": "Warning"     #C
      }
    }
  }
}
```

#A Rules to apply if there are no applicable rules for a provider
#B Rules to apply to the File provider
#C Rules to apply to the Console provider

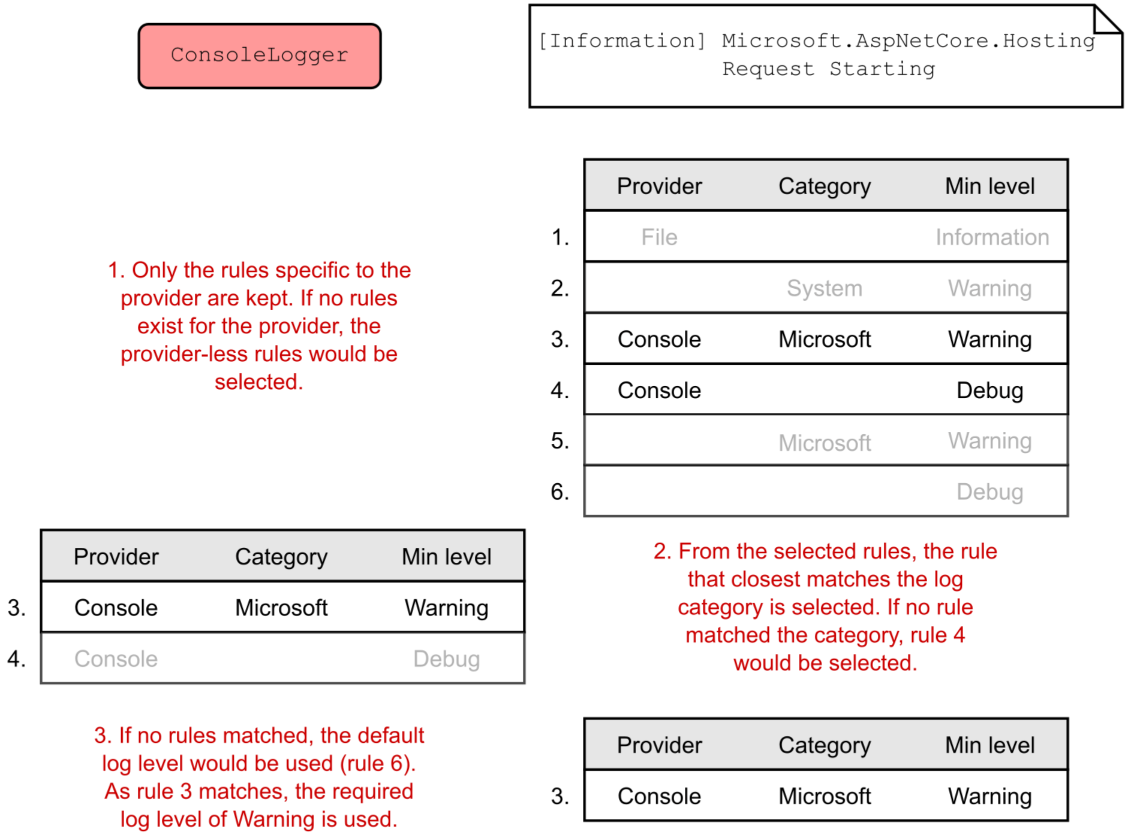
When creating your logging rules, the important thing to bear in mind is that if you have *any* provider-specific rules, these will take precedence over the category-based rules defined in the `"LogLevel"` section. Therefore, for the configuration defined in listing 17.8, if your app *only* uses the file or console logging providers, then the rules in the `"LogLevel"` section will effectively never apply.

If you find this confusing, don't worry, so do I. Whenever I'm setting up logging, I check the algorithm used to determine which rule will apply for a given provider and category, which is as follows:

1. Select all rules for the given provider. If no rules apply, select all rules that don't define a provider (the top `"LogLevel"` section from listing 17.8).
2. From the selected rules, select rules with the longest matching category prefix. If no selected rules match the category prefix, select the `"Default"` if present.
3. If multiple rules are selected, use the last one.
4. If no rules are selected, use the global minimum level, `"LogLevel:Default"` (`Debug` in listing 17.8).

Each of these steps (except the last) narrows down the applicable rules for a log message, until you're left with a single rule. You saw this in effect for a `"Microsoft"` category log in figure 17.10. Figure 17.11 shows the process in more detail.

> **WARNING** **Log filtering rules aren't merged together; a single rule is selected. Including provider-specific rules will override global category-specific rules, so I tend to stick to category-specific rules in my apps to make the overall set of rules easier to understand.**



```
[Information] Microsoft.AspNetCore.Hosting
              Request Starting
```

	Provider	Category	Min level
1.	File		Information
2.		System	Warning
3.	Console	Microsoft	Warning
4.	Console		Debug
5.		Microsoft	Warning
6.			Debug

1. Only the rules specific to the provider are kept. If no rules exist for the provider, the provider-less rules would be selected.

	Provider	Category	Min level
3.	Console	Microsoft	Warning
4.	Console		Debug

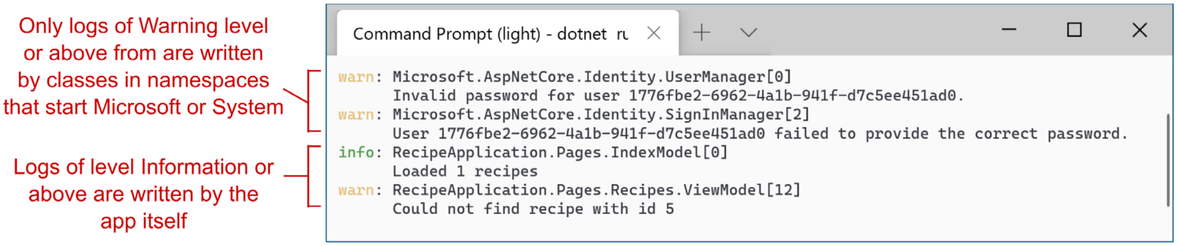
2. From the selected rules, the rule that closest matches the log category is selected. If no rule matched the category, rule 4 would be selected.

	Provider	Category	Min level
3.	Console	Microsoft	Warning

3. If no rules matched, the default log level would be used (rule 6). As rule 3 matches, the required log level of Warning is used.

Figure 17.11 Selecting a rule to apply from the available set for the console provider and an `Information` level log. Each step reduces the number of rules that apply until you're left with only one.

With some effective filtering in place, your production logs should be much more manageable, as shown in figure 17.12. Generally, I find it's best to limit the logs from the ASP.NET Core infrastructure and referenced libraries to `Warning` or above, while keeping logs that my app writes to `Debug` in development and `Information` in production.



Only logs of Warning level or above from are written by classes in namespaces that start Microsoft or System

Logs of level Information or above are written by the app itself

```
warn: Microsoft.AspNetCore.Identity.UserManager[0]
      Invalid password for user 1776fbe2-6962-4a1b-941f-d7c5ee451ad0.
warn: Microsoft.AspNetCore.Identity.SignInManager[2]
      User 1776fbe2-6962-4a1b-941f-d7c5ee451ad0 failed to provide the correct password.
info: RecipeApplication.Pages.IndexModel[0]
      Loaded 1 recipes
warn: RecipeApplication.Pages.Recipes.ViewModel[12]
      Could not find recipe with id 5
```

Figure 17.12 Using filtering to reduce the number of logs written. In this example, category filters have been added to the Microsoft and System namespaces, so only logs of Warning and above are recorded. That increases the number of logs that are directly relevant to your application.

This is close to the default configuration used in the ASP.NET Core templates. You may find you need to add additional category-specific filters, depending on which NuGet libraries you use and the categories they write to. The best way to find out is generally to run your app and see if you get flooded with uninteresting log messages!

Even with your log verbosity under your control, if you stick to the default logging providers like the file or console loggers, then you'll probably regret it in the long run. These log providers work perfectly well, but when it comes to finding specific error messages, or analyzing your logs, you'll have your work cut out for you. In the next section, you'll see how structured logging can help tackle this problem.

17.5 Structured logging: creating searchable, useful logs

In this section you'll learn how structured logging makes working with log messages easier. You'll learn to attach key-value pairs to log messages, and how to store and query for key values using the structured logging provider, Seq. Finally, you'll learn how to use scopes to attach key value pairs to all log messages within a block.

Let's imagine you've rolled out the recipe application we've been working on into production. You've added logging to the app so that you can keep track of any errors in your application, and you're storing the logs in a file.

One day, a customer calls and says they can't view their recipe. Sure enough, when you look through the log messages you a see a warning:

```
warn: RecipeApplication.Controllers.RecipeController[12]
      Could not find recipe with id 3245
```

This piques your interest—why did this happen? Has it happened before for this *customer*? Has it happened before for this *recipe*? Has it happened for *other* recipes? Does it happen regularly?

How would you go about answering these questions? Given that the logs are stored in a text file, you might start doing basic text searches in your editor of choice, looking for the phrase "`Could not find recipe with id`". Depending on your notepad-fu skills, you could probably get a fair way in answering your questions, but it would likely be a laborious, error-prone, and painful process.

The limiting factor is that the logs are stored as *unstructured* text, so text processing is the only option available to you. A better approach is to store the logs in a *structured* format, so that you can easily query the logs, filter them, and create analytics. Structured logs could be stored in any format, but these days they're typically represented as JSON. For example, a structured version of the same recipe warning log might look something like

```
{
  "eventLevel": "Warning",
  "cateogry": "RecipeApplication.Controllers.RecipeController",
  "eventId": "12",
  "messageTemplate": "Could not find recipe with {recipeId}",
  "message": "Could not find recipe with id 3245",
  "recipeId": "3245"
}
```

This structured log message contains all the same details as the unstructured version, but in a format that would easily let you search for specific log entries. It makes it simple to filter logs by their `EventLevel`, or to only show those logs relating to a specific recipe ID.

> **NOTE** **This is only an example of what a structured log could look like. The format used for the logs will vary depending on the logging provider used and could be anything. The key point is that properties of the log are available as key-value pairs.**

Adding structured logging to your app requires a logging provider that can create and store structured logs. Elasticsearch is a popular general search and analytics engine that can be used to store and query your logs. Serilog includes a sink for writing logs to Elasticsearch that you can add to your app in the same way as you added the console sink in section 17.3.2.

> **TIP** **If you want to learn more about Elasticsearch, *Relevant Search* by Doug Turnbull and John Berryman (Manning, 2016) is a great choice, and will show how you can make the most of your structured logs.**

Elasticsearch is a powerful production-scale engine for storing your logs, but setting it up isn't for the faint of heart. Even after you've got it up and running, there's a somewhat steep learning curve associated with the query syntax. If you're interested in something more user-friendly for your structured logging needs, then Seq (https://getseq.net) is a great option. In the next section, I'll show how adding Seq as a structured logging provider makes analyzing your logs that much easier.

17.5.1 Adding a structured logging provider to your app

To demonstrate the advantages of structured logging, in this section, you'll configure an app to write logs to Seq. You'll see that configuration is essentially identical to unstructured providers, but that the possibilities afforded by structured logging make considering it a no-brainer.

Seq is installed on a server or your local machine and collects structured log messages over HTTP, providing a web interface for you to view and analyze your logs. It is currently available as a Windows app or a Linux Docker container. You can install a free version for development,[80] which will allow you to experiment with structured logging in general.

From the point of view of your app, the process for adding the Seq provider should be familiar:

1. Install the Seq logging provider using Visual Studio or the .NET CLI with

```
dotnet add package Seq.Extensions.Logging
```

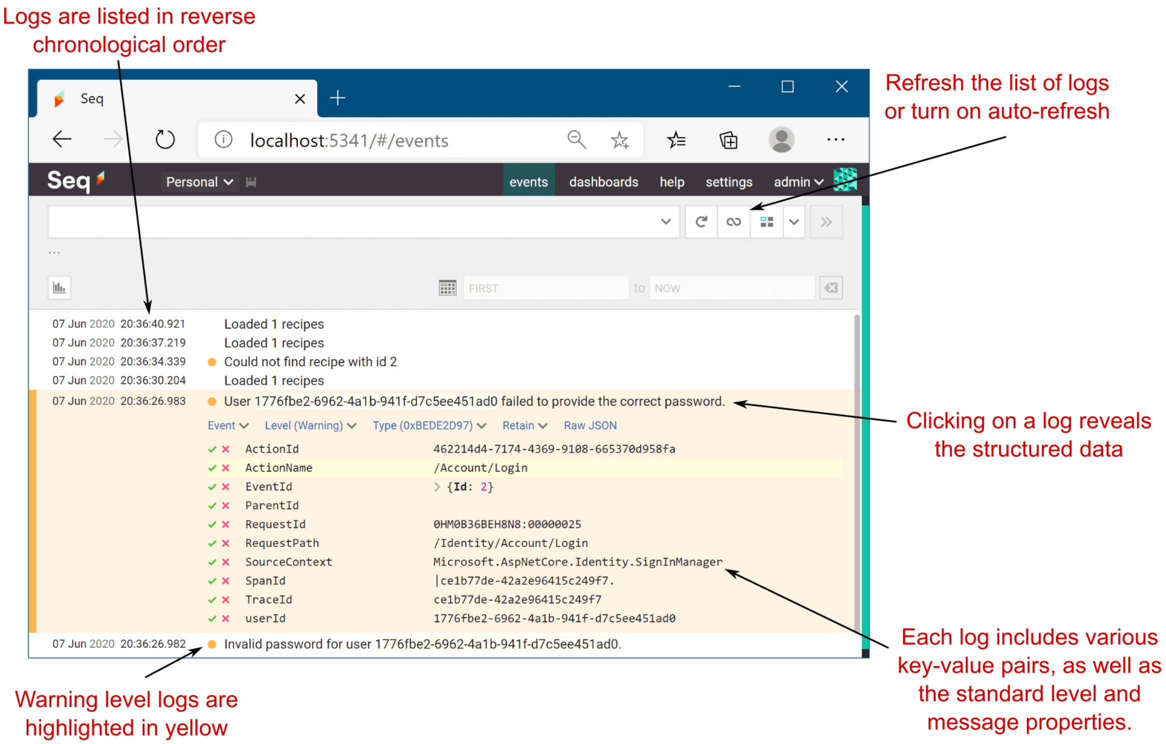
2. Add the Seq logging provider in Program.cs inside the `ConfigureLogging` method. To add the Seq provider in addition to the console and debug providers included as part of `CreateDefaultBuilder`, use

```
Host.CreateDefaultBuilder(args)
    .ConfigureLogging(builder => builder.AddSeq())
    .ConfigureWebHostDefaults(webBuilder =>
    {
        webBuilder.UseStartup<Startup>();
    });
```

That’s all you need to add Seq to your app. This will send logs to the default local URL when you have Seq installed in your local environment. The `AddSeq()` extension method includes additional overloads to customize Seq when you move to production, but this is all you need to start experimenting locally.

If you haven’t already, install Seq on your development machine and navigate to the Seq app at http://localhost:5341. In a different tab, open up your app and start browsing around and generating logs. Heading back to Seq, if you refresh the page, you’ll see a list of logs, something like in figure 17.13. Clicking on a log expands it and shows you the structured data recorded for the log.

[80] You can download the Windows installer for Seq from https://getseq.net/Download.



Logs are listed in reverse chronological order

Refresh the list of logs or turn on auto-refresh

Clicking on a log reveals the structured data

Each log includes various key-value pairs, as well as the standard level and message properties.

Warning level logs are highlighted in yellow

```
07 Jun 2020 20:36:40.921     Loaded 1 recipes
07 Jun 2020 20:36:37.219     Loaded 1 recipes
07 Jun 2020 20:36:34.339   ● Could not find recipe with id 2
07 Jun 2020 20:36:30.204     Loaded 1 recipes
07 Jun 2020 20:36:26.983   ● User 1776fbe2-6962-4a1b-941f-d7c5ee451ad0 failed to provide the correct password.
                             ✓ ✗ ActionId          462214d4-7174-4369-9108-665370d958fa
                             ✓ ✗ ActionName        /Account/Login
                             ✓ ✗ EventId           > {Id: 2}
                             ✓ ✗ ParentId
                             ✓ ✗ RequestId         0HM0B36BEH8N8:00000025
                             ✓ ✗ RequestPath       /Identity/Account/Login
                             ✓ ✗ SourceContext     Microsoft.AspNetCore.Identity.SignInManager
                             ✓ ✗ SpanId            |ce1b77de-42a2e96415c249f7.
                             ✓ ✗ TraceId           ce1b77de-42a2e96415c249f7
                             ✓ ✗ userId            1776fbe2-6962-4a1b-941f-d7c5ee451ad0
07 Jun 2020 20:36:26.982   ● Invalid password for user 1776fbe2-6962-4a1b-941f-d7c5ee451ad0.
```

Figure 17.13 The Seq UI. Logs are presented as a list. You can view the structured logging details of individual logs, view analytics for logs in aggregates, and search by log properties.

ASP.NET Core supports structured logging by treating each captured parameter from your message format string as a key-value-pair. If you create a log message using the format string

```
_log.LogInformation("Loaded {RecipeCount} recipes", Recipes.Count);
```

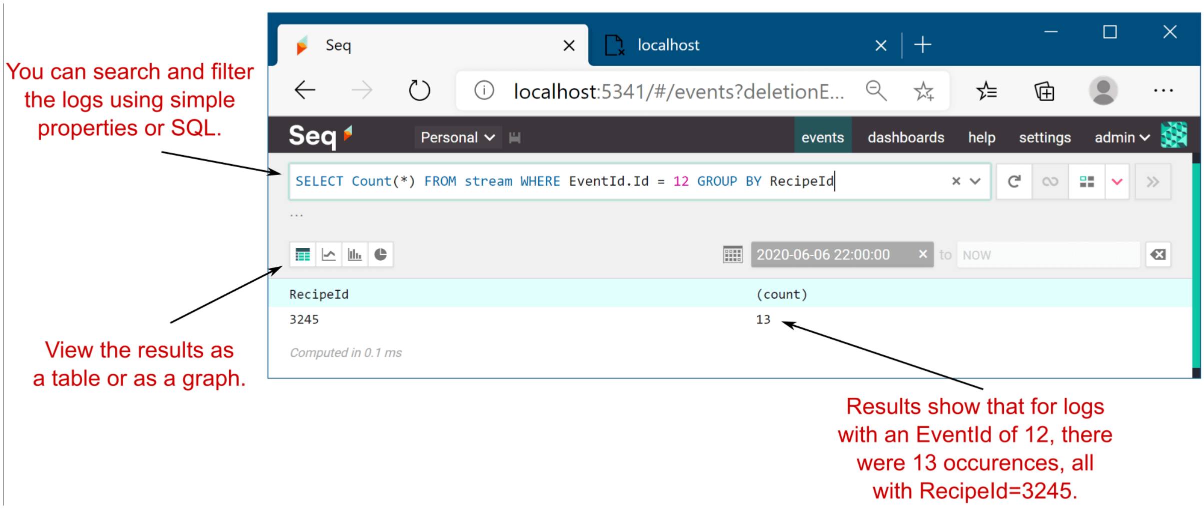
then the logging provider will create a `RecipeCount` parameter with a value of `Recipes.Count`. These parameters are added as properties to each structured log, as you can see in figure 17.13.

Structured logs are generally easier to read than your standard-issue console output, but their real power comes when you need to answer a specific question. Consider the problem from before, where you see the error

```
Could not find recipe with id 3245
```

and you want to get a feel for how widespread the problem is. The first step would be to identify how many times this error has occurred, and to see whether it’s happened to any other recipes. Seq lets you filter your logs, but it also lets you craft SQL queries to analyze your data, so finding the answer to the question takes a matter of seconds, as shown in figure 17.14.

> **NOTE** You don't need query languages like SQL for simple queries, but it makes digging into the data easier. Other structured logging providers may provide query languages other than SQL, but the principal is the same as this Seq example.



```
SELECT Count(*) FROM stream WHERE EventId.Id = 12 GROUP BY RecipeId
```

```
RecipeId                                        (count)
3245                                            13
Computed in 0.1 ms
```

You can search and filter the logs using simple properties or SQL.

View the results as a table or as a graph.

Results show that for logs with an EventId of 12, there were 13 occurences, all with RecipeId=3245.

Figure 17.14 Querying logs in Seq. Structured logging makes log analysis like this example easy.

A quick search shows that you've recorded the log message with `EventId.Id=12` (the `EventId` of the warning we're interested in) 13 times, and every time the offending `RecipeId` was 3245. This suggests that there may be something wrong with that recipe in particular, which points you in the right direction to find the problem.

More often than not, figuring out errors in production involves logging detective work like this to isolate where the problem occurred. Structured logging makes this process significantly easier, so it's well worth considering, whether you choose Seq, Elasticsearch, or a different provider.

I've already described how you can add structured properties to your log messages using variables and parameters from the message, but as you can see in figure 17.13, there are far more properties visible than exist in the message alone.

Scopes provide a way to add arbitrary data to your log messages. They're available in some unstructured logging providers, but they shine when used with structured logging providers. In the final section of this chapter, I'll demonstrate how you can use them to add additional data to your log messages.

17.5.2 Using scopes to add additional properties to your logs

You'll often find in your apps that you have a group of operations that all use the same data, which would be useful to attach to logs. For example, you might have a series of database operations that all use the same transaction ID, or you might be performing multiple operations with the same user ID or recipe ID. *Logging scopes* provide a way of associating the same data to every log message in such a group.

> **DEFINITION** *Logging scopes* are used to group multiple operations by adding the same data to each log message.

Logging scopes in ASP.NET Core are created by calling `ILogger.BeginScope<T>(T state)` and providing the `state` data to be logged. You create scopes inside a `using` block; any log messages written inside the scope block will have the associated data, whereas those outside won't.

Listing 17.9 Adding scope properties to log messages with `BeginScope`

```
_logger.LogInformation("No, I don't have scope");          #A

using(_logger.BeginScope("Scope value"))                   #B
using(_logger.BeginScope(new Dictionary<string, object>    #C
    {{ "CustomValue1", 12345 } }))                         #C
{
    _logger.LogInformation("Yes, I have the scope!");      #D
}

_logger.LogInformation("No, I lost it again");             #A
```

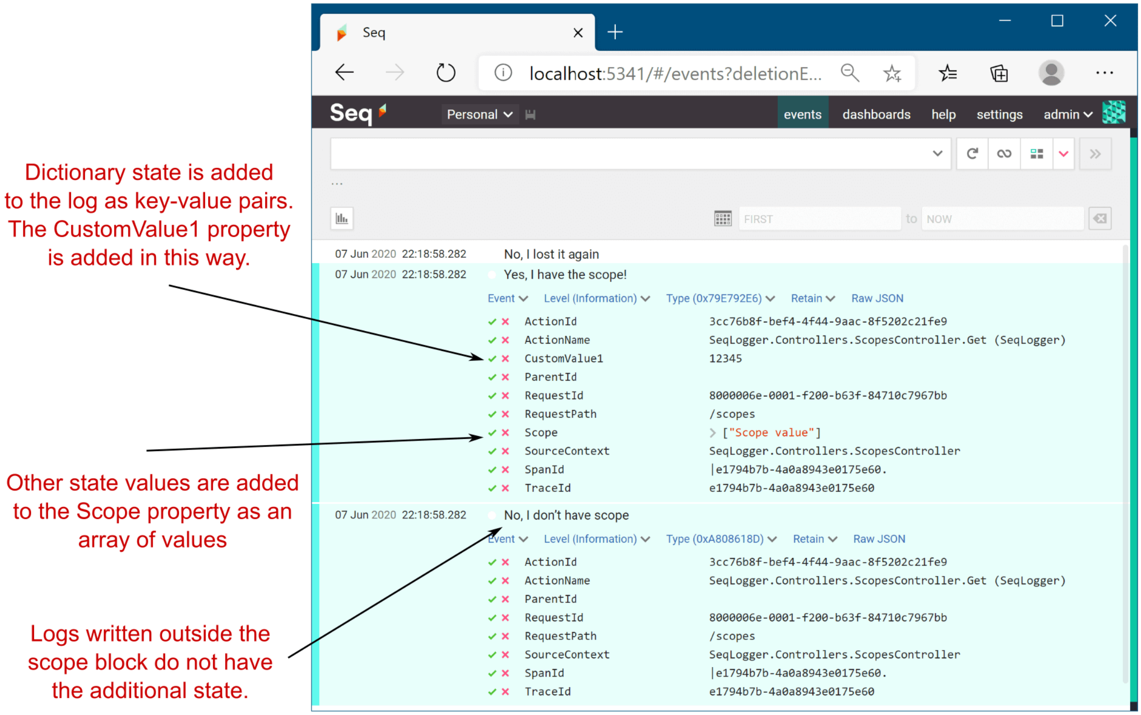
#A Log messages written outside the scope block don't include the scope state.
#B Calling BeginScope starts a scope block, with a scope state of "Scope value".
#C You can pass anything as the state for a scope.
#D Log messages written inside the scope block include the scope state.

The scope state can be any object at all: an `int`, a `string`, or a `Dictionary`, for example. It's up to each logging provider implementation to decide how to handle the state you provide in the `BeginScope` call, but typically it will be serialized using `ToString()`.

> **TIP** The most common use for scopes I've found is to attach additional key-value pairs to logs. To achieve this behavior in Seq and Serilog, you need to pass `Dictionary<string, object>` as the state object.[81]

[81] Nicholas Blumhardt, the creator of Serilog and Seq, has examples and the reasoning for this on his blog: https://nblumhardt.com/2016/11/ilogger-beginscope/.

When the log messages inside the scope block are written, the scope state is captured and written as part of the log, as shown in figure 17.15. The `Dictionary<>` of key-value pairs is added directly to the log message (`CustomValue1`), and the remaining state values are added to the `Scope` property. You will likely find the dictionary approach the more useful of the two, as the added properties are more easily filtered on, as you saw in figure 17.14.



```
07 Jun 2020  22:18:58.282   No, I lost it again
07 Jun 2020  22:18:58.282   Yes, I have the scope!
                            ✓ ✗  ActionId          3cc76b8f-bef4-4f44-9aac-8f5202c21fe9
                            ✓ ✗  ActionName        SeqLogger.Controllers.ScopesController.Get (SeqLogger)
                            ✓ ✗  CustomValue1      12345
                            ✓ ✗  ParentId
                            ✓ ✗  RequestId         8000006e-0001-f200-b63f-84710c7967bb
                            ✓ ✗  RequestPath       /scopes
                            ✓ ✗  Scope             > ["Scope value"]
                            ✓ ✗  SourceContext     SeqLogger.Controllers.ScopesController
                            ✓ ✗  SpanId            |e1794b7b-4a0a8943e0175e60.
                            ✓ ✗  TraceId           e1794b7b-4a0a8943e0175e60
07 Jun 2020  22:18:58.282   No, I don't have scope
                            ✓ ✗  ActionId          3cc76b8f-bef4-4f44-9aac-8f5202c21fe9
                            ✓ ✗  ActionName        SeqLogger.Controllers.ScopesController.Get (SeqLogger)
                            ✓ ✗  ParentId
                            ✓ ✗  RequestId         8000006e-0001-f200-b63f-84710c7967bb
                            ✓ ✗  RequestPath       /scopes
                            ✓ ✗  SourceContext     SeqLogger.Controllers.ScopesController
                            ✓ ✗  SpanId            |e1794b7b-4a0a8943e0175e60.
                            ✓ ✗  TraceId           e1794b7b-4a0a8943e0175e60
```

Dictionary state is added to the log as key-value pairs. The CustomValue1 property is added in this way.

Other state values are added to the Scope property as an array of values

Logs written outside the scope block do not have the additional state.

Figure 17.15 Adding properties to logs using scopes. Scope state added using the dictionary approach is added as structured logging properties, but other state is added to the `Scope` property. Adding properties makes it easier to associate related logs with one another.

That brings us to the end of this chapter on logging. Whether you use the built-in logging providers or opt to use a third-party provider like Serilog or NLog, ASP.NET Core makes it easy to get detailed logs not only for your app code, but for the libraries that make up your app's infrastructure, like Kestrel and EF Core. Whichever you choose, I encourage you to add more logs than you *think* you'll need—future-you will thank me when it comes to tracking down a problem!

In the next chapter, we'll look in detail at a variety of web security problems that you should consider when building your apps. ASP.NET Core takes care of some of these issues for you automatically, but it’s important to understand where your app’s vulnerabilities lie, so you can mitigate them as best you can.

17.6 Summary

- Logging is critical to quickly diagnosing errors in production apps. You should always configure logging for your application so that logs are written to a durable location.
- You can add logging to your own services by injecting `ILogger<T>`, where `T` is the name of the service. Alternatively, inject `ILoggerFactory` and call `CreateLogger()`.
- The log level of a message is how important it is and ranges from `Trace` to `Critical`. Typically, you’ll create many low-importance log messages, and a few high-importance log messages.
- You specify the log level of a log by using the appropriate extension method of `ILogger` to create your log. To write an `Information` level log, use `ILogger.LogInformation(message)`.
- The log category indicates which component created the log. It is typically set to the fully qualified name of the class creating the log, but you can set it to any string if you wish. `ILogger<T>` will have a log category of `T`.
- You can format messages with placeholder values, similar to the `string.Format` method, but with meaningful names for the parameters. Calling `logger.LogInfo("Loading Recipe with id {RecipeId}", 1234)` would create a log reading `"Loading Recipe with id 1234"`, but would also capture the value `RecipeId=1234`. This *structured logging* makes analyzing log messages much easier.
- ASP.NET Core includes many logging providers out of the box. These include the console, debug, EventLog, and EventSource providers. Alternatively, you can add third-party logging providers.
- You can configure multiple `ILoggerProvider` instances in ASP.NET Core, which define where logs are output. The `CreateDefaultBuilder` method adds the console and debug providers, and you can add additional providers by calling `ConfigureLogging()`.
- Serilog is a mature logging framework that includes support for a large number of output locations. You can add Serilog to your app with the Serilog.AspNetCore package. This replaces the default `ILoggerFactory` with a Serilog-specific version.
- You can control logging output verbosity using configuration. The `CreateDefaultBuilder` helper uses the `"Logging"` configuration section to control output verbosity. You typically will filter out more logs in production compared to when developing your application.
- Only a single log filtering rule is selected for each logging provider when determining whether to output a log message. The most specific rule is selected based on the logging provider and the category of the log message.
- Structured logging involves recording logs so that they can be easily queried and filtered, instead of the default unstructured format that's output to the console. This makes analyzing logs, searching for issues, and identifying patterns easier.

- You can add additional properties to a structured log by using scope blocks. A scope block is created by calling `ILogger.BeginScope<T>(state)` in a `using` block. The state can be any object and is added to all log messages inside the scope block.

18 Improving your application's security

This chapter covers

- Encrypting traffic using HTTPS and configuring local SSL certificates
- Defending against cross-site scripting attacks
- Protecting from cross-site request forgery attacks
- Allowing calls to your API from other apps using CORS

Web application security is a hot topic at the moment. Practically every week another breach is reported, or confidential details are leaked. It may seem like the situation is hopeless, but the reality is that the vast majority of breaches could've been avoided with the smallest amount of effort.

In this chapter, we look at a few different ways to protect your application and your application's users from attackers. Because security is an extremely broad topic that covers lots of different avenues, this chapter is by no means an exhaustive guide. It's intended to make you aware of some of the most common threats to your app and how to counteract them, and to highlight areas where you can inadvertently introduce vulnerabilities if you're not careful.

TIP I strongly advise exploring additional resources around security after you've read this chapter. The Open Web Application Security Project (OWASP) (www.owasp.org) is an excellent resource, though it can be a little dry. Alternatively, Troy Hunt (www.troyhunt.com/) has some excellent courses and workshops on security, geared towards .NET developers.

We’ll start by looking at how to add HTTPS encryption to your website so that users can access your app without the risk of third parties spying on or modifying the content as it travels over the internet. This is effectively mandatory for production apps these days, and it is heavily encouraged by the makers of modern browsers such as Chrome and Firefox. You’ll see how to use the .NET Core development certificate to use HTTPS locally, how to configure an app for HTTPS in production, and how to enforce HTTPS across your whole app.

In sections 18.2 and 18.3, you’ll learn about two potential attacks that should be on your radar: cross-site scripting (XSS) and cross-site request forgery (CSRF). We’ll explore how the attacks work and how you can prevent them in your apps. ASP.NET Core has built-in protection against both types of attack, but you have to remember to use the protection correctly and resist the temptation to circumvent it, unless you’re certain it’s safe to do so.

Section 18.4 deals with a common scenario—you have an application that wants to use JavaScript AJAX (Asynchronous JavaScript and XML) requests to retrieve data from a second app. By default, web browsers block requests to other apps, so you need to enable cross-origin resource sharing (CORS) in your API to achieve this. We’ll look at how CORS works, how to create a CORS policy for your app, and how to apply it to specific action methods.

The final section of this chapter, section 18.5, is a collection of common threats to your application. Each one represents a potentially critical flaw that an attacker could use to compromise your application. The solutions to each threat are generally relatively simple; the important thing is to recognize where the flaws could exist in your own apps so that you can ensure you don’t leave yourself vulnerable.

We’ll start by looking at HTTPS and why you should use it to encrypt the traffic between your users’ browsers and your app. Without HTTPS, attackers could subvert many of the safeguards you add to your app, so it’s an important first step to take.

18.1 Adding HTTPS to an application

In this section you’ll learn about HTTPS, what it is, and why you need to be aware of it for all your production applications. You’ll see two approaches to adding HTTPS to your application: supporting HTTPS directly in your application and using SSL/TLS-offloading with a reverse-proxy. You’ll then learn how to use the development certificate to work with HTTPS on your local machine, and how to add an HTTPS certificate to your app in production. Finally, you’ll learn how to enforce HTTPS in your app using best practices such as security headers, and HTTP redirection.

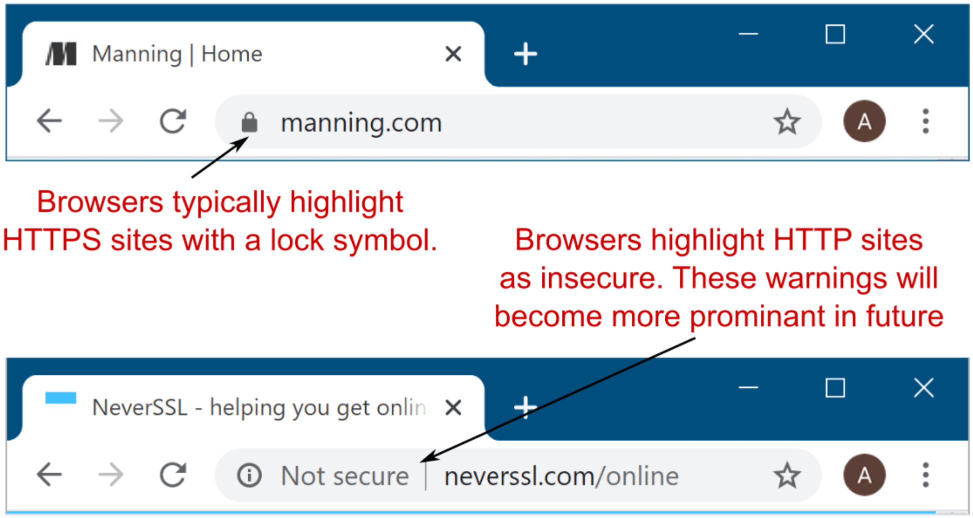
So far in this book, I’ve shown how the user’s browser sends a request across the internet to your app using the HTTP protocol. We haven’t looked too much into the details of that protocol, other than to establish that it uses *verbs* to describe the type of request (such as GET and POST), that it contains *headers* with metadata about the request, and optionally a *body* payload of data.

By default, HTTP requests are unencrypted; they’re plain text files being sent over the internet. Anyone on the same network as a user (such as using the same public Wi-Fi in a coffee shop) can read the requests and responses sent back and forth. Attackers can even *modify* the requests or responses as they're in transit.

Using unencrypted web apps in this way presents both a privacy and a security risk to your users. Attackers could read the data sent in forms and returned by your app, inject malicious code into your responses to attack users, or steal authentication cookies and impersonate the user on your app.

To protect your users, your app should encrypt the traffic between the user's browser and your app as it travels over the network by using the HTTPS protocol. This is similar to HTTP traffic, but it uses an SSL/TLS[82] certificate to encrypt requests and responses, so attackers cannot read or modify the contents. In browsers, you can tell a site is using HTTPS by the https:// prefix to URLs (notice the "s"), or sometimes, by a padlock, as shown in figure 18.1.

> **TIP** For details about how the SSL/TLS protocols work, see *Real-World Cryptography* by David Wong (Manning, 2021) https://livebook.manning.com/book/real-world-cryptography/chapter-9/.



Browsers typically highlight HTTPS sites with a lock symbol.

Browsers highlight HTTP sites as insecure. These warnings will become more prominant in future

Figure 18.1 Encrypted apps using HTTPS and unencrypted apps using HTTP in Edge. Using HTTPS protects your application from being viewed of tampered with by attackers.

The reality is that, these days, you should always serve your production websites over HTTPS. The industry is pushing toward HTTPS by default, with most browsers moving to mark HTTP

[82] SSL is an older standard that facilitates HTTPS, but the SSL protocol has been superseded by Transport Layer Security (TLS) so I'll be using TLS preferentially throughout this chapter.

sites as explicitly “not secure.” Skipping HTTPS will hurt the perception of your app in the long run, so even if you’re not interested in the security benefits, it’s in your best interest to set up HTTPS.

In order to configure HTTPS, you need to obtain and configure a TLS certificate for your server. Unfortunately, although that process is a lot easier than it used to be, and is now essentially free thanks to Let’s Encrypt (https://letsencrypt.org/), it’s still far from simple in many cases. If you’re setting up a production server, I recommend carefully following the tutorials on the Let’s Encrpyt site. It’s easy to get it wrong, so take your time!

> **TIP** If you’re hosting your app in the cloud, then most providers will provide “one-click” TLS certificates so that you don’t have to manage certificates yourself. This is *extremely* useful, and I highly recommend it for everyone.[83]

As an ASP.NET Core application developer, you can often get away without *directly* supporting HTTPS in your app by taking advantage of the reverse proxy architecture, as shown in figure 18.2, in a process called SSL/TLS offloading/termination. Instead of your application handling requests using HTTPS directly, it continues to use HTTP. The reverse proxy is responsible for encrypting and decrypting HTTPS traffic to the browser. This often gives you the best of both worlds—data is encrypted between the user’s browser and the server, but you don’t have to worry about configuring certificates in your application.[84]

[83] You don’t even have to be hosting your application in the cloud to take advantage of this. Cloudflare (www.cloudflare.com) provides a CDN service that you can add SSL to. You can even use it for free.

[84] If you’re concerned that the traffic is unencrypted between the reverse proxy and your app, then I recommend reading this post by Troy Hunt: http://mng.bz/eHCi. It discusses the pros and cons of the issue as it relates to using Cloudflare to provide HTTPS encryption.

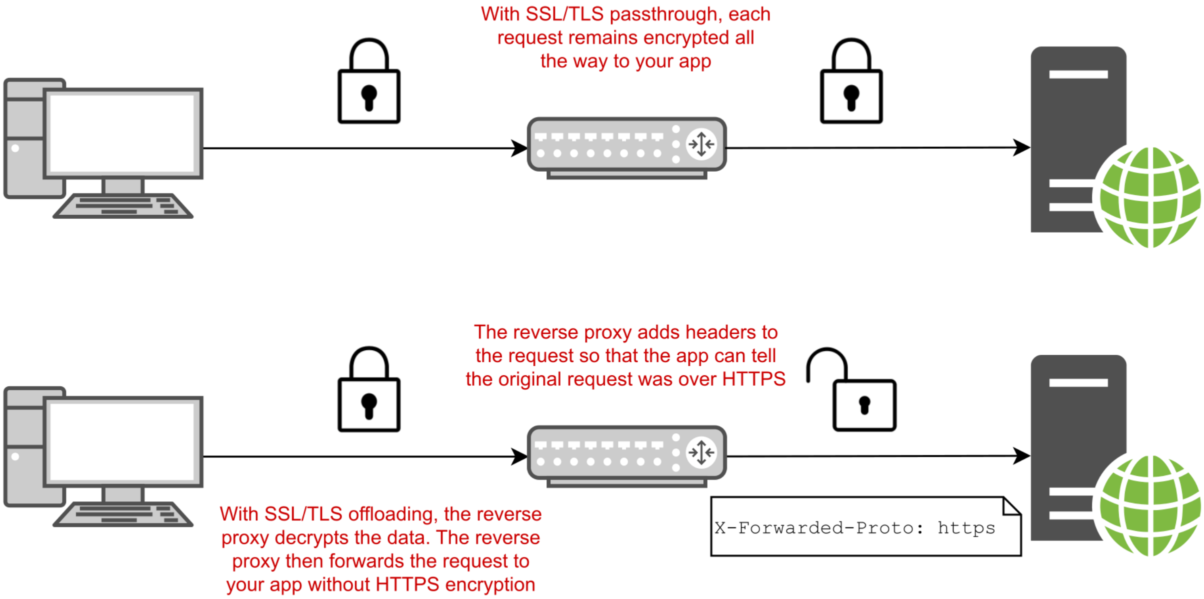

With SSL/TLS passthrough, each request remains encrypted all the way to your app
The reverse proxy adds headers to the request so that the app can tell the original request was over HTTPS
With SSL/TLS offloading, the reverse proxy decrypts the data. The reverse proxy then forwards the request to your app without HTTPS encryption
X-Forwarded-Proto: https

Figure 18.2 You have two options when using HTTPS with a reverse proxy: SSL/TLS passthrough and SSL/TLS offloading. In SSL/TLS passthrough, the data is encrypted all the way to your ASP.NET Core app. For SSL/TLS termination, the reverse proxy handles decrypting the data, so your app doesn't have to.

Depending on the specific infrastructure where you're hosting your app, SSL/TLS could be offloaded to a dedicated device on your network, a third-party service like Cloudflare, or a reverse proxy (such as IIS, NGINX, or HAProxy), running on the same or a different server.

Nevertheless, in some situations, you may need to handle SSL/TLS directly in your app, for example:

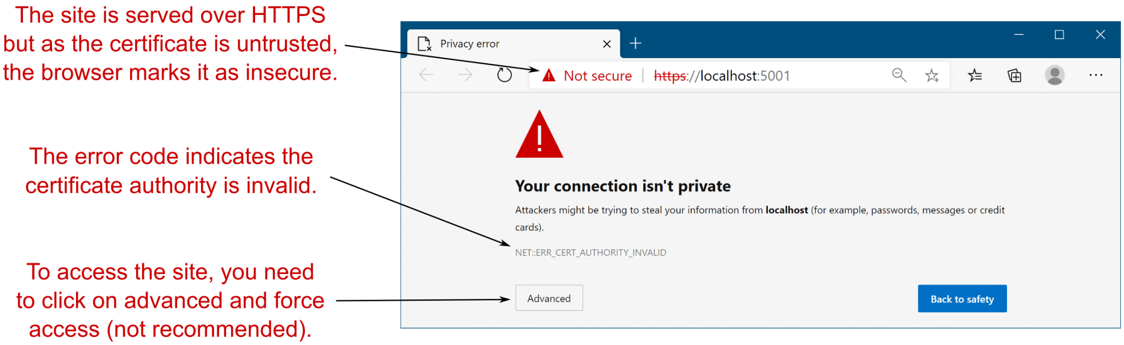
- *If you're exposing Kestrel to the internet directly, without a reverse proxy*. This became more common with ASP.NET Core 3.0 due to hardening of the Kestrel server. It is also often the case when you're developing your app locally.
- *If having HTTP between the reverse proxy and your app is not acceptable.* While securing traffic *inside* your network is less critical compared to external traffic, it is undoubtedly more secure to use HTTPS for internal traffic too.
- *If you're using technology that requires HTTPS*. Some newer network protocols, such as gRPC (discussed in chapter 20) and HTTP/2 require an HTTPS connection.

In each of these scenarios, you need to configure a TLS certificate for your application, so Kestrel can receive HTTPS traffic. In section 18.1.1 you'll see the easiest way to get started with HTTPS when developing locally, and in section 18.1.2 you'll see how to configure your application for production.

18.1.1 Using the .NET Core and IIS Express HTTPS development certificates

Working with HTTPS certificates is easier than it used to be, but unfortunately it can still be confusing topic, especially as a newcomer to the web. The .NET Core SDK, Visual Studio, and IIS Express try and improve this experience by handling a lot of the grunt-work for you.

The first time you run a `dotnet` command using the .NET Core SDK, the SDK installs an HTTPS development certificate onto your machine. Any ASP.NET Core application you create using the default templates (or for which you don't explicitly configure certificates) will use this development certificate to handle HTTPS traffic. However, the development certificate is not *trusted* by default. That means you'll get a browser warning, as shown in figure 18.3 when accessing a site after first installing the .NET Core SDK.


The site is served over HTTPS but as the certificate is untrusted, the browser marks it as insecure.

The error code indicates the certificate authority is invalid.

To access the site, you need to click on advanced and force access (not recommended).

Your connection isn't private

Attackers might be trying to steal your information from **localhost** (for example, passwords, messages or credit cards).

NET::ERR_CERT_AUTHORITY_INVALID

Figure 18.3. The developer certificate is not trusted by default, so apps serving HTTPS traffic using it will be marked as insecure by browsers. Although you can bypass the warnings if necessary, you should instead update the certificate to be trusted.

A brief primer on certificates and signing

HTTPS uses *public key cryptography* as part of the data-encryption process. This uses two keys: a *public* key that *anyone* can see, and a *private* key that only *your* server can see. Anything encrypted with the public key can only be decrypted with the private key. That way, a browser can encrypt something with your server's public key, and only your server can decrypt it. A complete TLS certificate consists of both the public and private parts.

When a browser connects to your app, the server sends the public key part of the TLS certificate. But how does the browser know that it was definitely *your* server that sent the certificate? To achieve this, your TLS certificate contains additional certificates, including a certificate from a third party, a certificate authority (CA). This trusted certificate is called a *root certificate*.

CAs are special trusted entities. Browsers are hardcoded to trust certain root certificates. So, in order for the TLS certificate for your app to be trusted, it must contain (or be signed by) a trusted root certificate.

When you use the .NET Core development certificate, or if you create your own self-signed certificate, your site's HTTPS is missing that trusted root certificate. That means browsers won't trust your certificate and won't connect to your server by default. To get around this, you need to tell your development machine to explicitly trust the certificate.

In production, you can't use a development or self-signed certificate, as a user's browser won't trust it. Instead, you need to obtain a signed HTTPS certificate from a service like Let's Encrpyt, or from a cloud provider like AWS, Azure, or Cloudflare. These certificates will already be signed by a trusted CA, so will be automatically trusted by browsers.

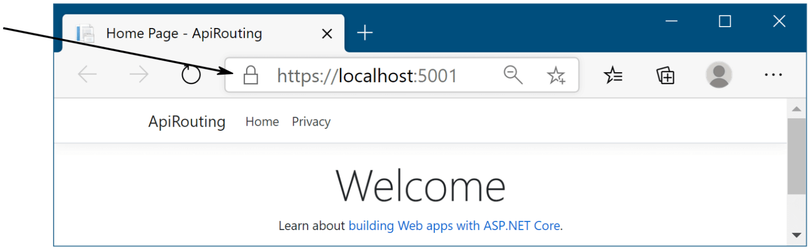
To solve these browser warnings, you need to *trust* the certificate. Trusting a certificate is a sensitive operation, as it's saying "I know this certificate doesn't look quite right, but just ignore that", so it's hard to do automatically. If you're running on Windows or macOS, you can trust the development certificate by running

```
dotnet dev-certs https --trust
```

This command trusts the certificate, by registering it in the operating system "certificate store". After you run this command, you should be able to access your websites without seeing any warnings or "not secure" labels, as shown in figure 16.4.

TIP You may need to close your browser after trusting the certificate to clear the browser's cache.

Now the certificate is trusted, so it has the lock symbol, is no longer marked "not secure", and isn't shown in red.



Learn about building Web apps with ASP.NET Core.

Figure 18.4. Once the development certificate is trusted, you will no longer see browser warnings about the connection.

The developer certificate works smoothly on Windows and macOS. Unfortunately, trusting the certificate in Linux is a little trickier, and depends on the particular flavor you're using. On top of that, software on Linux often uses its own certificate store, so you'll probably need to add the certificate directly to your favorite browser. I suggest looking at the documentation for your favorite browser to figure out the best approach. For advice on other platforms, such as Docker, see the documentation at https://docs.microsoft.com/aspnet/core/security/enforcing-ssl#how-to-set-up-a-developer-certificate-for-docker.

If you're using Windows, Visual Studio, and IIS Express for development, then you may not find the need to trust the development certificate. IIS Express acts as a reverse proxy when you're developing locally, so handles the SSL/TLS setup itself. On top of that, Visual Studio should trust the IIS development certificate as part of installation, so you may never see the browser warnings at all!

The .NET Core and IIS development certificates make it easy to use Kestrel with HTTPS locally, but those certificates won’t help you once you move to production. In the next section, I show how to configure Kestrel to use a production TLS certificate.

18.1.2 Configuring Kestrel with a production HTTPS certificate

Creating a TLS certificate for production is often a laborious process, as it requires proving to a third-party certificate authority (CA) that you own the domain you’re creating the certificate for. This an important step in the “trust” process and ensures that attackers can’t impersonate your servers. The result of the process is one or more files, which is the HTTPS certificate you need to configure for your app.

> **TIP** The specifics of how to obtain a certificate vary by provider, and by your OS platform, so follow your provider’s documentation carefully. The vagaries and complexities of this process is one of the reasons I strongly favor the SSL/TLS-offloading or “one-click” approaches described previously. Those approaches mean my apps don’t need to deal with certificates, and I don’t need to use the approaches described in section 18.1.2; I delegate that responsibility to another piece of the network, or the underlying platform.

Once you have a certificate, you need to configure Kestrel to use it to serve HTTPS traffic. In chapter 16, you saw how to set the port your application listens on with the `ASPNETCORE_URLS` environment variable or via the command line, and you saw that you could provide an https URL. As you didn’t provide any certificate configuration, Kestrel used the development certificate by default. In production, you need to tell Kestrel which certificate to use.

Kestrel is very configurable, allowing you to configure your certificates in multiple ways. You can use different certificates for different ports, you can load from a .pfx file or from the OS certificate store, or you can have different configuration for each URL endpoint you expose. For full details, see the documentation at https://docs.microsoft.com/aspnet/core/fundamentals/servers/kestrel#endpoint-configuration.

The following listing shows one possible way to set a custom HTTPS certificate for your production app, by configuring the default certificate Kestrel uses for HTTPS connections. You can add the "`Kestrel:Certificates:Default`" section to your appsettings.json file (or using any other configuration source, as described in chapter11) to define the pfx file of the certificate to use. You must also provide the password for accessing the certificate.

Listing 18.1 Configuring the default HTTPS certificate for Kestrel using a pfx file

```
{
  "Kestrel": {                                      #A
    "Certificates": {                               #A
      "Default": {                                  #A
        "Path": "localhost.pfx",                    #B
        "Password": "testpassword"                  #C
      }
    }
  }
}
```

#A Create a configuration section at Kestrel:Certificates:Default
#B The relative or absolute path to the certificate
#C The password for opening the certificate

The example above is the simplest way to replace the HTTPS certificate, as it doesn't require changing any of Kestrel's defaults. You can use a similar approach to load the HTTPS certificate from the OS certificate store (on Windows or macOS), as shown in the documentation: https://docs.microsoft.com/aspnet/core/fundamentals/servers/kestrel#endpoint-configuration.

> **WARNING** Listing 18.1 has hardcoded the certificate filename and password for simplicity, but you should either load these from a configuration store like user-secrets, as you saw in Chapter 11, or load the certificate from the local store. **Never** put production passwords in your appsettings.json files.

All the default ASP.NET Core templates configure your application to serve both HTTP and HTTPS traffic, and with the configuration you've seen so far, you can ensure your application can handle both HTTP and HTTPS in development and in production.

However, whether you use HTTP or HTTPS may depend on the URL users use when they first browse to your app. For example, if your app listens using the default URLS, http://localhost:5000 for HTTP traffic and https://localhost:5001 for HTTPS traffic, then if a user navigates to the HTTP URL, then their traffic will be unencrypted. Seeing as you've gone to all the trouble to set up HTTPS, it's probably best that you force users to use it!

18.1.3 Enforcing HTTPS for your whole app

Enforcing HTTPS across your whole website is practically required these days. Browsers are beginning to explicitly label HTTP pages as insecure, for security reasons you *must* use TLS any time you're transmitting sensitive data across the internet, and thanks to HTTP/2,[85] adding TLS can *improve* your app's performance.

There are multiple approaches to enforcing HTTPS for your application. If you're using a reverse proxy with SSL/TLS-offloading, then that might be handled for you anyway, without having to worry about it within your apps. Nevertheless, it doesn't hurt to enforce SSL/TLS in your applications too, regardless of what the reverse may be doing.

> **NOTE** If you're building a Web API, rather than a Razor Pages app, then it's common to just reject HTTP requests, without using the approaches described in this section. These protections apply primarily when

[85] HTTP/2 offers many performance improvements over HTTP/1.x, and all modern browsers require HTTPS to enable it. For a great introduction to HTTP/2, see https://developers.google.com/web/fundamentals/performance/http2/.

building apps to be consumed in a browser. For more details, see https://docs.microsoft.com/aspnet/core/security/enforcing-ssl.

One approach to improving the security of your app is to use HTTP *security headers*. These are HTTP headers, sent as part of your HTTP response, which tell the browser how it should behave. There are many different headers available, most of which restrict the features your app can use in exchange for increased security[86]. In the next chapter, you'll see how to add your own custom headers to your HTTP responses by creating custom middleware.

One of these security headers, the HTTP Strict Transport Security (HSTS) header, can help ensure browsers use HTTPS where it's available, instead of defaulting to HTTP.

ENFORCING HTTPS WITH HTTP STRICT TRANSPORT SECURITY HEADERS

It's unfortunate, but by default, browsers always load apps over HTTP, unless otherwise specified. That means your apps typically must support both HTTP and HTTPS, even if you don't want to serve any traffic over HTTP. One mitigation for this (and a security best practice), is to add HTTP Strict Transport Security headers to your responses.

DEFINITION HTTP Strict Transport Security (HSTS) is a header that instructs the browser to use HTTPS for all *subsequent* requests to your application. The browser will no longer send HTTP requests to your app and will only use HTTPS instead. It can only be sent with responses to HTTPS requests.

HSTS headers are strongly recommended for *production* apps. You generally don't want to enable them for local development, as that would mean you can never run a non-HTTPS app locally! In a similar fashion, you should only use HSTS sites for which you *always* intend to use HTTPS, as it's hard (sometimes impossible) to "turn-off" HTTPS once it's enforced with HSTS!

ASP.NET Core comes with a built-in middleware for setting HSTS headers, which is included in some of the default templates automatically. The following listing shows how you can configure the HSTS headers for your application using the `HstsMiddleware` in Startup.cs.

Listing 18.2 Using HstsMiddleware to add HSTS headers to an application

```
public class Startup
{
    public void ConfigureServices(IServiceCollection services)
    {
        services.AddRazorPages();
        services.AddHsts(options =>                         #A
        {                                                   #A
            options.MaxAge = TimeSpan.FromHours(1);         #A
        });                                                 #A
    }
```

[86] Scott Helme has some great guidance on, this and other security headers you can add to your site: https://scotthelme.co.uk/hardening-your-http-response-headers/ .

```
    public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
    {
        if (env.IsProduction())                         #B
        {
            app.UseHsts();                              #C
        }

        app.UseStaticFiles();                           #D
        app.UseRouting();                               #D
        app.UseAuthorization();                         #D
        app.UseEndpoints(endpoints =>                   #D
        {                                               #D
            endpoints.MapRazorPages();                  #D
        });                                             #D
    }
}
```

#A Configure your HSTS header settings. This changes the MaxAge from the default of 30 days.
#B You shouldn't use HSTS in local environments
#C Adds the HstsMiddleware.
#D The HstsMiddleware should be very early in the middleware pipeline.

> **TIP** The example above shows how to change the `MaxAge` sent in the HSTS header. It's a good idea to start with a small value initially. Once you're sure your app's HTTPS is functioning correctly, increase the age for greater security. For more details, on HSTS see https://scotthelme.co.uk/hsts-the-missing-link-in-tls/.

HSTS is a great option for forcing users to use HTTPS on your website. But one problem with the header is that it can only be added to HTTPS requests. That means you must have *already* made an HTTPS request before HSTS kicks-in: if the *initial* request is HTTP, then no HSTS header is sent, and you *stay* on HTTP! That's unfortunate, but you can mitigate it by redirecting insecure requests to HTTPS immediately.

REDIRECTING FROM HTTP TO HTTPS WITH THE HTTPS REDIRECTION MIDDLEWARE

The `HstsMiddleware` should generally be used in conjunction with middleware that redirects all HTTP requests to HTTPS.

> **TIP** It's possible to apply HTTPS redirection to only parts of your application, for example to specific Razor Pages, but I don't recommend that, as it's too easy to open up a security hole in your application.

ASP.NET Core comes with `HttpsRedirectionMiddleware`, which you can use to enforce HTTPS across your whole app. You add it to the middleware pipeline in the `Configure` section of `Startup`, and it ensures that any requests that pass through it are secure. If an HTTP request reaches the `HttpsRedirectionMiddleware`, the middleware immediately short-circuits the pipeline with a redirect to the HTTPS version of the request. The browser will then repeat the request using HTTPS instead of HTTP.

NOTE The eagle-eyed among you will notice that even with the HSTS and redirection middleware, there is still an inherent weakness. By default, browsers will always make an initial, *insecure*, request over HTTP to your app. The only way to avoid this is by HSTS-preloading, which tells browsers to *always* use HTTPS. You can find a great guide to HSTS, including preloading, here https://www.forwardpmx.com/insights/blog/the-ultimate-guide-to-hsts-protocol/.

The `HttpsRedirectionMiddleware` is added in the default ASP.NET Core templates. It is typically placed after the error handling and `HstsMiddleware`, as shown in the following listing. By default, the middleware redirects all HTTP requests to the secure endpoint, using an HTTP `307 Temporary Redirect` status code.

Listing 18.3 Using `RewriteMiddleware` to enforce HTTPS for an application

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
        app.UseExceptionHandler("/Error");
        if (env.IsProduction())
        {
            app.UseHsts();
        }

        app.UseHttpsRedirection();                          #A
        app.UseStaticFiles();
        app.UseRouting();
        app.UseAuthorization();
        app.UseEndpoints(endpoints =>
        {
            endpoints.MapRazorPages();
        });
    }
}
```

#A Adds the HttpsRedirectionMiddleware to the pipeline. Redirects all HTTP requests to HTTPS.

The `HttpsRedirectionMiddleware` will automatically redirect HTTP requests to the first configured HTTPS endpoint for your application. If your application isn't configured for HTTPS, the middleware *won't* redirect, and instead will log a warning:

```
warn: Microsoft.AspNetCore.HttpsPolicy.HttpsRedirectionMiddleware[3]
      Failed to determine the https port for redirect.
```

If you want the middleware to redirect to a different port than Kestrel knows about, you can configure that by setting the `ASPNETCORE_HTTPS_PORT` environment variable. This is sometimes necessary if you're using a reverse-proxy, and can be set in alternative ways, as described in https://docs.microsoft.com/aspnet/core/security/enforcing-ssl.

SSL/TLS offloading, header forwarding, and detecting secure requests

At the start of section 18.1, I encouraged you to consider terminating HTTPS requests at a reverse proxy. That way, the user uses HTTPS to talk to the reverse proxy, and the reverse proxy talks to your app using HTTP. With this setup, your users are protected but your app doesn't have to deal with TLS certificates itself.

In order for the `HttpsRedirectionMiddleware` to work correctly, Kestrel needs some way of knowing whether the *original* request that the reverse proxy received was over HTTP or HTTPS. The reverse proxy communicates to your app over HTTP, so Kestrel can't figure that out without extra help.

The standard approach used by most reverse proxies (such as IIS, NGINX, and HAProxy) is to add additional headers to the request before forwarding it to your app. Specifically, a header called `X-Forwarded-Proto` is added, indicating whether the original request protocol was HTTP or HTTPS.

ASP.NET Core includes the `ForwardedHeadersMiddleware` to look for this header (and others) and update the request accordingly, so your app treats a request that was *originally* secured by HTTPS as secure for all intents and purposes.

If you're using IIS with the `UseIisIntegration()` extension, the header forwarding is handled for you automatically. If you're using a different reverse proxy, such as NGINX or HAProxy, then you can enable the middleware by setting the environment variable `ASPNETCORE_FORWARDEDHEADERS_ENABLED=true`, as you saw in chapter 16. Alternatively, you can manually add the middleware to your application, as shown in section 16.3.2.

When the reverse proxy forwards a request, `ForwardedHeadersMiddleware` will look for the `X-Forwarded-Proto` header and will update the request details as appropriate. For all subsequent middleware, the request is considered secure. When adding the middleware manually, it's important you place `ForwardedHeadersMiddleware` before the call to `UseHsts()` or `UseHttpsRedirection()`, so that the forwarded headers are read and the request is marked secure, as appropriate.

HTTPS is one of the most basic requirements for adding security to your application these days. It can be tricky to set up initially, but once you're up and running, you can largely forget about it, especially if you're using SSL/TLS termination at a reverse proxy.

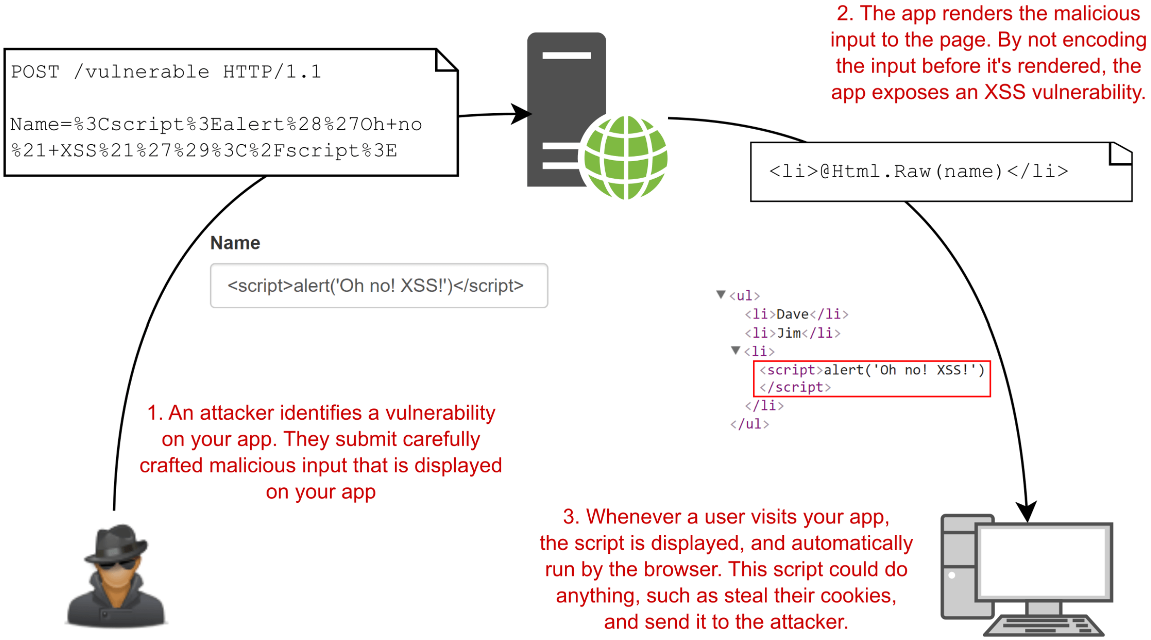
Unfortunately, most other security practices require rather more vigilance to ensure you don't accidentally introduce vulnerabilities into your app as it grows and develops. Many attacks are conceptually simple and have been known about for years, yet they're still commonly found in new applications. In the next section, we look at one such attack and see how to defend against it when building apps using Razor Pages.

18.2 Defending against cross-site scripting (XSS) attacks

In this section, I describe cross-site scripting attacks and how attackers can use them to compromise your users. I show how the Razor Pages framework protects you from these attacks, how to disable the protections when you need to, and what to look out for. I also discuss the difference between HTML-encoding and JavaScript-encoding, and the impact of using the wrong encoder.

Attackers can exploit a vulnerability in your app to create cross-site scripting (XSS) attacks[87] that execute code in another user's browser. Commonly, attackers submit content using a legitimate approach, such as an input form, which is later rendered somewhere to the page. By carefully crafting malicious input, the attacker can execute arbitrary JavaScript on a user's browsers, and so can steal cookies, impersonate the user, and generally do bad things.

Figure 18.5 shows a basic example of an XSS attack. Legitimate users of your app can send their name to your app by submitting a form. The app then adds the name to an internal list and renders the whole list to the page. If the names are not rendered safely, then a malicious user can execute JavaScript in the browser of every other user that views the list.



2. The app renders the malicious input to the page. By not encoding the input before it's rendered, the app exposes an XSS vulnerability.

```
POST /vulnerable HTTP/1.1

Name=%3Cscript%3Ealert%28%27Oh+no
%21+XSS%21%27%29%3C%2Fscript%3E
```

```
<li>@Html.Raw(name)</li>
```

```
▼<ul>
   <li>Dave</li>
   <li>Jim</li>
  ▼<li>
     <script>alert('Oh no! XSS!')
     </script>
   </li>
 </ul>
```

1. An attacker identifies a vulnerability on your app. They submit carefully crafted malicious input that is displayed on your app

3. Whenever a user visits your app, the script is displayed, and automatically run by the browser. This script could do anything, such as steal their cookies, and send it to the attacker.

Figure 18.5 How an XSS vulnerability is exploited. An attacker submits malicious content to your app, which is displayed in the browser of other users. If the app doesn't encode the content when writing to the page, the input becomes part of the HTML of the page and can run arbitrary JavaScript.

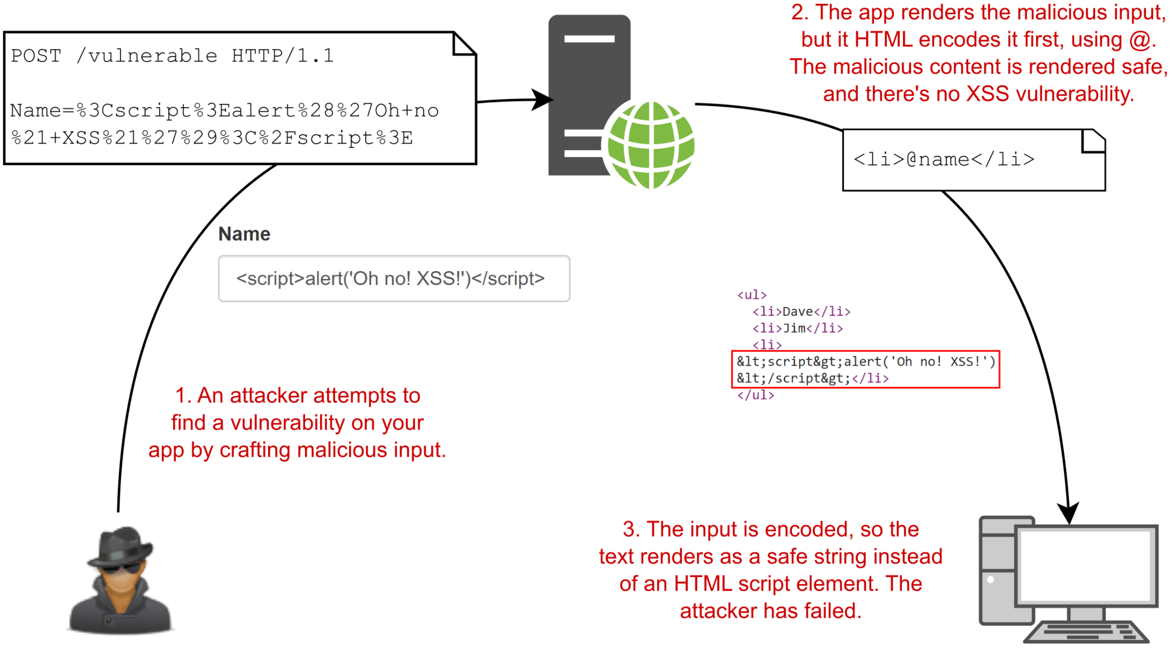
In figure 18.5, the user entered a snippet of HTML such as their name. When users view the list of names, the Razor template renders the names using `@Html.Raw()`, which writes the `<script>` tag directly to the document. The user's input has become part of the page's HTML

[87] For a detailed discussion, see OWASP at https://owasp.org/www-community/attacks/xss/.

structure. As soon as the page is loaded in the user's browser, the `<script>` tag executes, and the user is compromised. Once an attacker can execute arbitrary JavaScript on a user's browser, they can do pretty much anything.

The vulnerability here is due to rendering the user input in an unsafe way. If the data isn't encoded to make it safe before it's rendered, then you could open your users to attack. *By default, Razor protects against XSS attacks* by HTML-encoding any data written using Tag Helpers, HTML Helpers, or the `@` syntax. So, generally, you should be safe, as you saw in chapter 7.

Using `@Html.Raw()` is where the danger lies—if the HTML you're rendering contains user input (even indirectly), then you could have an XSS vulnerability. By rendering the user input with `@` instead, the content is encoded before it's written to the output, as shown in figure 18.6.



```
POST /vulnerable HTTP/1.1

Name=%3Cscript%3Ealert%28%27Oh+no
%21+XSS%21%27%29%3C%2Fscript%3E
```

```
<li>@name</li>
```

```
<ul>
  <li>Dave</li>
  <li>Jim</li>
  <li>
&lt;script&gt;alert('Oh no! XSS!')
&lt;/script&gt;</li>
</ul>
```

Name
<script>alert('Oh no! XSS!')</script>
1. An attacker attempts to find a vulnerability on your app by crafting malicious input.
2. The app renders the malicious input, but it HTML encodes it first, using @. The malicious content is rendered safe, and there's no XSS vulnerability.
3. The input is encoded, so the text renders as a safe string instead of an HTML script element. The attacker has failed.

Figure 18.6 Protecting against XSS attacks by HTML encoding user input using `@` in Razor templates. The <script> tag is encoded so that it is no longer rendered as HTML, and can't be used to compromise your app.

This example demonstrates using HTML encoding to prevent elements being directly added to the HTML DOM, but it's not the only case you have to think about. If you're passing untrusted data to JavaScript, or using untrusted data in URL query values, you must make sure you encode the data correctly.

A common scenario is when you're using jQuery or JavaScript with Razor pages, and you want to pass a value from the server to the client. If you use the standard `@` symbol to render the data to the page, then the output will be HTML-encoded. Unfortunately, if you HTML encode a string and inject it directly into JavaScript, you probably won't get what you expect.

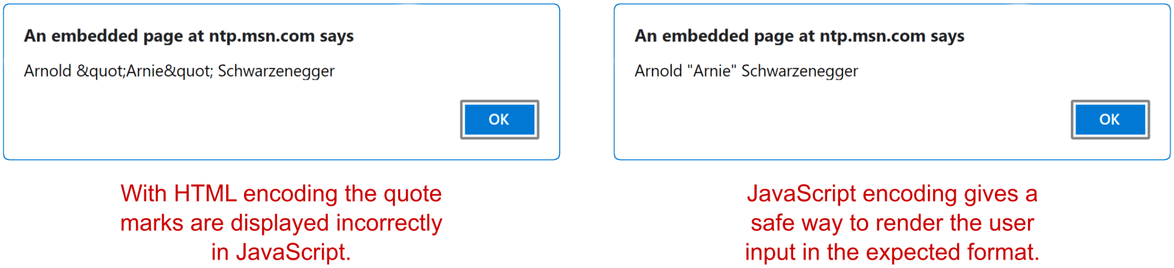
For example, if you have a variable in your Razor file called `name`, and you want to make it available in JavaScript, you might be tempted to use something like

```
<script>var name = '@name'</script>
```

If the name contains special characters, Razor will encode them using HTML encoding, which probably isn't what you want in this JavaScript context. For example, if `name` was `Arnold "Arnie" Schwarzenegger`, then rendering it as you did previously would give:

```
<script>var name = 'Arnold &quot;Arnie&quot; Schwarzenegger';</script>
```

Note how the quotation marks `"` have been HTML-encoded to `&quot;`. If you use this value in JavaScript directly, expecting it to be a "safe" encoded value, then it's going to look wrong, as shown in figure 18.7.



An embedded page at ntp.msn.com says

Arnold &quot;Arnie&quot; Schwarzenegger

With HTML encoding the quote marks are displayed incorrectly in JavaScript.

An embedded page at ntp.msn.com says

Arnold "Arnie" Schwarzenegger

JavaScript encoding gives a safe way to render the user input in the expected format.

Figure 18.7 Comparison of alerts when using JavaScript encoding compared to HTML encoding

Instead, you should encode the variable using JavaScript encoding so that the `"` is rendered as a safe Unicode character, `\u0022`. You can achieve this by injecting a `Java-ScriptEncoder` into the view (as you saw in chapter 10) and calling `Encode()` on the `name` variable:

```
@inject System.Text.Encodings.Web.JavaScriptEncoder encoder;
<script>var name = '@encoder.Encode(name)'</script>
```

To avoid having to remember to use JavaScript encoding, I recommend you don't write values into JavaScript like this. Instead, write the value to an HTML element's attributes, and then read that into the JavaScript variable later. That avoids the need for the JavaScript encoder entirely.

Listing 18.4 Passing values to JavaScript by writing them to HTML attributes

```
<div id="data" data-name="@name"></div>        #A
<script>
```

```
var ele = document.getElementById('data');      #B
var name = ele.getAttribute('data-name');      #C
</script>
```

#A Write the value you want in JavaScript to a data-* attribute. This will HTML encode the data.
#B Gets a reference to the HTML element
#C Reads the data-* attribute into JavaScript, which will convert it to JavaScript encoding

XSS attacks are still common, and it’s easy to expose yourself to them whenever you allow users to input data. Validation of the incoming data can sometimes help, but it’s often a tricky problem. For example, a naive name validator might require that you only use letters, which would prevent most attacks. Unfortunately, that doesn’t account for users with hyphens or apostrophes in their name, let alone users with non-western names. People get (understandably) upset when you tell them their name is invalid, so be wary of this approach!

Whether or not you use strict validation, you should always encode the data when you render it to the page. Think carefully whenever you find yourself writing `@Html.Raw()`. Is there any way for a user to get malicious data into that field? If so, you’ll need to find another way to display the data.

XSS vulnerabilities allow attackers to execute JavaScript on a user’s browser. The next vulnerability we’re going to consider lets them make requests to your API as though they’re a different logged-in user, even when the user isn’t using your app. Scared? I hope so!

18.3 Protecting from cross-site request forgery (CSRF) attacks

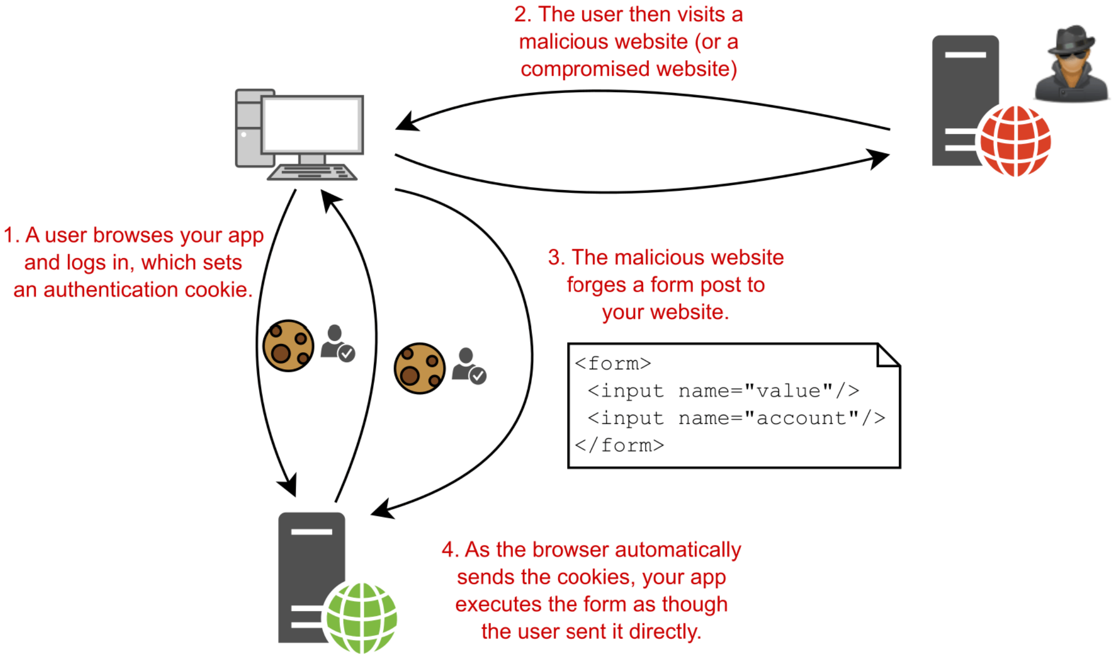
In this section you’ll learn about cross-site request forgery attacks, how attackers can use them to impersonate a user on your site, and how to protect against them using anti-forgery tokens. Razor Pages protects you from these attacks by default, but you can disable these verifications, so it’s important to understand the implications of doing so.

Cross-site request forgery (CSRF) attacks can be a problem for websites or APIs that use cookies for authentication. A CSRF attack involves a malicious website making an authenticated request to your API on behalf of the user, without the user initiating the request. In this section, we’ll explore how these attacks work and how you can mitigate them with anti-forgery tokens.

The canonical example of this attack is a bank transfer/withdrawal. Imagine you have a banking application that stores authentication tokens in a cookie, as is common (especially in traditional server-side rendered applications). Browsers automatically send the cookies associated with a domain with every request, so the app knows whether a user is authenticated.

Now imagine your application has a page that lets a user transfer funds from their account to another account, using a POST request to the `Balance` Razor Page. You have to be logged in to access the form (you’ve protected the Razor Page with the `[Authorize]` attribute), but otherwise you post a form that says how much you want to transfer, and where you want to transfer it.

Imagine a user visits your site, logs in, and performs a transaction. They then visit a second website that the attacker has control of. The attacker has embedded a form on their website that performs a POST to your bank’s website, identical to the transfer funds form on your banking website. This form does something malicious, such as transfer all the user’s funds to the attacker, as shown in figure 18.8. Browsers automatically send the cookies for the application when the page does a full form post, and the banking app has no way of knowing that this is a malicious request. The unsuspecting user has given all their money to the attacker!


2. The user then visits a malicious website (or a compromised website)
1. A user browses your app and logs in, which sets an authentication cookie.
3. The malicious website forges a form post to your website.
4. As the browser automatically sends the cookies, your app executes the form as though the user sent it directly.

```
<form>
 <input name="value"/>
 <input name="account"/>
</form>
```

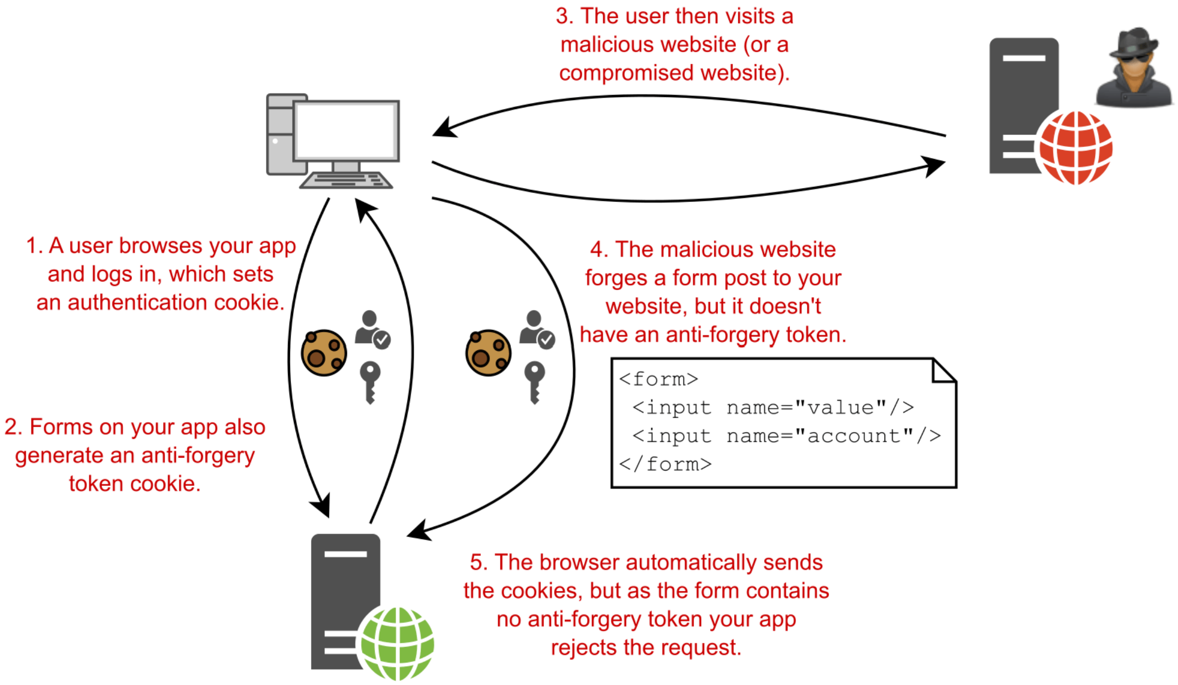
Figure 18.8 A CSRF attack occurs when a logged-in user visits a malicious site. The malicious site crafts a form that matches one on your app and POSTs it to your app. The browser sends the authentication cookie automatically, so your app sees the request as a valid request from the user.

The vulnerability here revolves around the fact that browsers automatically send cookies when a page is requested (using a GET request) or a form is POSTed. There’s no difference between a legitimate POST of the form in your banking app and the attacker’s malicious POST.

Unfortunately, this behavior is baked into the web; it’s what allows you to navigate websites seamlessly after initially logging in.

A common solution to the attack is the *synchronizer token* pattern,[88] which uses user-specific, unique, anti-forgery tokens to enforce a difference between a legitimate POST and a forged POST from an attacker. One token is stored in a cookie and another is added to the form you wish to protect. Your app generates the tokens at runtime based on the current logged-in user, so there’s no way for an attacker to create one for their forged form.

When the `Balance` Razor Page receives a form POST, it compares the value in the form with the value in the cookie. If either value is missing, or they don’t match, then the request is rejected. If an attacker creates a POST, then the browser will post the cookie token as usual, but there won’t be a token in the form itself, or the token won’t be valid. The Razor Page will reject the request, protecting from the CSRF attack, as in figure 18.9.


3. The user then visits a malicious website (or a compromised website).
1. A user browses your app and logs in, which sets an authentication cookie.
4. The malicious website forges a form post to your website, but it doesn't have an anti-forgery token.
2. Forms on your app also generate an anti-forgery token cookie.
5. The browser automatically sends the cookies, but as the form contains no anti-forgery token your app rejects the request.

```
<form>
 <input name="value"/>
 <input name="account"/>
</form>
```

Figure 18.9 Protecting against a CSRF attack using anti-forgery tokens. The browser automatically forwards the cookie token, but the malicious site can’t read it, and so can’t include a token in the form. The app rejects the malicious request as the tokens don’t match.

[88] The OWASP site gives a thorough discussion of the CSRF vulnerability, including the synchronizer token pattern: https://cheatsheetseries.owasp.org/cheatsheets/Cross-Site_Request_Forgery_Prevention_Cheat_Sheet.

The good news is that Razor Pages automatically protects you against CSRF attacks! The Form Tag Helper automatically sets an anti-forgery token cookie and renders the token to a hidden field called `__RequestVerificationToken` for every `<form>` element in your app (unless you specifically disable them). For example, take this simple Razor template that posts back to the same Razor Page:

```
<form method="post">
    <label>Amount</label>
    <input type="number" name="amount" />
    <button type="submit">Withdraw funds</button>
</form>
```

When rendered to HTML, the anti-forgery token is stored in the hidden field and posted back with a legitimate request:

```
<form method="post">
    <label>Amount</label>
    <input type="number" name="amount" />
    <button type="submit" >Withdraw funds</button>
    <input name="__RequestVerificationToken" type="hidden"
        value="CfDJ8Daz26qb0hBGsw7QCK">
</form>
```

ASP.NET Core automatically adds the anti-forgery tokens to every form, and Razor Pages automatically validates them. The framework ensures the anti-forgery tokens exist in both the cookie and the form data, ensures that they match, and will reject any requests where they don't.

If you're using MVC controllers with views instead of Razor Pages, ASP.NET Core still adds the anti-forgery tokens to every form. Unfortunately, it *doesn't* validate them for you. Instead, you have to decorate your controllers and actions with `[ValidateAntiForgeryToken]` attributes. These ensure the anti-forgery tokens exist in both the cookie and the form data, ensures they match, and will reject any requests where they don't.

> **WARNING** **ASP.NET Core *doesn't* automatically validate anti-forgery tokens if you're using MVC controllers with Views. You must make sure you mark all vulnerable methods with** `[ValidateAntiForgeryToken]` **attributes instead, as described in the documentation: https://docs.microsoft.com/aspnet/core/security/anti-request-forgery. Note that if you're using Web API controllers and are *not* using cookies for authentication, then you are not vulnerable to CSRF attacks.**

Generally, you only need to use anti-forgery tokens for POST, DELETE, and other dangerous request types that are used for modifying state. GET requests shouldn't be used for this purpose, so the framework doesn't require valid anti-forgery tokens to call them. Razor Pages validates anti-forgery tokens for dangerous verbs like POST and ignores safe verbs like GET. As long as you create your app following this pattern (and you should!), then the framework will do the right thing to keep you safe.

If you need to explicitly ignore anti-forgery tokens on a Razor Page for some reason, you can disable the validation by applying the `[IgnoreAntiforgeryToken]` attribute to a Razor

Page’s `PageModel`. This bypasses the framework protections, for those cases where you’re doing something that you know is safe and doesn’t need protecting, but in most cases it’s better to play it safe and validate, just in case.

CSRF attacks can be a tricky thing to get your head around from a technical point of view, but for the most part everything *should* work without much effort on your part. Razor will add anti-forgery tokens to your forms, and the Razor Pages framework will take care of validation for you.

Where things get trickier is if you’re making a lot of requests to an API using JavaScript and you’re posting JSON objects rather than form data. In these cases, you won’t be able to send the verification token as part of a form (as you’re sending JSON), so you’ll need to add it as a header in the request instead.[89]

> **TIP** If you’re not using cookie authentication, and instead have an SPA that sends authentication tokens in a header, then good news—you don’t have to worry about CSRF at all! Malicious sites can only send cookies, not headers, to your API, so they can’t make authenticated requests.

Generating unique tokens with the Data Protection APIs

The anti-forgery tokens used to prevent CSRF attacks rely on the ability of the framework to use strong symmetric encryption to encrypt and decrypt data. Encryption algorithms typically rely on one or more keys, which are used to initialize the encryption and to make the process reproducible. If you have the key, you can encrypt and decrypt data; without it, the data is secure.

In ASP.NET Core, encryption is handled by the Data Protection APIs. They’re used to create the anti-forgery tokens, to encrypt authentication cookies, and to generate secure tokens in general. Crucially, they also control the management of the *key files* that are used for encryption.

A key file is a small XML file that contains the random key value used for encryption in ASP.NET Core apps. It’s critical that it’s stored securely—if an attacker got hold of it, they could impersonate any user of your app, and generally do bad things!

The Data Protection system stores the keys in a safe location, depending on how and where you host your app. For example:

- *Azure Web App*—In a special synced folder, shared between regions.
- *IIS without user profile*—Encrypted in the registry.
- *Account with user profile*—In %LOCALAPPDATA%\ASP.NET\DataProtection-Keys on Windows, or ~/.aspnet/DataProtection-Keys on Linux or macOS.
- *All other cases*—In memory. When the app restarts, the keys will be lost.

So why do you care? In order for your app to be able to read your users’ authentication cookies, it must decrypt them using the same key that was used to encrypt them. If you’re running in a web-farm scenario, then, by default, each server will have its own key and won’t be able to read cookies encrypted by other servers.

To get around this, you must configure your app to store its data protection keys in a central location. This could be a shared folder on a hard drive, a Redis instance, or an Azure blob storage instance, for example.

[89] Exactly how you do this varies depending on the JavaScript framework you’re using. The documentation contains examples using JQuery and AngularJS, but you should be able to extend this to your JavaScript framework of choice: http://mng.bz/54Sl.

The documentation on the data protection APIs is extremely detailed, but it can be overwhelming. I recommend reading the section on configuring data protection, (http://mng.bz/d40i) and configuring a key storage provider for use in a web-farm scenario (http://mng.bz/5pW6).

It's worth clarifying that the CSRF vulnerability discussed in this section requires that a malicious site does a full form POST to your app. The malicious site can't make the request to your API using *client-side only* JavaScript, as browsers will block JavaScript requests to your API that are from a different origin.

This is a safety feature, but it can often cause you problems. If you're building a client-side SPA, or even if you have a little JavaScript on an otherwise server-side rendered app, you may find you need to make such *cross-origin* requests. In the next section, I'll describe a common scenario you're likely to run into and show how you can modify your apps to work around it.

18.4 Calling your web APIs from other domains using CORS

In this section you'll learn about cross-origin resource sharing (CORS), a protocol to allow JavaScript to make requests from one domain to another. CORS is a frequent area of confusion for many developers, so this section describes why it's necessary, and how CORS headers work. You'll then learn how to add CORS to both your whole application and specific Web API actions, and how to configure multiple CORS policies for your application.

As you've already seen, CSRF attacks can be powerful, but they would be even more dangerous if it weren't for browsers implementing the *same-origin* policy. This policy blocks apps from using JavaScript to call a web API at a different location unless the web API explicitly allows it.

> **DEFINITION** *Origins* are deemed the same if they match the scheme (HTTP or HTTPS), domain (example.com), *and* port (80 by default for HTTP, and 443 for HTTPS). If an app attempts to access a resource using JavaScript and the origins aren't identical, the browser blocks the request.

The same-origin policy is strict—the origins of the two URLs must be identical for the request to be allowed. For example, the following origins are the same:

- http://example.com/home
- http://example.com/site.css

The paths are different for these two URLs (`/home` and `/sites.css`), but the scheme, domain, and port (80) are identical. So, if you were on the homepage of your app, you could request the `/sites.css` file using JavaScript without any issues.

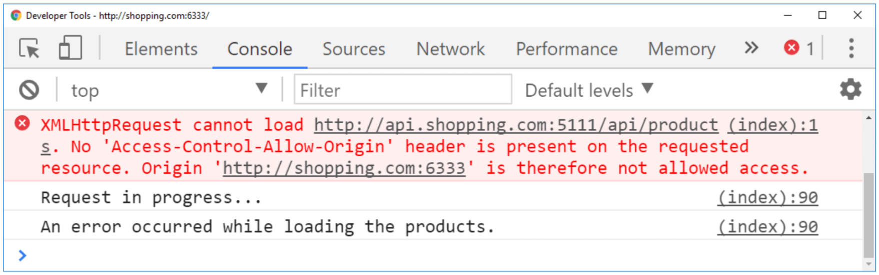
In contrast, the origins of the following sites are all different, so you couldn't request any of these URLs using JavaScript from the http://example.com origin:

- *https://example.com*—Different scheme (https)
- *http://www.example.com*—Different domain (includes a subdomain)

- *http://example.com:5000*—Different port (default HTTP port is 80)

For simple apps, where you have a single web app handling all of your functionality, this limitation might not be a problem, but it’s extremely common for an app to make requests to another domain.

For example, you might have an e-commerce site hosted at http://shopping.com, and you’re attempting to load data from http://api.shopping.com to display details about the products available for sale. With this configuration, you’ll fall foul of the same-origin policy. Any attempt to make a request using JavaScript to the API domain will fail, with an error similar to figure 18.10.



```
XMLHttpRequest cannot load http://api.shopping.com:5111/api/product (index):1
s. No 'Access-Control-Allow-Origin' header is present on the requested
resource. Origin 'http://shopping.com:6333' is therefore not allowed access.
Request in progress...                                          (index):90
An error occurred while loading the products.                   (index):90
```

The browser won't allow cross-origin requests by default, and will block your app from accessing the response.

Figure 18.10 The console log for a failed cross-origin request. Chrome has blocked a cross-origin request from the app http://shopping.com:6333 to the API at http://api.shopping.com:5111.

The need to make cross-origin requests from JavaScript is increasingly common with the rise of client-side SPAs and the move away from monolithic apps. Luckily, there’s a web standard that lets you work around this in a safe way; this standard is called cross-origin resource sharing (CORS). You can use CORS to control which apps can call your API, so you can enable scenarios like the one described earlier.

18.4.1 Understanding CORS and how it works

CORS is a web standard that allows your Web API to make statements about who can make cross-origin requests to it. For example, you could make statements such as

- Allow cross-origin requests from http://shopping.com and https://app.shopping.com
- Only allow GET cross-origin requests
- Allow returning the `Server` header in responses to cross-origin requests
- Allow credentials (such as authentication cookies or authorization headers) to be sent with cross-origin requests

You can combine these rules into a *policy* and apply different policies to different endpoints of your API. You could apply a policy to your entire application, or a different policy to every API action.

CORS works using HTTP headers. When your Web API application receives a request, it sets special headers on the response to indicate whether cross-origin requests are allowed, which origins they're allowed from, and which HTTP verbs and headers the request can use—pretty much everything about the request.

In some cases, before sending a real request to your API, the browser sends a *preflight* request. This is a request sent using the OPTIONS verb, which the browser uses to check whether it's allowed to make the real request. If the API sends back the correct headers, the browser will send the true cross-origin request, as shown in figure 18.11.

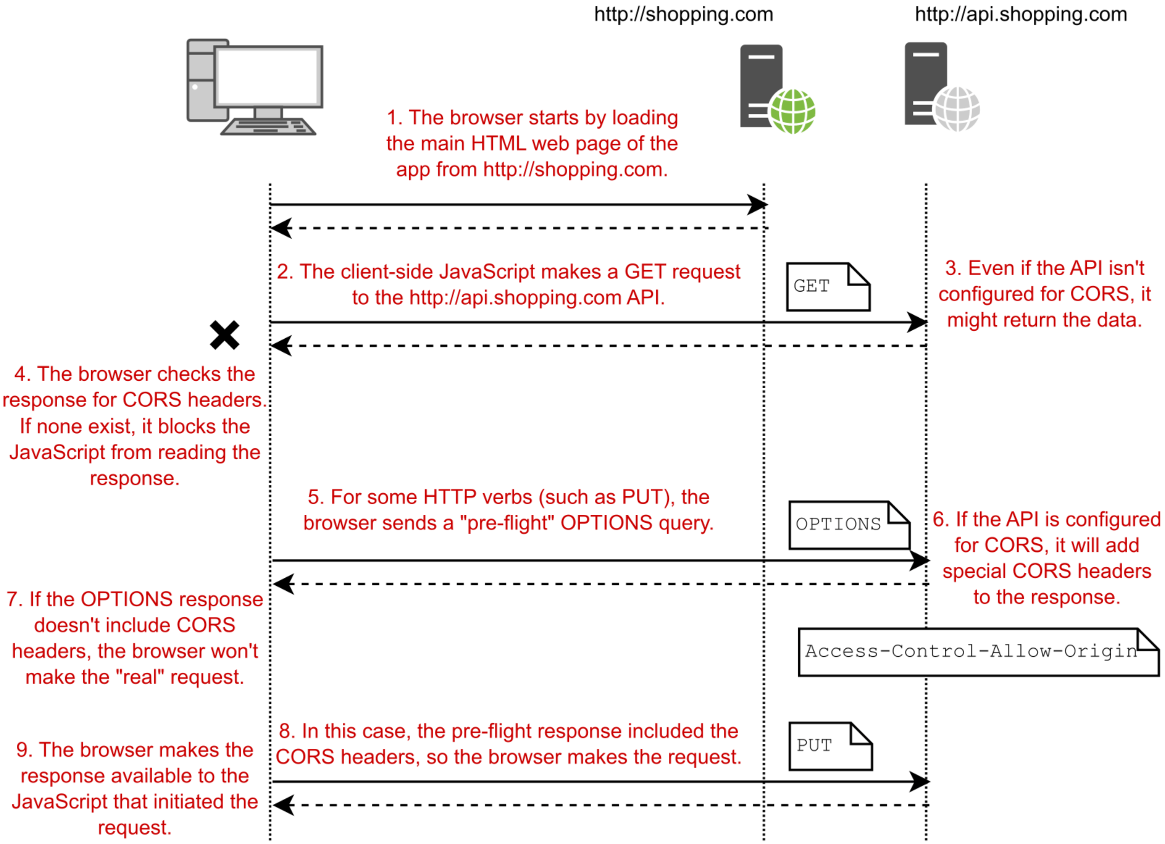

http://shopping.com
http://api.shopping.com
1. The browser starts by loading the main HTML web page of the app from http://shopping.com.
2. The client-side JavaScript makes a GET request to the http://api.shopping.com API.
GET
3. Even if the API isn't configured for CORS, it might return the data.
4. The browser checks the response for CORS headers. If none exist, it blocks the JavaScript from reading the response.
5. For some HTTP verbs (such as PUT), the browser sends a "pre-flight" OPTIONS query.
OPTIONS
6. If the API is configured for CORS, it will add special CORS headers to the response.
7. If the OPTIONS response doesn't include CORS headers, the browser won't make the "real" request.
Access-Control-Allow-Origin
8. In this case, the pre-flight response included the CORS headers, so the browser makes the request.
PUT
9. The browser makes the response available to the JavaScript that initiated the request.

Figure 18.11 Two cross-origin-requests. The response to the first request doesn't contain any CORS headers, so the browser blocks the app from reading it. The second request requires a preflight OPTIONS request, to check if CORS is enabled. As the response contains CORS headers, the real request can be made, and the response provided to the JavaScript app.

TIP For a more detailed discussion of CORS, see *CORS in Action* by Monsur Hossain (Manning, 2014), available at http://mng.bz/aD41.

The CORS specification, as with many technical documents, is pretty complicated,[90] with a variety of headers and processes to contend with. Thankfully, ASP.NET Core handles the details of the specification for you, so your main concern is working out exactly *who* needs to access your API, and under what circumstances.

18.4.2 Adding a global CORS policy to your whole app

Typically, you shouldn't set up CORS for your APIs until you need it. Browsers block cross-origin communication for a reason—it closes an avenue of attack—they're not being awkward! Wait until you have an API on a different domain to an app that needs to access it.

Adding CORS support to your application requires four things:

- Add the CORS services to your app.
- Configure at least one CORS policy.
- Add the CORS middleware to your middleware pipeline.
- Either set a default CORS policy for your entire app or decorate your Web API actions with the `[EnableCors]` attribute to selectively enable CORS for specific endpoints.

Adding the CORS services to your application involves calling `AddCors()` in your `Startup.ConfigureServices` method:

```
services.AddCors();
```

The bulk of your effort in configuring CORS will go into policy configuration. A CORS policy controls how your application will respond to cross-origin requests. It defines which origins are allowed, which headers to return, which HTTP methods to allow, and so on. You normally define your policies inline when you add the CORS services to your application.

For example, consider the previous e-commerce site example. You want your API that is hosted at http://api.shopping.com to be available from the main app via client-side JavaScript, hosted at http://shopping.com. You therefore need to configure the *API* to allow cross-origin requests.

> **NOTE** Remember, it's the main app that will get errors when attempting to make cross-origin requests, but it's the ***API*** you're accessing that you need to add CORS to, ***not*** the app making the requests.

The following listing shows how to configure a policy called `"AllowShoppingApp"` to enable cross-origin requests from http://shopping.com to the API. Additionally, we explicitly allow any HTTP verb type; without this call, only simple methods (GET, HEAD, and POST) are allowed. The policies are built up using the familiar "fluent builder" style you've seen throughout this book.

[90] If that's the sort of thing that floats your boat, you can read the spec here: https://fetch.spec.whatwg.org/#http-cors-protocol.

Listing 18.5 Configuring a CORS policy to allow requests from a specific origin

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddCors(options => {                         #A
        options.AddPolicy("AllowShoppingApp", policy =>   #B
            policy.WithOrigins("http://shopping.com")     #C
                .AllowAnyMethod());                       #D
    });
    // other service configuration
}
```

#A The AddCors method exposes an Action<CorsOptions> overload.
#B Every policy has a unique name.
#C The WithOrigins method specifies which origins are allowed. Note the URL has no trailing /.
#D Allows all HTTP verbs to call the API

> **WARNING** **When listing origins in** `WithOrigins()`**, ensure that they don't have a trailing** `"/"`**, otherwise the origin will never match and your cross-origin requests will fail.**

Once you've defined a CORS policy, you can apply it to your application. In the following listing, apply the `"AllowShoppingApp"` policy to the whole application using `CorsMiddleware` by calling `UseCors()` in the `Configure` method of Startup.cs.

Listing 18.6 Adding the CORS middleware and configuring a default CORS policy

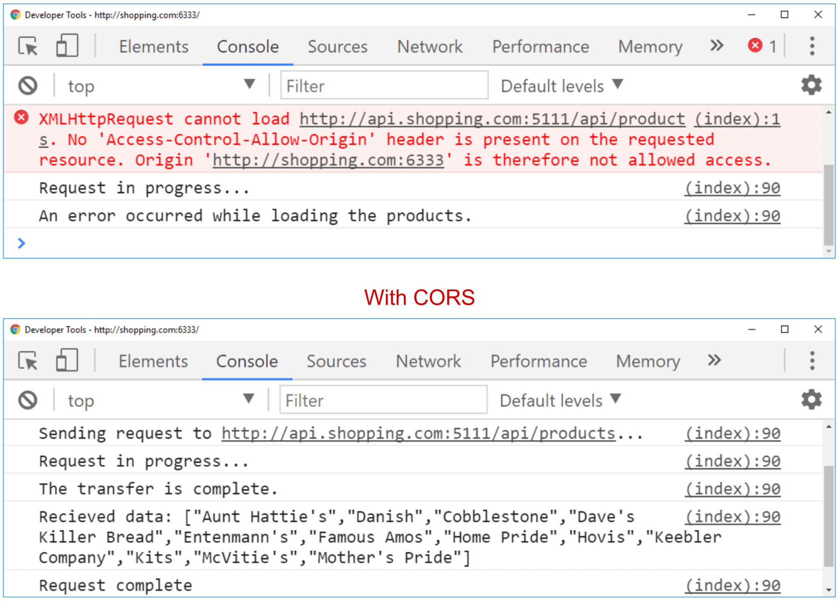
```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    app.UseRouting();                      #A

    app.UseCors("AllowShoppingApp");       #B
    app.UseAuthentication();
    app.UseAuthorization();

    app.UseEndpoints(endpoints =>          #C
    {
        endpoints.MapControllers();
    });
}
```

#A The CORS middleware must come after the call to UseRouting()
#B Adds the CORS middleware and uses AllowShoppingApp as the default policy
#B Place the CORS middleware before the endpoint middleware

> **NOTE** **As with all middleware, the order of the CORS middleware is important. You must place the call to** `UseCors()` ***after*** `UseRouting()` **and before** `UseEndpoints()`**.The CORS middleware needs to intercept cross-origin requests to your Web API actions, so it can generate the correct responses to preflight requests and add the necessary headers. It's typical to place the CORS middleware before the call to** `UseAuthentication()`.

With the CORS middleware in place for the API, the shopping app can now make cross-origin requests. You can call the API from the http://shopping.com site and the browser lets the

CORS request through, as shown in figure 18.12. If you make the same request from a domain other than http://shopping.com, the request continues to be blocked.



```
XMLHttpRequest cannot load http://api.shopping.com:5111/api/product (index):1
s. No 'Access-Control-Allow-Origin' header is present on the requested
resource. Origin 'http://shopping.com:6333' is therefore not allowed access.
Request in progress...                                          (index):90
An error occurred while loading the products.                   (index):90
```

The browser won't allow cross-origin requests by default, and will block your app from accessing the response.

With CORS

```
Sending request to http://api.shopping.com:5111/api/products... (index):90
Request in progress...                                          (index):90
The transfer is complete.                                       (index):90
Recieved data: ["Aunt Hattie's","Danish","Cobblestone","Dave's  (index):90
Killer Bread","Entenmann's","Famous Amos","Home Pride","Hovis","Keebler
Company","Kits","McVitie's","Mother's Pride"]
Request complete                                                (index):90
```

With CORS enabled, the API sends CORS headers with the response. The browser sees these headers, and passes the response to the JavaScript.

Figure 18.12 With CORS enabled, as in the lower image, cross-origin requests can be made and the browser will make the response available to the JavaScript. Compare this to the upper image, in which the request was blocked.

Applying a CORS policy globally to your application in this way may be overkill. If there’s only a subset of actions in your API that need to be accessed from other origins, then it’s prudent to only enable CORS for those specific actions. This can be achieved with the `[EnableCors]` attribute.

18.4.3 Adding CORS to specific Web API actions with EnableCorsAttribute

Browsers block cross-origin requests by default for good reason—they have the potential to be abused by malicious or compromised sites. Enabling CORS for your entire app may not be worth the risk if you know that only a subset of actions will ever need to be accessed cross-origin.

If that’s the case, it’s best to only enable a CORS policy for those specific actions. ASP.NET Core provides the `[EnableCors]` attribute, which lets you select a policy to apply to a given controller or action method.

This approach lets you apply different CORS policies to different action methods. For example, you could allow GET requests access to your entire API from the http://shopping.com domain, but only allow other HTTP verbs for a specific controller, while allowing anyone to access your product list action method.

You define these policies in `ConfigureServices` using `AddPolicy()` and giving the policy a name, as you saw in listing 18.5. However, instead of calling `UseCors("AllowShoppingApp")` as you saw in listing 18.6, add the middleware without a default policy, by calling `UseCors()` only.

To apply a policy to a controller or an action method, apply the `[EnableCors]` attribute, as shown in the following listing. An `[EnableCors]` attribute on an action takes precedence over an attribute on a controller, or you can use the `[DisableCors]` attribute to disable cross-origin access to the method entirely.

Listing 18.7 Applying the `EnableCors` attribute to a controller and action

```
[EnableCors("AllowShoppingApp")]                                  #A
public class ProductController: Controller
{
    [EnableCors("AllowAnyOrigin")                                 #B
    public IActionResult GeteProducts() { /* Method */ }

    public IActionResult GeteProductPrice(int id) { /* Method */ }   #C

    [DisableCors]
    public IActionResult DeleteProduct(int id) { /* Method */ }      #D
}
```

#A Applies the AllowShoppingApp CORS policy to every action method
#B The AllowAnyOrigin policy is “closer” to the action, so it takes precedence.
#C The AllowShoppingApp policy (from the controller) will be applied.
#D The DisableCors attribute disables CORS for the action method completely.

If you want to apply a CORS policy to most of your actions, but want to use a different policy or disable CORS entirely for some actions, you can pass a default policy when configuring the middleware using `UseCors("AllowShoppingApp")` for example. Actions decorated with `[EnableCors("OtherPolicy")]` will apply `OtherPolicy` preferentially, and actions decorated with `[DisableCors]` will not have CORS enabled at all.

Whether you choose to use a single, a default CORS policy or multiple policies, you need to configure the CORS policies for your application in `ConfigureServies`. Many different options are available when configuring CORS. In the next section, I provide an overview of the possibilities.

18.4.4 Configuring CORS policies

Browsers implement the cross-origin policy for security reasons, so you should carefully consider the implications of relaxing any of the restrictions they impose. Even if you enable cross-origin requests, you can still control what data cross-origin requests can send, and what your API will return. For example, you can configure:

- The origins that may make a cross-origin request to your API

- The HTTP verbs (such as GET, POST, and DELETE) that can be used
- The headers the browser can send
- The headers that the browser can read from your app's response
- Whether the browser will send authentication credentials with the request

You define all of these options when creating a CORS policy in your call to `AddCors()` using the `CorsPolicyBuilder`, as you saw in listing 18.5. A policy can set all, or none of these options, so you can customize the results to your heart's content. Table 18.1 shows some of the options available, and their effects.

Table 18.1 The methods available for configuring a CORS policy, and their effect on the policy

`CorsPolicyBuilder` method example	Result
`WithOrigins("http://shopping.com")`	Allows cross-origin requests from http://shopping .com.
`AllowAnyOrigin()`	Allows cross-origin requests from any origin. This means *any* website can make JavaScript requests to your API.
`WithMethods()/AllowAnyMethod()`	Sets the allowed methods (such as GET, POST, and DELETE) that can be made to your API.
`WithHeaders()/AllowAnyHeader()`	Sets the headers that the browser may send to your API. If you restrict the headers, you must include at least `"Accept"`, `"Content-Type"`, and `"Origin"` to allow valid requests.
`WithExposedHeaders()`	Allows your API to send extra headers to the browser. By default, only the `Cache-Control`, `Content-Language`, `Content-Type`, `Expires`, `Last-Modified`, and `Pragma` headers are sent in the response.
`AllowCredentials()`	By default, the browser won't send authentication details with cross-origin requests unless you explicitly allow it. You must also enable sending credentials client-side in JavaScript when making the request.

One of the first issues in setting up CORS is realizing you have a cross-origin problem at all. Several times I've been stumped trying to figure out why a request won't work, until I realize the request is going cross-domain, or from HTTP to HTTPS, for example.

Whenever possible, I recommend avoiding cross-origin requests completely. You can end up with subtle differences in the way browsers handle them, which can cause more headaches. In particular, avoid HTTP to HTTPS cross-domain issues by running all of your applications behind HTTPS. As discussed in section 18.1, that's a best practice anyway, and it'll help avoid a whole class of CORS headaches.

Once I've established I definitely need a CORS policy, I typically start with the `WithOrigins()` method. I then expand or restrict the policy further, as need be, to provide cross-origin lock-down of my API, while still allowing the required functionality. CORS can be tricky to work around, but remember, the restrictions are there for your safety.

Cross-origin requests are only one of many potential avenues attackers could use to compromise your app. Many of these are trivial to defend against, but you need to be aware of them, and know how to mitigate them.[91] In the next section, we'll look at common threats and how to avoid them.

18.5 Exploring other attack vectors

So far in this chapter, I've described two potential ways attackers can compromise your apps—XSS and CSRF attacks—and how to prevent them. Both of these vulnerabilities regularly appear on the OWASP top ten list of most critical web app risks,[92] so it's important to be aware of them, and to avoid introducing them into your apps. In this section, I provide an overview of some of the other most common vulnerabilities and how to avoid them in your apps.

18.5.1 Detecting and avoiding open redirect attacks

A common OWASP vulnerability is due to *open redirect* attacks. An open redirect attack is where a user clicks a link to an otherwise safe app and ends up being redirected to a malicious website; for example, one that serves malware. The safe app contains no direct links to the malicious website, so how does this happen?

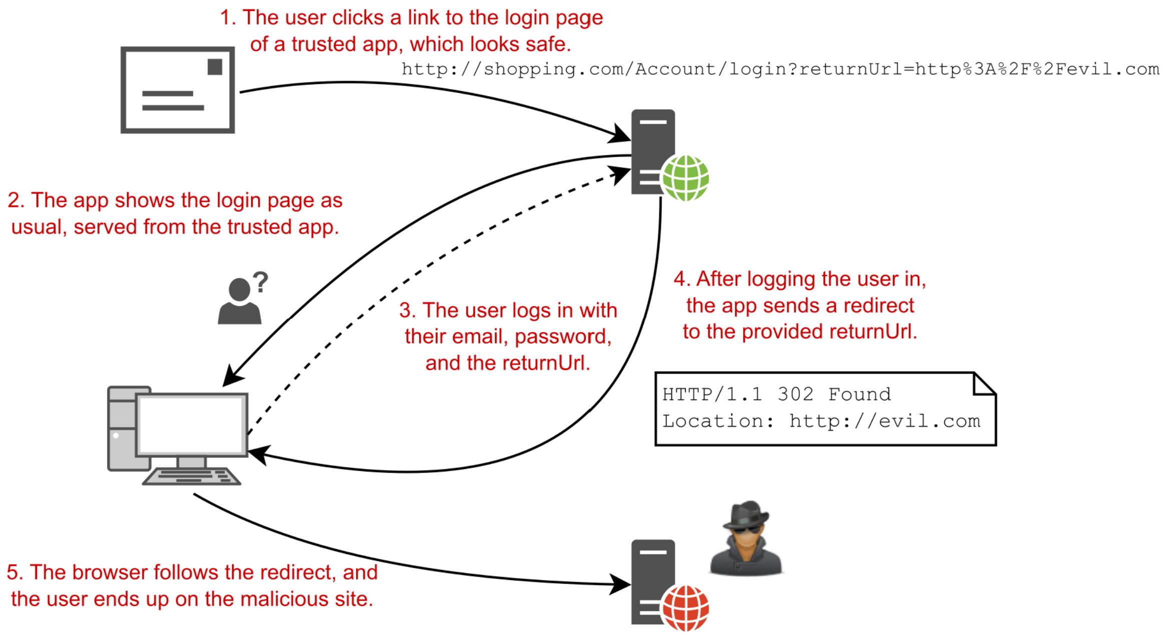
Open redirect attacks occur where the next page is passed as a parameter to an action method. The most common example is when logging in to an app. Typically, apps remember the page a user is on before redirecting them to a login page by passing the current page as a `returnUrl` query string parameter. After the user logs in, the app redirects the user to the `returnUrl` to carry on where they left off.

Imagine a user is browsing an e-commerce site. They click Buy on a product and are redirected to the login page. The product page they were on is passed as the `returnUrl`, so after they log in, they're redirected to the product page, instead of being dumped back to the home screen.

An open redirect attack takes advantage of this common pattern, as shown in figure 18.13. A malicious attacker creates a login URL where the `returnUrl` is set to the website they want to send the user and convinces the user to click the link to your web app. After the user logs in, a vulnerable app will then redirect the user to the malicious site.

[91] For an example of how incorrectly configured CORS policies could expose vulnerabilities in your app, see http://mng.bz/211b.

[92] OWASP publishes the list online, with descriptions of each attack and how to prevent those attacks. You can view the lists dating back to 2003 at http://mng.bz/yXd3, and a cheat sheet for staying safe here: https://cheatsheetseries.owasp.org/.



1. The user clicks a link to the login page of a trusted app, which looks safe.

http://shopping.com/Account/login?returnUrl=http%3A%2F%2Fevil.com

2. The app shows the login page as usual, served from the trusted app.

3. The user logs in with their email, password, and the returnUrl.

4. After logging the user in, the app sends a redirect to the provided returnUrl.

```
HTTP/1.1 302 Found
Location: http://evil.com
```

5. The browser follows the redirect, and the user ends up on the malicious site.

Figure 18.13 An open redirect makes use of the common return URL pattern. This is typically used for login pages but may be used in other areas of your app too. If your app doesn't verify the URL is safe before redirecting the user, it could redirect users to malicious sites.

The simple solution to this attack is to always validate that the `returnUrl` is a local URL that belongs to your app *before* redirecting users to it. The default Identity UI does this already, so you shouldn't have to worry about the login page if you're using Identity, as described in chapter 14.

If you have redirects in other parts of your app, ASP.NET Core provides a couple of helper methods for staying safe, the most useful of which is `Url.IsLocalUrl()`. The following listing shows how you could verify a provided return URL is safe, and if it isn't, redirect to the app's homepage. You can also use the `LocalRedirect()` helper method on the `ControllerBase` and Razor Page `PageModel` classes, which throws an exception if the provided URL isn't local.

Listing 18.8 Detecting open redirect attacks by checking for local return URLs

```
[HttpPost]
public async Task<IActionResult> Login(
    LoginViewModel model, string returnUrl = null)        #A
{
    // Verify password, and sign user in

    if (Url.IsLocalUrl(returnUrl))                        #B
    {
        return Redirect(returnUrl);                       #C
    }
    else
    {
        return RedirectToAction("Index", "Home");         #D
    }
}
```

#A The return URL is provided as an argument to the action method.
#B Returns true if the return URL starts with / or ~/
#C The URL is local, so it's safe to redirect to it.
#D The URL was not local, could be an open redirect attack, so redirect to the homepage for safety.

This simple pattern protects against open redirect attacks that could otherwise expose your users to malicious content. Whenever you're redirecting to a URL that comes from a query string or other user input, you should use this pattern.

Open redirect attacks present a risk to your *users* rather than to your app directly. The next vulnerability represents a critical vulnerability in your app itself.

18.5.2 Avoiding SQL injection attacks with EF Core and parameterization

SQL injection attacks represent one of the most dangerous threats to your application. Attackers craft simple malicious input, which they send to your application as traditional form-based input or by customizing URLs and query strings to execute arbitrary code against your database. An SQL injection vulnerability could expose your entire database to attackers, so it's critical that you spot and remove any such vulnerabilities in your apps.

Hopefully, I've scared you a little with that introduction, so now for the good news—if you're using EF Core (or pretty much any other ORM) in a standard way, then you should be safe. EF Core has built-in protections against SQL injection, so as long as you're not doing anything funky, you should be fine.

SQL injection vulnerabilities occur when you build SQL statements yourself and include dynamic input that an attacker provides, even indirectly. EF Core provides the ability to create raw SQL queries using the `FromSqlRaw()` method, so you must be careful when using this method.

Imagine your recipe app has a search form that lets you search for a recipe by name. If you write the query using LINQ extension methods (as discussed in chapter 12), then you would have no risk of SQL injection attacks. However, if you decide to write your SQL query by hand, you open yourself up to such a vulnerability.

Listing 18.9 An SQL injection vulnerability in EF Core due to string concatenation

```
public IList<User> FindRecipe(string search)         #A
{
    return _context.Recipes                           #B
        .FromSqlRaw("SELECT * FROM Recipes" +         #C
                 "WHERE Name = '" + search + "'")     #D
        .ToList();
}
```

#A The search parameter comes from user input, so it’s unsafe.
#B The current EF Core DbContext is held in the _context field.
#C You can write queries by hand using the FromSqlRaw extension method.
#D This introduces the vulnerability—including unsafe content directly in an SQL string.

In this listing, the user input held in `search` is included *directly* in the SQL query. By crafting malicious input, users can potentially perform any operation on your database. Imagine an attacker searches your website using the text

```
'; DROP TABLE Recipes; --
```

Your app assigns this to the `search` parameter, and the SQL query executed against your database becomes

```
SELECT * FROM Recipes WHERE Name = ''; DROP TABLE Recipes; --'
```

By simply entering text into the search form of your app, the attacker has deleted the entire Recipes table from your app! That’s catastrophic, but an SQL injection vulnerability provides more or less unfettered access to your database. Even if you’ve set up database permissions correctly to prevent this sort of destructive action, attackers will likely be able to read all the data from your database, including your users’ details.

The simple way to avoid this happening is to avoid creating SQL queries by hand like this. If you do need to write your own SQL queries, then don’t use string concatenation, as you did in listing 18.9. Instead, use parameterized queries, in which the (potentially unsafe) input data is separate from the query itself, as shown here.

Listing 18.10 Avoiding SQL injection by using parameterization

```
public IList<User> FindRecipe(string search)
{
    return _context.Recipes
        .FromSqlRaw("SELECT * FROM Recipes WHERE Name = '{0}'",     #A
                 search)                                          #B
        .ToList();
}
```

#A The SQL query uses a placeholder {0} for the parameter.
#B The dangerous input is passed as a parameter, separate from the query.

Parameterized queries are not vulnerable to SQL injection attacks, so the same attack presented earlier won’t work. If you use EF Core (or other ORMs) to access data using standard LINQ queries, you won’t be vulnerable to injection attacks. EF Core will automatically create all SQL queries using parameterized queries to protect you.

> **NOTE** I’ve only talked about SQL injection attacks in terms of a relational database, but this vulnerability can appear in NoSQL and document databases too. Always use parameterized queries (or equivalent) and don’t craft queries by concatenating strings with user input.

Injection attacks have been the number one vulnerability on the web for over a decade, so it's crucial that you're aware of them and how they arise. Whenever you need to write raw SQL queries, make sure you always use parameterized queries.

The next vulnerability is also related to attackers accessing data they shouldn't be able to. It's a little subtler than a direct injection attack but is trivial to perform—the only skill the attacker needs is the ability to count.

18.5.3 Preventing insecure direct object references

Insecure direct object reference is a bit of a mouthful, but it means users accessing things they shouldn't by noticing patterns in URLs. Let's revisit our old friend the recipe app. As a reminder, the app shows you a list of recipes. You can view any of them, but you can only edit recipes you created yourself. When you view someone else's recipe, there's no Edit button visible.

For example, a user clicks the edit button on one of their recipes and notices the URL is `/Recipes/Edit/120`. That "120" is a dead giveaway as the underlying database ID of the entity you're editing. A simple attack would be to change that ID to gain access to a *different* entity, one that you wouldn't normally have access to. The user could try entering `/Recipes/Edit/121`. If that lets them edit or view a recipe that they shouldn't be able to, you have an insecure direct object reference vulnerability.

The solution to this problem is simple—you should have resource-based authentication and authorization in your action methods. If a user attempts to access an entity they're not allowed to access, they should get a permission denied error. They shouldn't be able to bypass your authorization by typing a URL directly into the search bar of their browser.

In ASP.NET Core apps, this vulnerability typically arises when you attempt to restrict users by hiding elements from your UI, for example, by hiding the Edit button. Instead, you should use resource-based authorization, as discussed in chapter 15.

> **WARNING** You must always use resource-based authorization to restrict which entities a user can access. Hiding UI elements provides an improved user experience, but it isn't a security measure.

You can sidestep this vulnerability somewhat by avoiding integer IDs for your entities in the URLs; for example, using a pseudorandom GUID (for instance, `C2E296BA-7EA8-4195-9CA7-C323304CCD12`) instead. This makes the process of guessing other entities harder as you can't just add one to an existing number, but it's only masking the problem rather than fixing it. Nevertheless, using GUIDs can be useful when you want to have publicly accessible pages (that don't require authentication), but you don't want their IDs to be easily discoverable.

The final section in this chapter doesn't deal with a single vulnerability. Instead, I discuss a separate, but related, issue: protecting your users' data.

18.5.4 Protecting your users' passwords and data

For many apps, the most sensitive data you'll be storing is the personal data of your users. This could include emails, passwords, address details, or payment information. You should be careful when storing any of this data. As well as presenting an inviting target for attackers, you may have legal obligations for how you handle it, such as data protection laws and PCI compliance requirements.

The easiest way to protect yourself is to not store data that you don't need. If you don't *need* your user's address, don't ask for it. That way, you can't lose it! Similarly, if you use a third-party identity service to store user details, as described in chapter 14, then you won't have to work as hard to protect your users' personal information.

If you store user details in your own app, or build your own identity provider, then you need to make sure to follow best practices when handling user information. The new project templates that use ASP.NET Core Identity follow most of these practices by default, so I highly recommend you start from one of these. You need to consider many different aspects—too many to go into detail here[93]—but they include:

- Never store user passwords anywhere directly. You should only store cryptographic hashes, computed using an expensive hashing algorithm, such as BCrypt or PBKDF2.
- Don't store more data than you need. You should never store credit card details.
- Allow users to use two-factor authentication (2FA) to sign in to your site.
- Prevent users from using passwords that are known to be weak or compromised.
- Mark authentication cookies as "http" (so they can't be read using JavaScript) and "secure" so they'll only be sent over an HTTPS connection, never over HTTP.
- Don't expose whether a user is already registered with your app or not. Leaking this information can expose you to enumeration attacks.[94]

These are all guidelines, but they represent the minimum you should be doing to protect your users. The most important thing is to be aware of potential security issues as you're building your app. Trying to bolt on security at the end is always harder than thinking about it from the start, so it's best to think about it earlier rather than later.

This chapter has been a whistle-stop tour of things to look out for. We've touched on most of the big names in security vulnerabilities, but I strongly encourage you to check out the other resources mentioned in this chapter. They provide a more exhaustive list of things to consider complementing the defenses mentioned in this chapter. On top of that, don't forget about input validation and mass assignment/over-posting, as discussed in chapter 6. ASP.NET

[93] The NIST (National Institute of Standards and Technology) recently released their Digital Identity Guidelines on how to handle user details: https://pages.nist.gov/800-63-3/sp800-63-3.html.

[94] You can learn more about website enumeration in this video tutorial from Troy Hunt: http://mng.bz/PAAA.

Core includes basic protections against some of the most common attacks, but you can still shoot yourself in the foot. Make sure it's not your app making headlines for being breached!

18.6 Summary

- HTTPS is used to encrypt your app's data as it travels from the server to the browser and back. This prevents third parties from seeing or modifying it.
- HTTPS is virtually mandatory for production apps, as modern browsers like Chrome and Firefox mark non-HTTPS apps as explicitly "not secure."
- In production, you can avoid handling the TLS in your app by using SSL/TLS offloading. This is where a reverse proxy uses HTTPS to talk to the browser, but the traffic is unencrypted between your app and the reverse proxy. The reverse proxy could be on the same or a different server, such as IIS or NGINX, or it could be a third-party service, such as Cloudflare.
- You can use the .NET Core developer certificate or the IIS express developer certificate to enable HTTPS during development. This can't be used for production, but it's sufficient for testing locally. You must run `dotnet dev-certs https --trust` when you first install .NET Core to trust the certificate.
- You can configure an HTTPS certificate for Kestrel in production using the `Kestrel:Certificates:Default` configuration section. This does not require any changes to your application—Kestrel will automatically load the certificate when your app starts and use it to serve HTTPS requests.
- You can use the `HstsMiddleware` to set HTTP Strict Transport Security (HSTS) headers for your application, to ensure the browser sends HTTPS requests to your app instead of HTTP requests. This can only be enforced once an HTTPS request is made to your app, so is best used in conjunction with HTTP to HTTPS redirection.
- You can enforce HTTPS for your whole app using the `HttpsRedirectionMiddleware`. This will redirect HTTP requests to HTTPS endpoints.
- Cross-site scripting (XSS) attacks involve malicious users injecting content into your app, typically to run malicious JavaScript when users browse your app. You can avoid XSS injection attacks by always encoding unsafe input before writing it to a page. Razor Pages do this automatically unless you use the `@Html.Raw()` method, so use it sparingly and carefully.
- Cross-site request forgery (CSRF) attacks are a problem for apps that use cookie-based authentication, such as ASP.NET Core Identity. It relies on the fact that browsers automatically send cookies to a website. A malicious website could create a form that POSTs to your API, and the browser will send the authentication cookie with the request. This allows malicious websites to send requests as though they're the logged-in user.
- You can mitigate CSRF attacks using anti-forgery tokens. These involve writing a hidden field in every form that contains a random string based on the current user. A similar token is stored in a cookie. A legitimate request will have both parts, but a

forged request from a malicious website will only have the cookie half; they cannot recreate the hidden field in the form. By validating these tokens, your API can reject forged requests.

- The Razor Pages framework automatically adds anti-forgery tokens to any forms you create using Razor and validates the tokens for inbound requests. You can disable the validation check if necessary, using the `[IgnoreAntiForgeryToken]` attribute.
- Browsers won't allow websites to make JavaScript AJAX requests from one app to others at different origins. To match the origin, the app must have the same scheme, domain, and port. If you wish to make cross-origin requests like this, you must enable cross-origin resource sharing (CORS) in your API.
- CORS uses HTTP headers to communicate with browsers and defines which origins can call your API. In ASP.NET Core, you can define multiple policies, which can be applied either globally to your whole app, or to specific controllers and actions.
- You can add the CORS middleware by calling `UseCors()` in `Startup.Configure` and optionally providing the name of the default CORS policy to apply. You can also apply CORS to a Web API action or controller by adding the `[EnableCors]` attribute and providing the name of the policy to apply.
- Open redirect attacks use the common `returnURL` mechanism after logging in to redirect users to malicious websites. You can prevent this attack by ensuring you only redirect to local URLs, URLs that belong to your app.
- Insecure direct object references are a common problem where you expose the ID of database entities in the URL. You should always verify that users have permission to access or change the requested resource by using resource-based authorization in your action methods.
- SQL injection attacks are a common attack vector when you build SQL requests manually. Always use parameterized queries when building requests, or instead use a framework like EF Core, which isn't vulnerable to SQL injection.
- The most sensitive data in your app is often the data of your users. Mitigate this risk by only storing data that you need. Ensure you only store passwords as a hash, protect against weak or compromised passwords, and provide the option for 2FA. ASP.NET Core Identity provides all of this out of the box, so it's a great choice if you need to create an identity provider.

19 Building custom components

This chapter covers

- **Building custom middleware**
- **Creating simple endpoints that generate a response using middleware**
- **Using configuration values to set up other configuration providers**
- **Replacing the built-in DI container with a third-party container**

When you're building apps with ASP.NET Core, most of your creativity and specialization goes into the services and models that make up your business logic, and the Razor Pages and controllers that expose them through views or APIs. Eventually, however, you're likely to find that you can't quite achieve a desired feature using the components that come out of the box. At that point, you may need to build a custom component.

This chapter shows how to create some ASP.NET Core components that you're likely to need as your app grows. You probably won't need to use all of them, but each solves a specific problem you may run into.

We start by looking at the middleware pipeline. You saw how to build pipelines by piecing together existing middleware in chapter 3, but in this chapter, you'll create your own custom middleware. You'll explore the basic middleware constructs of the `Map`, `Use`, and `Run` methods, and how to create standalone middleware classes. You'll use these to build middleware components that can add headers to all your responses as well as middleware that return responses.

In section 19.2, you'll see how to use your custom middleware to create simple endpoints using endpoint routing. By using endpoint routing, you can take advantage of the power of the routing and authorization systems that you learned about in chapters 5 and 15, without needing the additional complexity that comes with using API controllers.

Chapter 11 described the configuration provider system used by ASP.NET Core, but in section 19.3, we look at more complex scenarios. In particular, I show you how to handle the situation where a configuration provider itself needs some configuration values. For example, a configuration provider that reads values from a database might need a connection string. You'll also see how to use DI when configuring strongly typed `IOptions` objects, something not possible using the methods you've seen so far.

We stick with DI in section 19.4 where I show how to replace the built-in DI container with a third-party alternative. The built-in container is fine for most small apps, but your `ConfigureServices` function can quickly get bloated as your app grows and you register more services. I show you how to integrate the third-party library, Lamar, into an existing app, so you can make use of extra features such as automatic service registration by convention.

The components and techniques shown in this chapter are common across all ASP.NET Core applications. For example, I use the subject of the first topic—custom middleware—in almost every project I build. In chapter 20 we look at some additional components that are specific to Razor Pages and API controllers.

19.1 Customizing your middleware pipeline

In this section you'll learn how to create custom middleware. You'll learn how to use the `Map`, `Run`, and `Use` extension methods to create simple middleware using lambda expressions. You'll then see how to create equivalent middleware components using dedicated classes. You'll also learn how to split the middleware pipeline into branches, and find out when this is useful.

The middleware pipeline is one of the fundamental building blocks of ASP.NET Core apps, so we covered it in depth in chapter 3. Every request passes through the middleware pipeline, and each middleware component in turn gets an opportunity to modify the request, or to handle it and return a response.

ASP.NET Core includes middleware out of the box for handling common scenarios. You'll find middleware for serving static files, for handling errors, for authentication, and many more. However, you'll spend most of your time during development working with Razor Pages and Web API controllers. These are exposed as the endpoints for most of your app's business logic and call methods on your app's various business services and models.

Sometimes, however, you don't need all the power (and associated complexity) that comes with Razor Pages and API controllers. You might want to create a very simple app that, when called, returns the current time. Or you might want to add a health-check URL to an existing app, where calling the URL doesn't do any significant processing, but checks that the app is running. Although you *could* use API controllers for these, you could also create small, dedicated middleware components to handle these requirements.

Other times, you might have requirements that lie outside the remit of Razor Pages and API controllers. For example, you might want to ensure all responses generated by your app include a specific header. This sort of cross-cutting concern is a perfect fit for custom middleware. You could add the custom middleware early in your middleware pipeline to ensure that every response from your app includes the required header, whether it comes from the static file middleware, the error-handling middleware, or a Razor Page.

In this section, I show three ways to create custom middleware components, as well as how to create branches in your middleware pipeline where a request can flow down either one branch or another. By combining the methods demonstrated in this section, you'll be able to create custom solutions to handle your specific requirements.

We'll start by creating a middleware component that returns the current time as plain text, whenever the app receives a request. From there, we'll look at branching the pipeline, creating general-purpose middleware components, and finally, how to encapsulate your middleware into standalone classes. In section 19.2. you'll see an alternative approach to exposing response-generating middleware using endpoint routing.

19.1.1 Creating simple endpoints with the Run extension

As you've seen in previous chapters, you define the middleware pipeline for your app in the `Configure` method of your `Startup` class. You add middleware to a provided `IApplicationBuilder` object, typically using extension methods. For example:

```
public void Configure(IApplicationBuilder)
{
    app.UseDeveloperExceptionPage();
    app.UseStaticFiles();
}
```

When your app receives a request, the request passes through each middleware, which gets a chance to modify the request, or to handle it by generating a response. If a middleware component generates a response, it effectively short-circuits the pipeline; no subsequent middleware in the pipeline will see the request. The response passes back through the earlier middleware components on its way back to the browser.

You can use the `Run` extension method to build a simple middleware component that always generates a response. This extension takes a single lambda function that runs whenever a request reaches the component. The `Run` extension always generates a response, so no middleware placed after it will ever execute. For that reason, you should always place the `Run` middleware last in a middleware pipeline.

> **TIP** Remember, middleware runs in the order you add them to the pipeline. If a middleware handles a request and generates a response, later middleware will never see the request.

The `Run` extension method provides access to the request in the form of the `HttpContext` object you saw in chapter 3. This contains all the details of the request via the `Request` property, such as the URL path, the headers, and the body of the request. It also contains a `Response` property you can use to return a response.

The following listing shows how you could build a simple middleware that returns the current time. It uses the provided `HttpContext` context object and the `Response` property to set the `Content-Type` header of the response and writes the body of the response using `WriteAsync(text)`.

Listing 19.1 Creating simple middleware using the `Run` extension

```
public void Configure(IApplicationBuilder app)
{
    app.Run(async (HttpContext context) =>                #A
    {
        context.Response.ContentType = "text/plain";      #B
        await context.Response.WriteAsync(                #C
            DateTime.UtcNow.ToString());                  #C
    });

    app.UseStaticFiles();                                 #D
}
```

#A Uses the Run extension to create a simple middleware that always returns a response
#B You should set the content-type of the response you're generating.
#C Returns the time as a string in the response. The 200 OK status code is used if not explicitly set.
#D Any middleware added after the Run extension will never execute.

The `Run` extension is useful for building simple middleware. You can use it to create very basic endpoints that always generate a response. But as the component always generates some sort of response, you must always place it at the end of the pipeline, as no middleware placed after it will execute.

A more common scenario is where you want your middleware component to only respond to a specific URL path. In the next section, you'll see how you can combine `Run` with the `Map` extension method to create simple branching middleware pipelines.

19.1.2 Branching middleware pipelines with the Map extension

So far, when discussing the middleware pipeline, we've always considered it as a single pipeline of sequential components. Each request passes through every middleware, until a component generates a response, which passes back through the previous middleware.

The `Map` extension method lets you change that simple pipeline into a branching structure. Each branch of the pipeline is independent; a request passes through one branch or the other, but not both, as shown in figure 19.1.

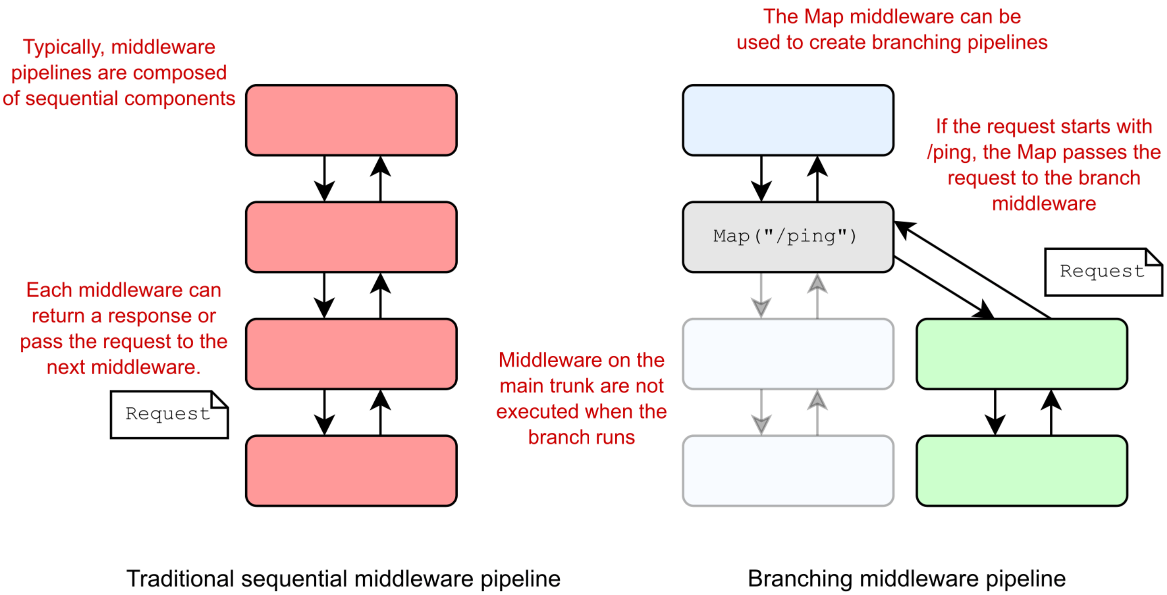

Typically, middleware pipelines are composed of sequential components
Each middleware can return a response or pass the request to the next middleware.
Request
The Map middleware can be used to create branching pipelines
If the request starts with /ping, the Map passes the request to the branch middleware
Map("/ping")
Request
Middleware on the main trunk are not executed when the branch runs
Traditional sequential middleware pipeline
Branching middleware pipeline

Figure 19.1 A sequential middleware pipeline compared to a branching pipeline created with the `Map` extension. In branching middleware, requests only pass through one of the branches at most. Middleware on the other branch never see the request and aren't executed.

The `Map` extension method looks at the path of the request's URL; if the path matches the required pattern, the request travels down the branch of the pipeline, otherwise it remains on the main trunk. This lets you have completely different behavior in different branches of your middleware pipeline.

> **NOTE** The URL matching used by `Map` is conceptually similar to the routing you've seen since chapter 6, but it is much more basic, with many limitations. For example, it uses a simple string-prefix match, and you can't use route parameters. Generally you should favor creating *endpoints* instead of branching using `Map`, as you'll see in section 19.2.

For example, imagine you want to add a simple health-check endpoint to your existing app. This endpoint is a simple URL you can call that indicates whether your app is running correctly. You could easily create a health-check middleware using the `Run` extension, as you saw in listing 19.1, but then that's *all* your app can do. You only want the health-check to respond to a specific URL, `/ping`; your Razor Pages should handle all other requests as normal.

> **TIP** The health-check scenario is a simple example to demonstrate the `Map` method, but ASP.NET Core includes built-in support for health-check endpoints which you should use instead of creating your own. You

can learn more about creating health checks at https://docs.microsoft.com/aspnet/core/host-and-deploy/health-checks.

One solution to this would be to create a branch using the `Map` extension method and to place the health-check middleware on that branch, as shown next. Only those requests that match the `Map` pattern `/ping` will execute the branch, all other requests will be handled by the standard routing middleware and Razor Pages on the main trunk instead.

Listing 19.2 Using the `Map` extension to create branching middleware pipelines

```
public void Configure(IApplicationBuilder app)
{
    app.UseDeveloperExceptionPage();                        #A

    app.Map("/ping", (IApplicationBuilder branch) =>        #B
    {
        branch.UseExceptionHandler();                       #C

        branch.Run(async (HttpContext context) =>           #D
        {                                                   #D
            context.Response.ContentType = "text/plain";    #D
            await context.Response.WriteAsync("pong");      #D
        });                                                 #D
    });

    app.UseStaticFiles();                                   #E
    app.UseRouting();                                       #E
    app.UseEndpoints(endpoints =>                           #E
    {                                                       #E
        endpoints.MapRazorPages();                          #E
    });                                                     #E
}
```

#A Every request will pass though this middleware.
#B The Map extension method will branch if a request starts with /ping.
#C This middleware will only run for requests matching the /ping branch.
#D The Run extension always returns a response, but only on the /ping branch.
#E The rest of the middleware pipeline will run for requests that don't match the /ping branch.

The `Map` middleware creates a completely new `IApplicationBuilder` (called `branch` in the listing), which you can customize as you would your main `app` pipeline. Middleware added to the `branch` builder are only added to the branch pipeline, not the main trunk pipeline.

In this example, you add the `Run` middleware to the branch, so it will only execute for requests that start with `/ping`, such as `/ping`, `/ping/go`, or `/ping?id=123`. Any requests that don't start with `/ping` are ignored by the `Map` extension. Those requests stay on the main trunk pipeline and execute the next middleware in the pipeline after `Map` (in this case, the `StaticFilesMiddleware`).

If you need to, you can create sprawling branched pipelines using `Map`, where each branch is independent of every other. You could also nest calls to `Map`, so you have branches coming off branches.

The `Map` extension can be useful, but if you try to get too elaborate, it can quickly get confusing. Remember, you should use middleware for implementing cross-cutting concerns or very simple endpoints. The endpoint routing mechanism of controllers and Razor Pages is better suited to more complex routing requirements, so don't be afraid to use it.

TIP In section 19.2 you'll see how to create endpoints that use the endpoint routing system.

The final point you should be aware of when using the `Map` extension is that it modifies the effective `Path` seen by middleware on the branch. When it matches a URL prefix, the `Map` extension cuts off the matched segment from the path, as shown in figure 19.2. The removed segments are stored on a property of `HttpContext` called `PathBase`, so they're still accessible if you need them.

NOTE ASP.NET Core's link generator (used in Razor for example, as discussed in chapter 5) uses `PathBase` to ensure it generates URLs that include the `PathBase` as a prefix.

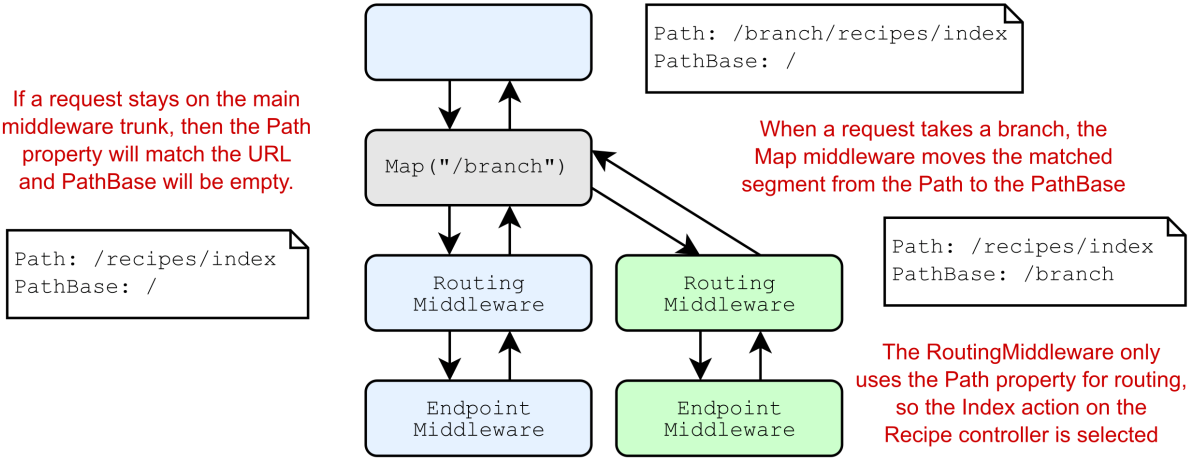

Path: /branch/recipes/index
PathBase: /
If a request stays on the main middleware trunk, then the Path property will match the URL and PathBase will be empty.
Map("/branch")
When a request takes a branch, the Map middleware moves the matched segment from the Path to the PathBase
Path: /recipes/index
PathBase: /
Routing Middleware
Routing Middleware
Path: /recipes/index
PathBase: /branch
Endpoint Middleware
Endpoint Middleware
The RoutingMiddleware only uses the Path property for routing, so the Index action on the Recipe controller is selected

Figure 19.2 When the `Map` extension diverts a request to a branch, it removes the matched segment from the `Path` property and adds it to the `PathBase` property.

You've seen the `Run` extension, which always returns a response, and the `Map` extension which creates a branch in the pipeline. The next extension we'll look at is the general-purpose `Use` extension.

19.1.3 Adding to the pipeline with the Use extension

You can use the Use extension method to add a general-purpose piece of middleware. You can use it to view and modify requests as they arrive, to generate a response, or to pass the request on to subsequent middleware in the pipeline.

Similar to the Run extension, when you add the Use extension to your pipeline, you specify a lambda function that runs when a request reaches the middleware. The app passes two parameters to this function:

- The HttpContext representing the current request and response. You can use this to inspect the request or generate a response, as you saw with the Run extension.
- A pointer to the rest of the pipeline as a Func<Task>. By executing this task, you can execute the rest of the middleware pipeline.

By providing a pointer to the rest of the pipeline, you can use the Use extension to control exactly how and when the rest of the pipeline executes, as shown in figure 19.3. If you don't call the provided Func<Task> at all, then the rest of the pipeline doesn't execute for the request, so you have complete control.

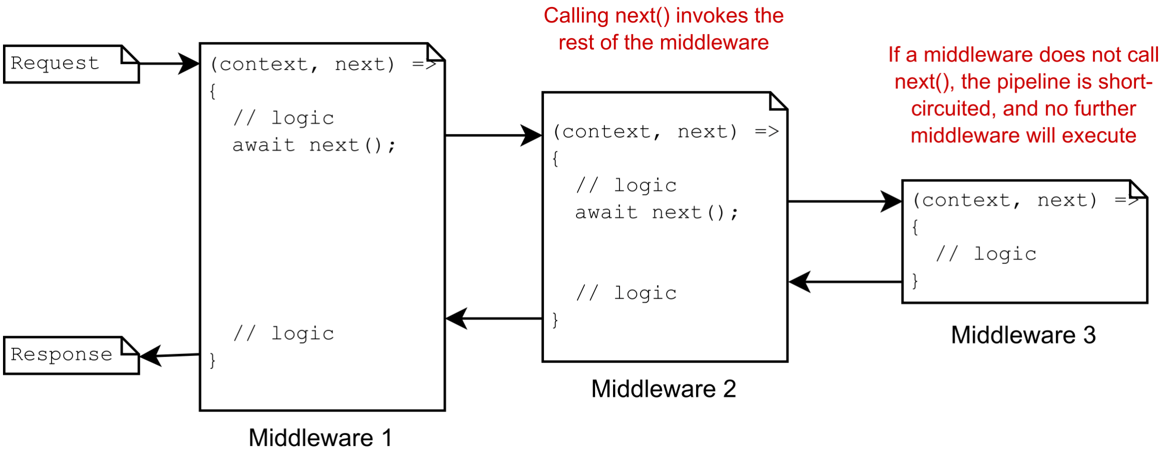


Figure 19.3 Three pieces of middleware, created with the Use extension. Invoking the provided Func<Task> using next() invokes the rest of the pipeline. Each middleware can run code before and after calling the rest of the pipeline, or it can choose to not call next() at all to short-circuit the pipeline.

Exposing the rest of the pipeline as a Func<Task> makes it easy to conditionally short-circuit the pipeline, which opens up many different scenarios. Instead of branching the pipeline to implement the health-check middleware with Map and Run, as you did in listing 19.2, you could use a single instance of the Use extension. This provides the same required functionality as before but does so without branching the pipeline.

Listing 19.3 Using the `Use` extension method to create a health-check middleware

```
public void Configure(IApplicationBuilder app)
{
    app.Use(async (HttpContext context, Func<Task> next) =>      #A
    {
        if (context.Request.Path.StartsWithSegments("/ping"))    #B
        {
            context.Response.ContentType = "text/plain";         #C
            await context.Response.WriteAsync("pong");           #C
        }
        else
        {
            await next();                                        #D
        }
    });

    app.UseStaticFiles();
}
```

#A The Use extension takes a lambda with HttpContext (context) and Func<Task> (next) parameters.
#B The StartsWithSegments method looks for the provided segment in the current path.
#C If the path matches, generate a response, and short-circuit the pipeline
#D If the path doesn't match, call the next middleware in the pipeline, in this case UseStaticFiles().

If the incoming request starts with the required path segment (`/ping`), then the middleware responds and doesn't call the rest of the pipeline. If the incoming request doesn't start with `/ping`, then the extension calls the next middleware in the pipeline, no branching necessary.

With the `Use` extension, you have control over when, and if, you call the rest of the middleware pipeline. But it's important to note that you generally shouldn't modify the `Response` object after calling `next()`. Calling `next()` runs the rest of the middleware pipeline, so a subsequent middleware may start streaming the response to the browser. If you try to modify the response *after* executing the pipeline, you may end up corrupting the response or sending invalid data.

> **WARNING** **Don't *modify* the `Response` object after calling `next()`. Also, don't call `next()` if you've written to the `Response.Body`: writing to this `Stream` can trigger Kestrel to start streaming the response to the browser and you could cause invalid data to be sent. You can generally *read* from the `Response` object safely, to inspect the final `StatusCode` or `ContentType` of the response, for example.**

Another common use for the `Use` extension method is to modify every request or response that passes through it. For example there are various HTTP headers that you should send with all your applications for security reasons. These headers often disable old, insecure, legacy behaviors by browsers, or restrict the features enabled by the browser. You learned about the HSTS header in chapter 18, but there are other headers you can add for additional security.[95]

Imagine you've been tasked with adding one such header, `X-Content-Type-Options: nosniff` (which provides added protection against XSS attacks), to every response generated by your app. This sort of cross-cutting concern is perfect for middleware. You can use the `Use` extension method to intercept every request, set the response header, and then execute the rest of the middleware pipeline. No matter what response the pipeline generates, whether it's a static file, an error, or a Razor Page, the response will always have the security header.

Listing 19.4 shows a robust way to achieve this. When the middleware receives a request, it registers a callback that runs before Kestrel starts sending the response back to the browser. It then calls `next()` to run the rest of the middleware pipeline. When the pipeline generates a response, likely in some later middleware, Kestrel executes the callback and adds the header. This approach ensures the header isn't accidentally removed by other middleware in the pipeline and also that you don't try to modify the headers after the response has started streaming to the browser.

Listing 19.4 Adding headers to a response with the `Use` extension

```
public void Configure(IApplicationBuilder app)
{
    app.Use(async (HttpContext context, Func<Task> next) =>          #A
    {
        context.Response.OnStarting(() =>                            #B
        {
            context.Response.Headers["X-Content-Type-Options"] =     #C
                "nosniff";                                           #C
            return Task.CompletedTask;                               #D
        });
        await next();                                                #E
    }

    app.UseStaticFiles();                                            #F
    app.UseRouting();                                                #F
    app.UseEndpoints(endpoints =>                                    #F
    {                                                                #F
        endpoints.MapControllers();                                  #F
    });                                                              #F
}
```

#A Adds the middleware at the start of the pipeline
#B Sets a function that should be called before the response is sent to the browser
#C Adds an HSTS header. For 60 seconds the browser will only send HTTPS requests to your app
#D The function passed to OnStarting must return a Task
#E Invokes the rest of the middleware pipeline
#F No matter what response is generated, it'll have the security header added

[95] You can test the security headers for your app using https://securityheaders.com/, which also provides information about what headers you should add to your application and why.

Simple cross-cutting middleware like the security header example are common, but they can quickly clutter your `Configure` method, and make it difficult to understand the pipeline at a glance. Instead, it's common to encapsulate your middleware into a class that's functionally equivalent to the `Use` extension, but which can be easily tested and reused.

19.1.4 Building a custom middleware component

Creating middleware with the `Use` extension, as you did in listings 19.3 and 19.4, is convenient but it's not easy to test, and you're somewhat limited in what you can do. For example, you can't easily use DI to inject scoped services inside of these basic middleware components. Normally, rather than calling the `Use` extension directly, you'll encapsulate your middleware into a class that's functionally equivalent.

Custom middleware components don't have to derive from a specific base class or implement an interface, but they have a certain shape, as shown in listing 19.5. ASP.NET Core uses reflection to execute the method at runtime. Middleware classes should have a constructor that takes a `RequestDelegate` object, which represents the rest of the middleware pipeline, and they should have an `Invoke` function with a signature similar to

```
public Task Invoke(HttpContext context);
```

The `Invoke()` function is equivalent to the lambda function from the `Use` extension, and is called when a request is received. Here's how you could convert the headers middleware from listing 19.4 into a standalone middleware class.[96]

Listing 19.5 Adding headers to a `Response` using a custom middleware component

```
public class HeadersMiddleware
{
    private readonly RequestDelegate _next;          #A
    public HeadersMiddleware(RequestDelegate next)   #A
    {                                                #A
        _next = next;                                #A
    }                                                #A

    public async Task Invoke(HttpContext context)    #B
    {
        context.Response.OnStarting(() =>                          #C
        {                                                          #C
            context.Response.Headers["X-Content-Type-Options"] =   #C
                "nosniff";                                         #C
            return Task.CompletedTask;                             #C
        });                                                        #C

        await _next(context);        #D
```

[96] Using this "shape" approach makes the middleware more flexible. In particular, it means you can easily use DI to inject services into the `Invoke` method. This wouldn't be possible if the `Invoke` method were an overridden base class method or an interface. However, if you prefer, you can implement the `IMiddleware` interface, which defines the basic Invoke method.

```
    }
}
```

#A The RequestDelegate represents the rest of the middleware pipeline
#B The Invoke method is called with HttpContext when a request is received
#C Adds the HSTS header response as before
#D Invokes the rest of the middleware pipeline. Note that you must pass in the provided HttpContext

This middleware is effectively identical to the example in listing 19.4 but encapsulated in a class called `HeadersMiddleware`. You can add this middleware to your app in `Startup.Configure` by calling

```
app.UseMiddleware<HeadersMiddleware>();
```

A common pattern is to create helper extension methods to make it easy to consume your extension method from `Startup.Configure` (so that IntelliSense reveals it as an option on the `IApplicationBuilder` instance). Here's how you could create a simple extension method for `HeadersMiddleware`.

Listing 19.6 Creating an extension method to expose `HeadersMiddleware`

```
public static class MiddlewareExtensions
{
    public static IApplicationBuilder UseSecurityHeaders(     #A
        this IApplicationBuilder app)                         #A
    {
        return app.UseMiddleware<HeadersMiddleware>();        #B
    }
}
```

#A By convention, the extension method should return an IApplicationBuilder to allow chaining
#B Adds the middleware to the pipeline

With this extension method, you can now add the headers middleware to your app using

```
app.UseSecurityHeaders();
```

> **TIP** There is a NuGet package available that makes it easy to add security headers using middleware, without having to write your own. The package provides a fluent interface for adding the recommend security headers to your app. You can find instructions on how to install it at https://github.com/andrewlock/NetEscapades.AspNetCore.SecurityHeaders.

Listing 19.5 is a simple example, but you can create middleware for many different purposes. In some cases, you may need to use DI to inject services and use them to handle a request. You can inject singleton services into the constructor of your middleware component, or you can inject services with any lifetime into the `Invoke` method of your middleware, as demonstrated in the following listing.

Listing 19.7 Using DI in middleware components

```
public class ExampleMiddleware
{
    private readonly RequestDelegate _next;
    private readonly ServiceA _a;                              #A
    public HeadersMiddleware(RequestDelegate next, ServiceA a)    #A
    {
        _next = next;
        _a = a;                                                #A
    }

    public async Task Invoke(
        HttpContext context, ServiceB b, ServiceC c)             #B
    {
        // use services a, b, and c
        // and/or call _next.Invoke(context);
    }
}
```

#A You can inject additional services in the constructor. These must be singletons
#B You can inject services into the Invoke method. These may have any lifetime

> **WARNING** **ASP.NET Core creates the middleware only once for the lifetime of your app, so any dependencies injected in the constructor must be singletons. If you need to use scoped or transient dependencies, inject them into the** `Invoke` **method.**

That covers pretty much everything you need to start building your own middleware components. By encapsulating your middleware into custom classes, you can easily test their behavior, or distribute them in NuGet packages, so I strongly recommend taking this approach. Apart from anything else, it will make your `Startup.Configure()` method less cluttered and easier to understand.

19.2 Creating custom endpoints with endpoint routing

In this section you'll learn how to create custom endpoints from your middleware using endpoint routing. We take the simple middleware branches used in section 19.1 and convert them to use endpoint routing, and demonstrate the additional features this enables, such as routing and authorization.

In section 19.1 I described creating a simple "endpoint" using the `Map` and `Run` extension methods, that returns a plain-text `pong` response whenever a `/ping` request is received, by branching the middleware pipeline. This is fine because it's so simple, but what if you have more complex requirements?

Consider a basic enhancement of the ping-pong example: how would you add authorization to the request? The `AuthorizationMiddleware` added to your pipeline by `UseAuthorization()` looks for metadata on endpoints like Razor Pages to see if there's an `[Authorize]` attribute, but it doesn't know how to work with your ping-pong `Map` extension.

Similarly, what if you wanted to use more complex routing? Maybe you want to be able to call `/ping/3` and have your ping-pong middleware reply `pong-pong-pong` (no, I can't think why you would either!). You now have to try and parse that integer from the URL, make sure it's valid and so on. That's sounding like a lot more work!

When your requirements start ramping up like this, one option is to move to using Web API controllers or Razor Pages. These provide the greatest flexibility in your app and have the most features, but they're also comparatively heavy weight compared to middleware. What if you want something in-between?

In ASP.NET Core 3.0, the routing system was re-written to use *endpoint routing*, to provide exactly this balance. Endpoint routing allows you to create endpoints that can use the same routing and authorization framework as you get with Web API controllers and Razor Pages, but with the simplicity of middleware.

REMINDER I discussed endpoint routing in detail in chapter 5.

In this section you'll see how to convert the simple branch-based middleware from the previous section to a custom endpoint. You'll see how taking this approach makes it easy to apply authorization to the endpoint, using the declarative approaches you're already familiar with from chapter 15.

19.2.1 Creating a custom endpoint routing component

As I described in chapter 5, endpoint routing splits the process of executing an endpoint into two steps, implemented by two separate pieces of middleware:

1. `RoutingMiddleware`. Uses the incoming request to *select* an endpoint to execute. Exposes the metadata about the selected endpoint on `HttpContext`, such as authorization requirements applied using the `[Authorize]` attribute.
2. `EndpointMiddleware`. *Executes* the selected endpoint to generate a response.

The advantage of using a two-step process is that you can place middleware *between* the middleware that selects the endpoint and the middleware that executes it to generate a response. For example, the `AuthorizationMiddleware` uses the selected endpoint to determine whether to short-circuit the pipeline, *before* the endpoint is executed.

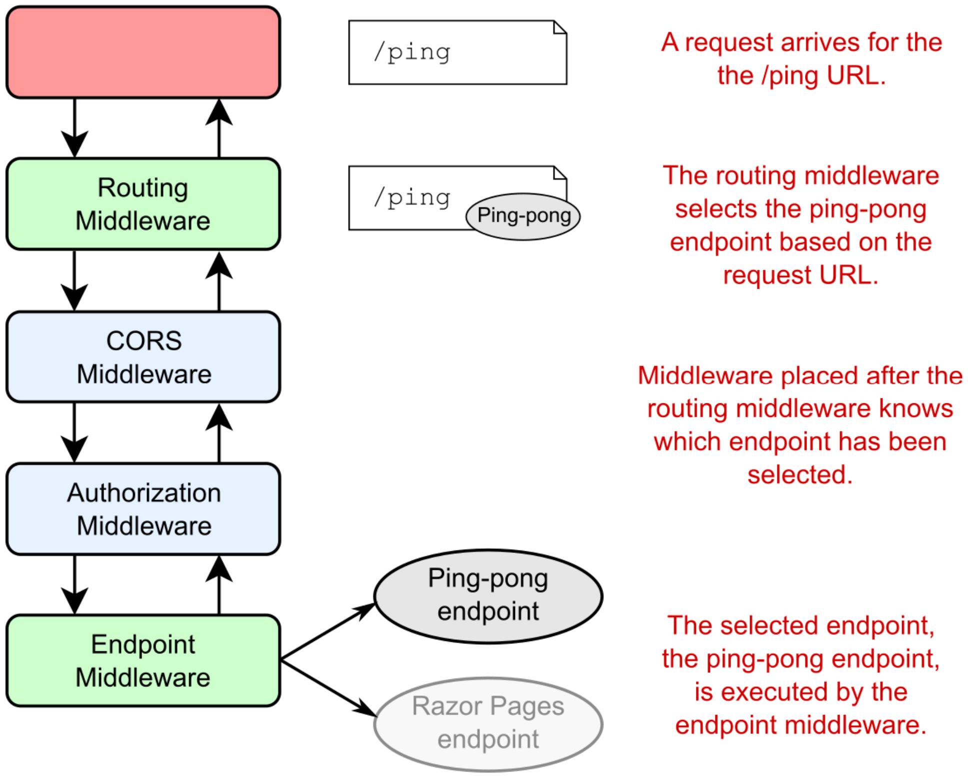
Let's imagine that you need to apply authorization to the simple ping-pong endpoint you created in section 19.1.2. This is much easier to achieve with endpoint routing than using simple middleware branches like `Map` or `Use`. The first step is to create a middleware component for the functionality, using the approach you saw in section 19.1.4, as shown in the following listing.

Listing 19.8 The `PingPongMiddleware` implemented as a middleware component

```
public class PingPongMiddleware
{
    public PingPongMiddleware(RequestDelegate next)          #A
    {
    }

    public async Task Invoke(HttpContext context)           #B
    {
        context.Response.ContentType = "text/plain";        #C
        await context.Response.WriteAsync("pong");          #C
    }
}
```

#A Even though it isn't used in this case, you must inject a RequestDelegate in the constructor
#B Invoke is called to execute the middleware
#C The middleware always returns a "pong" response

Note that this middleware always returns a `"pong"` response, regardless of the request URL—we will configure the `"/ping"` path later. We can use this class to convert a middleware pipeline from the "branching" version shown in figure 19.1, to the "endpoint" version shown in figure 19.4.



A request arrives for the the /ping URL.

The routing middleware selects the ping-pong endpoint based on the request URL.

Middleware placed after the routing middleware knows which endpoint has been selected.

The selected endpoint, the ping-pong endpoint, is executed by the endpoint middleware.

Figure 19.4. Endpoint routing separates the selection of an endpoint from the execution of an endpoint. The routing middleware selects an endpoint based on the incoming request and exposes metadata about the

endpoint. Middleware placed before the endpoint middleware can act based on the selected endpoint, such as short-circuiting unauthorized requests. If the request is authorized, the endpoint middleware executes the selected endpoint and generates a response.

Converting the ping-pong middleware to an endpoint doesn’t require any changes to the middleware itself. Instead, you need to create a “mini” middleware pipeline, containing your ping-pong middleware only.

> **TIP** Converting a response-generating middleware to an endpoint essentially requires converting it into its own mini-pipeline, so you can include additional middleware in the “endpoint pipeline” if you wish.

You must create your endpoint pipeline *inside* the `UseEndpoints()` lambda argument as shown in the following listing. Use `CreateApplicationBuilder()` to create a new `IApplicationBuilder`, add your middleware that makes up your endpoint, and then call `Build()` to create the pipeline.

Listing 19.9 Mapping the ping-pong endpoint in UseEndpoints

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    app.UseRouting();

    app.UseAuthentication();
    app.UseAuthorization();

    app.UseEndpoints(endpoints =>
    {
        var endpoint = endpoints                          #A
            .CreateApplicationBuilder()                   #A
            .UseMiddleware<PingPongMiddleware>()          #B
            .Build();                                     #B

        endpoints.Map("/ping", endpoint);                 #C
        endpoints.MapRazorPages();
        endpoints.MapHealthChecks("/healthz");
    });
}}
```

#A Create a miniature, standalone, IApplicationBuilder to build your endpoint
#B Add the middleware and build the final endpoint. This is executed when the endpoint is executed
#C Add the new endpoint to the endpoint collection associated with the route template “/ping”

Once you have a pipeline, you can associate it with a given route by calling `Map()` on the `IEndpointRouteBuilder` instance, and passing in a route template.

> **TIP** Note that the `Map()` function on `IEndpointRouteBuilder` creates a new endpoint (consisting of your mini-pipeline) with an associated route. Although it has the same name, this is conceptually different to the `Map` function on `IApplicationBuilder` from section 19.1.2 which is used to *branch* the middleware pipeline.

If you have many custom endpoints, the `UseEndpoints()` method can quickly get cluttered. I like to extract this functionality into an extension method, to make the `UseEndpoints()` method cleaner and easier to read. The following listing extracts the code to create an endpoint from listing 19.9 into a separate class, taking the route template to use as a method parameter.

Listing 19.10 An extension method for using the PingPongMiddleware as an endpoint

```
public static class EndpointRouteBuilderExtensions
{
    public static IEndpointConventionBuilder MapPingPong(         #A
        this IEndpointRouteBuilder endpoints,                     #A
        string route)                                             #B
    {
        var pipeline = endpoints.CreateApplicationBuilder()       #C
            .UseMiddleware<PingPongMiddleware>()                  #C
            .Build();                                             #C

        return endpoints                                  #D
            .Map(route, pipeline)                         #D
            .WithDisplayName("Ping-pong");                #E
    }
}
```

#A Create an extension method for registering the PingPongMiddleware as an endpoint
#B Allows the caller to pass in a route template for the endpoint
#C Create the endpoint pipeline
#D Add the new endpoint to the provided endpoint collection, using the provide route template
#E You can add additional metadata here directly, or the caller can add metadata themselves

Now that you have an extension method, `MapPingPong()`, you can update your `UseEndpoints()` method in `Startup.Configure()` to be simpler and easier to understand.

```
app.UseEndpoints(endpoints =>
{
    endpoints.MapPingPong("/ping");
    endpoints.MapRazorPages();
    endpoints.MapHealthChecks("/healthz");
});
```

Congratulations, you've created your first custom endpoint! You haven't added any additional *functionality* yet, but by using the endpoint routing system it's now much easier to satisfy the additional authorization requirements, as you'll see in section 19.2.2.

> **TIP** **This example used a very basic route template, "`/ping`", but you can also use templates that contain route parameters, for example "`/ping/{count}`", using the same routing framework you learned in chapter 5. For examples of how to access this data from your middleware, as well as best practice advice, see https://andrewlock.net/accessing-route-values-in-endpoint-middleware-in-aspnetcore-3/.**

Converting a branching middleware to use endpoint routing can be useful for taming a middleware pipeline with lots of branches, but you won't necessarily always want to use it.

Using simple branches can be faster than using the routing infrastructure, so in some cases it may be best to avoid endpoint routing.

A good example of this trade-off is the built-in `StaticFileMiddleware`. This middleware serves static files based on the request's URL, but it *doesn't* use endpoint routing due to the performance impact of adding many (potentially hundreds) of routes for each static file in your application. The downside to that choice is that adding authorization to static files is not easy to achieve: if endpoint routing were used, adding authorization would be simple.

19.2.2 Applying authorization to endpoints

One of the main advantages of endpoint routing is the ability to easily apply authorization to your endpoint. For Razor Pages and API controllers, this is achieved by adding the `[Authorize]` attribute, as you saw in chapter 15.

For other endpoints, such as the ping-pong endpoint you created in section 19.2.1, you can apply authorization declaratively when you add the endpoint to your application, by calling `RequireAuthorization()` on the `IEndpointConventionBuilder`, as shown in the following listing.

Listing 19.11 Applying authorization to an endpoint using `RequireAuthorization()`

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    app.UseRouting();

    app.UseAuthentication();
    app.UseAuthorization();

    app.UseEndpoints(endpoints =>
    {
        endpoints.MapPingPong("/ping")                    #A
            .RequireAuthorization();                      #A
        endpoints.MapRazorPages();
        endpoints.MapHealthChecks("/healthz")             #B
            .RequireAuthorization("HealthCheckPolicy")    #B
    });
}}
```

#A Require authorization. This is equivalent to applying the [Authorize] attribute.
#B Require authorization using a specific policy, HealthCheckPolicy.

Listing 19.11 shows two examples of applying authorization to endpoints

- `RequireAuthorization()`. If you don't provide a method argument, this applies the default authorization policy to the endpoint. It is equivalent to applying the `[Authorize]` attribute to a Razor Page or API controller endpoint.
- `RequireAuthorization(policy)`. If you provide a policy name, the chosen authorization policy will be used. The policy must be configured in `ConfigureServices`, as you saw in chapter 15. This is equivalent to applying `[Authorize("HealthCheckPolicy")]` to a Razor Page or API controller endpoint.

If you are globally applying authorization to your application (as described in chapter 15), then you can "punch a hole" in the global policy with the complimentary `AllowAnonymous()` method, for example:

```
endpoints.MapPingPong("/ping").AllowAnonymous();
```

This is equivalent to using the `[AllowAnonymous]` attribute on your Razor Pages and actions.

> **NOTE The `AllowAnonymous()` method for endpoints is new in .NET 5.**

Authorization is the canonical example of adding metadata to endpoints to add functionality, but there are other options available too. Out of the box you can use the following methods:

- `RequireAuthorization()`. Applies authorization policies to the endpoint, as you've already seen.
- `AllowAnonymous()`. Overrides a global authorization policy to allow anonymous access to an endpoint
- `RequireCors(policy)`. Apply a CORS policy to the endpoint, as described in chapter 18.
- `RequireHost(hosts)`. Only allow routing to the endpoint if the incoming request matches one of the provided hostnames.
- `WithDisplayName(name)`. Sets the friendly name for the endpoint. Used primarily in logging to describe the endpoint.
- `WithMetadata(items)`. Add arbitrary values as metadata to the endpoint. You can access these values in middleware after an endpoint is selected by the routing middleware.

These features allow various functionality, such as CORS and authorization, to work seamlessly across Razor Pages, API controllers, built in endpoints like the health check endpoints, and custom endpoints like your ping-pong middleware. They should allow you to satisfy most requirements you get around custom endpoints. And if you find you need something more complex, like model-binding for example, then you can always fall back to using API controllers instead. The choice is yours!

In the next section we move away from the middleware pipeline and look at how to handle complex configuration requirements. In particular, you'll see how to set up complex configuration providers that require their own configuration values, and how to use DI services to build your strongly typed `IOptions` objects.

19.3 Handling complex configuration requirements

In this section I describe how to handle two complex configuration requirements: configuration providers that need configuring themselves; and using services to configure `IOptions` objects. In the first scenario, you will see how to partially build your configuration to allow building the provider. In the second scenario, you will see how to use the IConfigureOptions interface to allow accessing services when configuring your options objects.

In chapter 11, we discussed the ASP.NET Core configuration system in depth. You saw how an IConfiguration object is built from multiple layers, where subsequent layers can add to or replace configuration values from previous layers. Each layer is added by a configuration provider, which can read values from a file, from environment variables, from User Secrets, or from any number of possible locations.

You also saw how to *bind* configuration values to strongly typed POCO objects, using the IOptions interface. You can inject these strongly typed objects into your classes to provide easy access to your settings, instead of having to read configuration using string keys.

In this section, we'll look at two scenarios that are slightly more complex. In the first scenario, you're trying to use a configuration provider that requires some configuration itself.

As an example, imagine you want to store some configuration in a database table. In order to load these values, you'd need some sort of connection string, which would most likely also come from your IConfiguration. You're stuck with a chicken-and-egg situation: you need to build the IConfiguration object to add the provider, but you can't add the provider without building the IConfiguration object!

In the second scenario, you want to configure a strongly typed IOptions object with values returned from a service. But the service won't be available until after you've configured all of the IOptions objects. In section 19.3.2, you'll see how to handle this by implementing the IConfigureOptions interface.

19.3.1 Partially building configuration to configure additional providers

ASP.NET Core includes many configuration providers, such as file and environment variable providers, that don't require anything more than basic details to set up. All you need to read a JSON file, for example, is the path to that file.

But the configuration system is highly extensible, and more complex configuration providers may require some degree of configuration themselves. For example, you may have a configuration provider that loads configuration values from a database, a provider that loads values from a remote API, or a provider that loads secrets from Azure Key Vault.[97]

Each of these providers require some sort of configuration themselves: a connection string for the database, a URL for the remote service, or a key to decrypt the data from Key Vault. Unfortunately, this leaves you with a circular problem: you need to add the provider to build your configuration object, but you need a configuration object to add the provider!

The solution is to use a two-stage process to build your final IConfiguration configuration object, as shown in figure 19.5. In the first stage, you load the configuration values that are

[97] Azure Key Vault is a service that lets you securely store secrets in the cloud. Your app retrieves the secrets from Azure Key Vault at runtime by calling an API and providing a client ID and a secret. The client ID and secret must come from local configuration values, so that you can retrieve the rest from Azure Key Vault. Read more, including how to get started, at https://docs.microsoft.com/aspnet/core/security/key-vault-configuration.

available locally, such as JSON files and environment variables, and build a temporary `IConfiguration`. You can use this object to configure the complex providers, add them to your configuration builder, and build the final `IConfiguration` for your app.

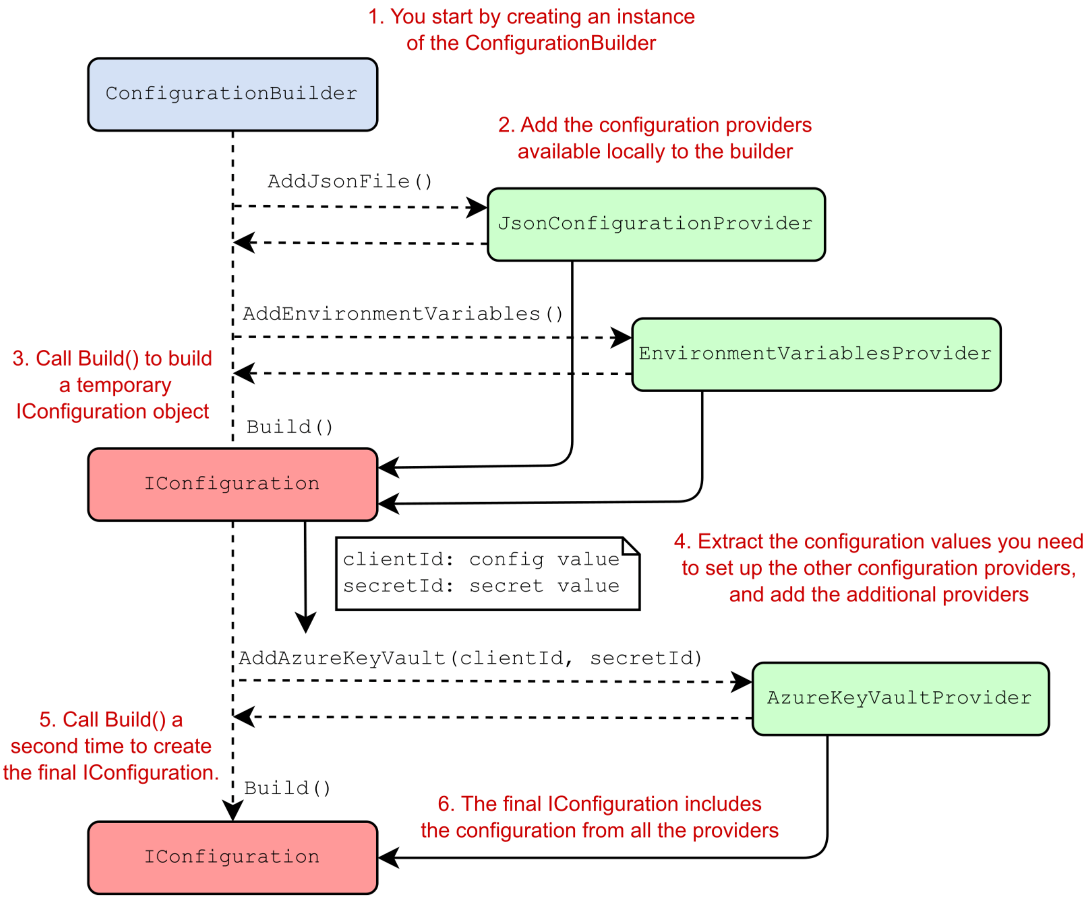

1. You start by creating an instance of the ConfigurationBuilder
ConfigurationBuilder
2. Add the configuration providers available locally to the builder
AddJsonFile()
JsonConfigurationProvider
AddEnvironmentVariables()
EnvironmentVariablesProvider
3. Call Build() to build a temporary IConfiguration object
Build()
IConfiguration
clientId: config value
secretId: secret value
4. Extract the configuration values you need to set up the other configuration providers, and add the additional providers
AddAzureKeyVault(clientId, secretId)
AzureKeyVaultProvider
5. Call Build() a second time to create the final IConfiguration.
Build()
6. The final IConfiguration includes the configuration from all the providers
IConfiguration

Figure 19.5 Adding a configuration provider that requires configuration. Start by adding configuration providers that you have the details for and build a temporary `IConfiguration` object. You can use this configuration object to load the settings required by the complex provider, add the provider to your builder, and build the final `IConfiguration` object using all three providers.

You can use this two-phase process whenever you have configuration providers that need configuration themselves. Building the configuration object twice means that the values are loaded from each of the initial configuration providers twice, I've never found that to be a problem.

As an example of this process, in listing 19.12, you'll create a temporary `IConfiguration` object built using the contents of an XML file. This contains a configuration property called `"SettingsFile"` with the filename of a JSON file.

In the second phase of configuration, you add the JSON file provider (using the filename from the partial `IConfiguration`) and the environment variable provider. When you finally call `Build()` on the `IHostBuilder`, a new `IConfiguration` object will be built, containing the configuration values from the XML file, the JSON file, and the environment variables.

Listing 19.12 Using multiple `IConfiguration` objects to configure providers

```
public static IHostBuilder CreateHostBuilder(string[] args) =>
    Host.CreateDefaultBuilder(args)
        .ConfigureAppConfiguration((context, config) =>
        {
            config.Sources.Clear();                               #A
            config.AddXmlFile("baseconfig.xml");                  #B

            IConfiguration partialConfig = config.Build();       #C
            string filename = partialConfig["SettingsFile"];     #D

            config.AddJsonFile(filename)                          #E
                .AddEnvironmentVariables();                       #F
        })
        .ConfigureWebHostDefaults(webBuilder =>
        {
            webBuilder.UseStartup<Startup>();
        });
```

#A Remove the default configuration sources
#B Adds an XML file to the configuration, which contains configuration for other providers
#C Builds the IConfiguration to read the XML file
#D Extracts the configuration required by other providers
#E Uses the extracted configuration to configure other providers
#F Remember, values from subsequent providers will overwrite values from previous providers

This is a somewhat contrived example—it's unlikely that you'd need to load configuration values to read a JSON file—but the principle is the same no matter which provider you use. A good example of this is the Azure Key Value provider. To load configuration values from Azure Key Vault, you need a URL, a client ID, and a secret. These must be loaded from other configuration providers, so you have to use the same two-phase process as shown in the previous listing.

Once you've loaded the configuration for your app, it's common to *bind* this configuration to strongly typed objects using the `IOptions` pattern. In the next section, we look at other ways to configure your `IOptions` objects and how to build them using DI services.

19.3.2 Using services to configure IOptions with IConfigureOptions

A common and encouraged practice is to bind your configuration object to strongly typed `IOptions<T>` objects, as you saw in chapter 11. Typically, you configure this binding in

Startup.ConfigureServices by calling services.Configure<T>() and providing an IConfiguration object or section to bind.

To bind a strongly typed object, called CurrencyOptions, to the "Currencies" section of an IConfiguration object, you'd use

```
public void ConfigureServices(IServiceCollection services)
{
   services.Configure<CurrencyOptions>(
        Configuration.GetSection("Currencies"));
}
```

This sets the properties of the CurrencyOptions object, based on the values in the "Currencies" section of your IConfiguration object. Simple binding like this is common, but sometimes you might want to customize the configuration of your IOptions<T> objects, or you might not want to bind them to configuration at all. The IOptions pattern only requires you to configure a strongly typed object before it's injected into a dependent service, it doesn't mandate that you *have* to bind it to an IConfiguration section.

> **TIP** Technically, even if you don't configure an IOptions<T> at all, you can still inject it into your services. In that case, the T object will always be created using the default constructor.

The services.Configure<T>() method has an overload that lets you provide a lambda function that the framework uses to configure the CurrencyOptions object. For example, in the following snippet, we use a lambda function to set the Currencies property on the configured CurrencyOptions object to a fixed array of strings:

```
public void ConfigureServices(IServiceCollection services)
{
    services.Configure<CurrencyOptions>(
        Configuration.GetSection("Currencies"));
    services.Configure<CurrencyOptions>(options =>
        options.Currencies = new string[] { "GBP", "USD"});
}
```

Each call to Configure<T>(), both the binding to IConfiguration and the lambda function, adds another configuration step to the CurrencyOptions object. When the DI container first requires an instance of IOptions<CurrencyOptions>, each of the steps run in turn, as shown in figure 19.6.

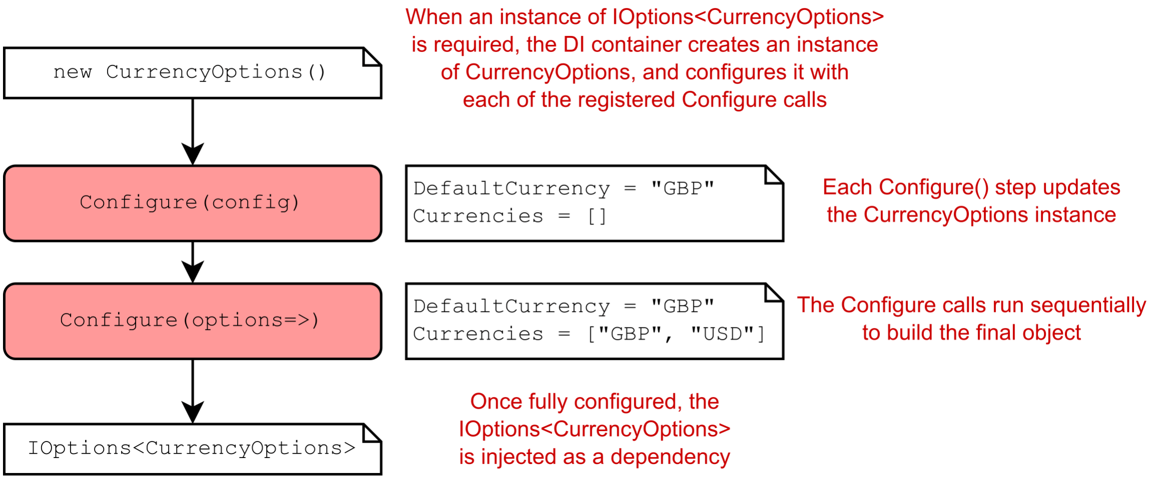

new CurrencyOptions()
Configure(config)
Configure(options=>)
IOptions<CurrencyOptions>
DefaultCurrency = "GBP"
Currencies = []
DefaultCurrency = "GBP"
Currencies = ["GBP", "USD"]
When an instance of IOptions<CurrencyOptions> is required, the DI container creates an instance of CurrencyOptions, and configures it with each of the registered Configure calls
Each Configure() step updates the CurrencyOptions instance
The Configure calls run sequentially to build the final object
Once fully configured, the IOptions<CurrencyOptions> is injected as a dependency

Figure 19.6 Configuring a `CurrencyOptions` object. When the DI container needs an `IOptions<>` instance of a strongly typed object, the container creates the object, and then uses each of the registered `Configure()` methods to set the object's properties.

In the example, you set the `Currencies` property to a static array of strings in a lambda function. But what if you don't know the correct values ahead of time? You might need to load the available currencies from a database, or from some remote service, for example.

Unfortunately, this situation, where you need a configured service to configure your `IOptions<T>` is hard to resolve. Remember, you declare your `IOptions<T>` configuration inside `ConfigureServices`, as part of the DI configuration. How can you get a fully configured instance of a currency service if you haven't registered it with the container yet?

The solution is to defer the configuration of your `IOptions<T>` object until the last moment, just before the DI container needs to create it to handle an incoming request. At that point, the DI container will be completely configured and will know how to create the currency service.

ASP.NET Core provides this mechanism with the `IConfigureOptions<T>` interface. You implement this interface in a configuration class and use it to configure the `IOptions<T>` object in any way you need. This class can use DI, so you can easily use any other required services.

Listing 19.13 Implementing `IConfigureOptions<T>` to configure an options object

```
public class ConfigureCurrencyOptions : IConfigureOptions<CurrencyOptions>
{
    private readonly ICurrencyProvider _currencyProvider;              #A
    public ConfigureCurrencyOptions(ICurrencyProvider currencyProvider)
    {
        _currencyProvider = currencyProvider;                          #A
    }
    public void Configure(CurrencyOptions options)                    #B
    {
        options.Currencies = _currencyProvider.GetCurrencies();       #C
    }
}
```

#A You can inject services that are only available after the DI is completely configured.
#B Configure is called when an instance of IOptions <CurrencyOptions> is required.
#C You can use the injected service to load the values from a remote API, for example.

All that remains is to register this implementation in the DI container. As always, order is important, so if you want `ConfigureCurrencyOptions` to run *after* binding to configuration, you must add it *after* the first call to `services.Configure<T>()`:

```
public void ConfigureServices(IServiceCollection services)
{
    services.Configure<CurrencyOptions>(
        Configuration.GetSection("Currencies"));
    services.AddSingleton
        <IConfigureOptions<CurrencyOptions>, ConfigureCurrencyOptions>();
}
```

> **WARNING The `CurrencyConfigureOptions` object is registered as a singleton, so it will capture any injected services of scoped or transient lifetimes.**[98]

With this configuration, when `IOptions<CurrencyOptions>` is injected into a controller or service, the `CurrencyOptions` object will first be bound to the `"Currencies"` section of your `IConfiguration` and will then be configured by the `ConfigureCurrencyOptions` class.

One piece of configuration not yet shown is `ICurrencyProvider` used by `ConfigureCurrencyOptions`. In the sample code for this chapter, I created a simple `CurrencyProvider` service and registered it with the DI container using

```
services.AddSingleton<ICurrencyProvider, CurrencyProvider>();
```

As your app grows, and you add extra features and services, you'll probably find yourself writing more and more of these simple DI registrations, where you register a `Service` that implements `IService`. The built-in ASP.NET Core DI container requires you to explicitly register each of these services manually. If you find this requirement frustrating, it may be time to look at third-party DI containers that can take care of some of the boilerplate for you.

[98] If you inject a scoped service into your configuration class (for example, a DbContext), you need to do a bit more work to ensure it's disposed of correctly. I describe how to achieve that here: http://mng.bz/6m17.

19.4 Using a third-party dependency injection container

In this section I show how to replace the default dependency injection container with a third-party alternative, Lamar. Third-party containers often provide additional features compared to the built-in container, such as assembly scanning, automatic service registration, and property injection. Replacing the built-in container can also be useful when porting an existing app that uses a third-party DI container to ASP.NET Core.

The .NET community had been using DI containers for years before ASP.NET Core decided to include one that is built-in. The ASP.NET Core team wanted a way to use DI in their own framework libraries, and to create a common abstraction[99] that allows you to replace the built-in container with your favorite third-party alternative, such as

- Autofac
- StructureMap/Lamar
- Ninject
- Simple Injector
- Unity

The built-in container is intentionally limited in the features it provides, and it won't be getting many more realistically. In contrast, third-party containers can provide a host of extra features. These are some of the features available in Lamar (https://jasperfx.github.io/lamar/documentation/ioc/), the spiritual successor to StructureMap (https://structuremap.github.io/):

- Assembly scanning for interface/implementation pairs based on conventions
- Automatic concrete class registration
- Property injection and constructor selection
- Automatic `Lazy<T>`/`Func<T>` resolution
- Debugging/testing tools for viewing inside your container

None of these features are a requirement for getting an application up and running, so using the built-in container makes a lot of sense if you're building a small app or you're new to DI containers in general. But if, at some undefined tipping point, the simplicity of the built-in container becomes too much of a burden, it may be worth replacing it.

> **TIP** A middle-of-the-road approach is to use the Scrutor NuGet package, which adds some features to the built-in DI container, without replacing it entirely. For an introduction and examples, see https://andrewlock.net/using-scrutor-to-automatically-register-your-services-with-the-asp-net-core-di-container/.

[99] Although the promotion of DI as a core practice has been applauded, this abstraction has seen some controversy. This post from one of the maintainers of the SimpleInjector DI library describes many of the arguments and concerns: https://blog.simpleinjector.org/2016/06/whats-wrong-with-the-asp-net-core-di-abstraction/. You can also read more about the decisions here: https://github.com/aspnet/DependencyInjection/issues/433.

In this section, I show how you can configure an ASP.NET Core app to use Lamar for dependency resolution. It won't be a complex example, or an in-depth discussion of Lamar itself. Instead, I'll cover the bare minimum to get up and running.

Whichever third-party container you choose to install into an existing app, the overall process is pretty much the same:

1. Install the container NuGet package.
2. Register the third-party container with the `IHostBuilder` in Program.cs
3. Add a `ConfigureContainer` method in `Startup`.
4. Configure the third-party container in `ConfigureContainer` to register your services.

Most of the major .NET DI containers have been ported to work on .NET Core and include an adapter that lets you add them to ASP.NET Core apps. For details, it's worth consulting the specific guidance for the container you're using. For Lamar, the process looks like this:

1. Install the Lamar.Microsoft.DependencyInjection NuGet package using the NuGet package manager, by running dotnet add package

   ```
   dotnet add package Lamar.Microsoft.DependencyInjection
   ```

   or by adding a `<PackageReference>` to your csproj file

   ```
   <PackageReference
       Include="Lamar.Microsoft.DependencyInjection" Version="4.3.0" />
   ```

2. Call `UseLamar()` on your `IHostBuilder` in Program.cs

   ```
   public static IHostBuilder CreateHostBuilder(string[] args) =>
       Host.CreateDefaultBuilder(args)
           .UseLamar()
           .ConfigureWebHostDefaults(webBuilder =>
           {
               webBuilder.UseStartup<Startup>();
           }
   ```

3. Add a `ConfigureContainer` method to your `Startup` class, with the following signature:

   ```
   public void ConfigureContainer(ServiceRegistry services) { }
   ```

4. Configure the Lamar `ServiceRegistry` in `ConfigureContainer`, as shown in the following listing. This is a basic configuration, but you can see a more complex example in the source code for this chapter.

Listing 19.14 Configuring StructureMap as a third-party DI container

```
public void ConfigureContainer(ServiceRegistry services)        #A
{
    services.AddAuthorization();                                #B
    services.AddControllers()                                   #B
        .AddControllersAsServices();                            #C
```

```
    config.Scan(_ => {                                          #D
        _.AssemblyContainingType(typeof(Startup));              #D
        _.WithDefaultConventions();                             #D
    });                                                         #D
}
```

#A Configure your services in ConfigureContainer instead of ConfigureServices
#B You can (and should) add ASP.NET Core framework services to the ServiceRegistry as usual.
#C Required so that Lamar is used to build your API controllers.
#D Lamar can automatically scan your assemblies for services to register.

In this example, I've used the default conventions to register services. This will automatically register concrete classes and services that are named following expected conventions (for example, `Service` implements `IService`). You can change these conventions or add other registrations in the `ConfigureContainer` method.

The `ServiceRegistry` passed into `ConfigureContainer` implements `IServiceCollection`, which means you can use all the built-in extension methods, such as `AddControllers()` and `AddAuthorization()`, to add framework services to your container.

> **WARNING** If you're using DI in your MVC controllers (almost certainly!) and you register those dependencies with Lamar, rather than the built-in container, you may need to call `AddControllersAsServices()`, as shown in listing 19.14. This is due to an implementation detail in the way the your MVC controllers are created by the framework. For details, see https://andrewlock.net/controller-activation-and-dependency-injection-in-asp-net-core-mvc/.

With this configuration in place, whenever your app needs to create a service, it will request it from the Lamar container, which will create the dependency tree for the class and create an instance. This example doesn't show off the power of Lamar, so be sure to check out the documentation (https://jasperfx.github.io/lamar/) and the associated source code for this chapter for more examples. Even in modestly sized applications, Lamar can greatly simplify your service registration code, but its party trick is showing all the services you have registered, and any associated issues.

That brings us to the end of this chapter on custom components. In this chapter, I focused on some of the most common components you will build for the configuration, dependency injection, and middleware systems of ASP.NET Core. In the next chapter, you'll learn about more custom components, with a focus on Razor Pages and API controllers.

19.5 Summary

- Use the `Run` extension method to create middleware components that always return a response. You should always place the `Run` extension at the end of a middleware pipeline or branch, as middleware placed after it will never execute.

- You can create branches in the middleware pipeline with the `Map` extension. If an incoming request matches the specified path prefix, the request will execute the pipeline branch, otherwise it will execute the trunk.
- When the `Map` extension matches a request path segment, it removes the segment from the request's `HttpContext.Path` and moves it to the `PathBase` property. This ensures that routing in branches works correctly.
- You can use the `Use` extension method to create generalized middleware components that can generate a response, modify the request, or pass the request on to subsequent middleware in the pipeline. This is useful for cross-cutting concerns, like adding a header to all responses.
- You can encapsulate middleware in a reusable class. The class should take a `RequestDelegate` object in the constructor, and should have a public `Invoke()` method that takes an `HttpContext` and returns a `Task`. To call the next middleware in the pipeline, invoke the `RequestDelegate` with the provided `HttpContext`.
- To create endpoints that generate a response, build a miniature pipeline containing the response-generating middleware, and call `endpoints.Map(route, pipeline)`. Endpoint routing will be used to map incoming requests to your endpoint.
- You can attach metadata to endpoints which is made available to any middleware placed between the calls to `UseRouting()` and `UseEndpoints()`. This metadata enables functionality such as authorization and CORS.
- To add authorization to an endpoint, call `RequireAuthorization()` after mapping the endpoint. This is equivalent to using the `[Authorize]` attribute on Razor Pages and API controllers. You can optionally provide an authorization policy name, instead of using the default policy.
- Some configuration providers require configuration values themselves. For example, a configuration provider that loads settings from a database might need a connection string. You can load these configuration providers by partially building an `IConfiguration` object using the other providers and reading the required configuration from it. You can then configure the database provider and add it to the `ConfigurationBuilder` before rebuilding to get the final `IConfiguration`.
- If you need to use services from the DI container to configure an `IOptions<T>` object, then you should create a separate class that implements `IConfigureOptions<T>`. This class can use DI in the constructor and is used to lazily build a requested `IOptions<T>` object at runtime.
- You can replace the built-in DI container with a third-party container. Third-party containers often provide additional features, such as convention-based dependency registration, assembly scanning, or property injection.
- To use a third-party container such as Lamar, install the NuGet package, enable the container on `IHostBuilder`, and implement `ConfigureContainer()` in Startup. Configure the third-party container in this method by registering both the required ASP.NET Core framework services and your app specific services.

20 Building custom MVC and Razor Pages components

This chapter covers

- **Creating custom Razor Tag Helpers**
- **Using view components to create complex Razor views**
- **Creating a custom `DataAnnotations` validation attribute**
- **Replacing the `DataAnnotations` validation framework with an alternative**

In the previous chapter, you learned how to customize and extend some of the core systems in ASP.NET Core: configuration, dependency injection, and your middleware pipeline. These components form the basis of all ASP.NET Core apps. In this chapter we're focusing on Razor Pages and MVC/API controllers. You'll learn how to build custom components that work with Razor views, as well as the validation framework used by both Razor Pages and API controllers.

We start by looking at Tag Helpers. In section 20.1, I show you how to create two different Tag Helpers: one that generates HTML to describe the current machine, and one that lets you write `if` statements in Razor templates without having to use C#. These will give you the details you need to create your own custom Tag Helpers in your own apps if the need arises.

In section 20.2, you'll learn about a new Razor concept: view components. View components are a bit like partial views, but they can contain business logic and database access. For example, on an e-commerce site, you might have a shopping cart, a dynamically populated menu, and a login widget, all on one page. Each of those sections is independent of the main page content and has its own logic and data-access needs. In an ASP.NET Core app using Razor Pages, you'd implement each of those as a View Component.

In section 20.3, I show how to create a custom validation attribute. As you saw in chapter 6, validation is a key responsibility of Razor Page handlers and action methods, and the DataAnnotations attributes provide a clean, declarative way for doing so. We previously only looked at the built-in attributes, but you'll often find you need to add attributes tailored to your app's domain. In section 20.3, you'll see how to create a simple validation attribute, and how to extend it to use services registered with the DI container.

Throughout this book I've mentioned that you can easily swap out core parts of the ASP.NET Core framework if you wish. In section 20.4 you'll do just that, by replacing the built-in attribute-based validation framework with a popular alternative, FluentValidation. This open source library allows you to separate your binding models from the validation rules, which makes building certain validation logic easier. Many people prefer this approach of separating concerns to the declarative approach of DataAnnotations.

When you're building pages with Razor Pages, one of the best productivity features is Tag Helpers, and in the next section you'll see how you can create your own.

20.1 Creating a custom Razor Tag Helper

In this section you'll learn how to create your own Tag Helpers, which allow you to customize your HTML output. You'll learn how to create Tag Helpers that add new elements to your HTML markup, as well as Tag Helpers that can be used to remove or customize existing markup. You'll also see that your custom Tag Helpers integrate with the tooling of your IDE to provide rich IntelliSense in the same way as the built-in Tag Helpers.

In my opinion, Tag Helpers are one of the best additions to the venerable Razor template language in ASP.NET Core. They allow you to write Razor templates that are easier to read, as they require less switching between C# and HTML, and they *augment* your HTML tags, rather than replacing them (as opposed to the HTML Helpers used extensively in the previous version of ASP.NET).

ASP.NET Core comes with a wide variety of Tag Helpers (see chapter 8), which will cover many of your day-to-day requirements, especially when it comes to building forms. For example, you can use the Input Tag Helper by adding an asp-for attribute to an <input> tag and passing a reference to a property on your PageModel, in this case Input.Email:

```
<input asp-for="Input.Email" />
```

The Tag Helper is activated by the presence of the attribute and gets a chance to augment the <input> tag when rendering to HTML. The Input Tag Helper uses the name of the property to set the <input> tag's name and id properties, the value of the model to set the value property, and the presence of attributes such as [Required] or [EmailAddress] to add attributes for validations:

```
<input type="email" id="Input_Email" name="Input.Email"
    value="test@example.com" data-val="true"
    data-val-email="The Email Address field is not a valid e-mail address."
    data-val-required="The Email Address field is required."
    />
```

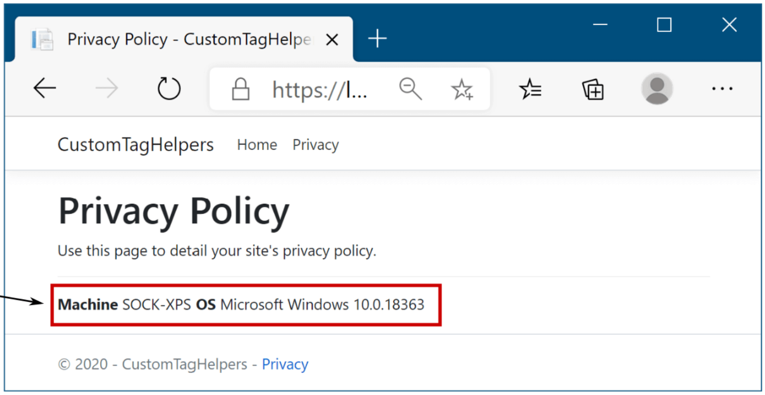
Tag Helpers help reduce the duplication in your code, or they can simplify common patterns. In this section, I show how you can create your own custom Tag Helpers.

In section 20.1.1, you create a system information Tag Helper, which prints details about the name and operating system of the server your app is running on. In section 20.1.2, you create a Tag Helper that you can use to conditionally show or hide an element based on a C# Boolean property. In section 20.1.3 you create a Tag Helper that reads the Razor content written *inside* the Tag Helper and transforms it.

20.1.1 Printing environment information with a custom Tag Helper

A common problem you may run into when you start running your web applications in production, especially if you're using a server-farm setup, is working out which machine rendered the page you're currently looking at. Similarly, when deploying frequently, it can be useful to know which *version* of the application is running. When I'm developing and testing, I sometimes like to add a little "info dump" at the bottom of my layouts, so I can easily work out which server generated the current page, which environment it's running in, and so on.

In this section, I'm going to show you how to build a custom Tag Helper to output system information to your layout. You'll be able to toggle the information it displays, but by default, it will display the machine name and operating system on which the app is running, as shown in figure 20.1.



Privacy Policy

Use this page to detail your site's privacy policy.

Machine SOCK-XPS **OS** Microsoft Windows 10.0.18363

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The SystemInfoTagHelper displays information about the server on which the app is executing

Figure 20.1 The `SystemInfoTagHelper` displays the machine name and operating system on which the application is running. It can be useful for identifying which instance of your app handled the request when running in a web farm scenario.

You can call this Tag Helper from Razor by creating a `<system-info>` element in your template, for example:

```
<footer>
  <system-info></system-info>
</footer>
```

TIP You probably don’t want to expose this sort of information in production, so you could also wrap it in an `<environment>` Tag Helper, as you saw in chapter 8.

The easiest way to create a custom Tag Helper is to derive from the `TagHelper` base class and override the `Process()` or `ProcessAsync()` function that describes how the class should render itself. The following listing shows your complete custom Tag Helper, the `SystemInfoTagHelper`, which renders the system information to a `<div>`. You could easily extend this class if you wanted to display additional fields or add additional options.

Listing 20.1 `SystemInfoTagHelper` to render system information to a view

```
public class SystemInfoTagHelper : TagHelper      #A
{
    private readonly HtmlEncoder _htmlEncoder;                #B
    public SystemInfoTagHelper(HtmlEncoder htmlEncoder)       #B
    {
        _htmlEncoder = htmlEncoder;
    }

    [HtmlAttributeName("add-machine")]        #C
    public bool IncludeMachine { get; set; } = true;

    [HtmlAttributeName("add-os")]         #C
    public bool IncludeOS { get; set; } = true;

    public override void Process(         #D
        TagHelperContext context, TagHelperOutput output)       #D
    {
        output.TagName = "div";           #E
        output.TagMode = TagMode.StartTagAndEndTag;      #F
        var sb = new StringBuilder();

        if (IncludeMachine)      #G
        {           #G
           sb.Append(" <strong>Machine</strong> ");    #G
           sb.Append(_htmlEncoder.Encode(Environment.MachineName));       #G
        }             #G

        if (IncludeOS)           #H
        {                #H
           sb.Append(" <strong>OS</strong> ");     #H
           sb.Append(         #H
              _htmlEncoder.Encode(RuntimeInformation.OSDescription));    #H
        }           #H
        output.Content.SetHtmlContent(sb.ToString());         #I
    }
}
```

#A Derives from the TagHelper base class
#B An HtmlEncoder is necessary when writing HTML content to the page.
#C Decorating properties with HtmlAttributeName allows you to set their value from Razor markup
#D The main function called when an element is rendered.
#E Replaces the <system-info> element with a <div> element
#F Renders both the <div> </div> start and end tag

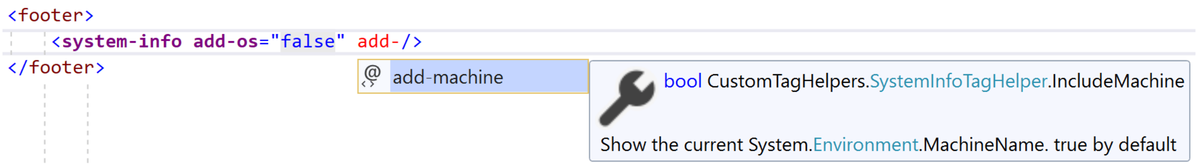
#G If required, adds a <strong> element and the HTML-encoded machine name
#H If required, adds a <strong> element and the HTML-encoded OS name
#I Sets the inner content of the <div> tag with the HTML-encoded value stored in the string builder

There’s a lot of new code in this sample, so we’ll work through it line by line. First, the class name of the Tag Helper defines the name of the element you must create in your Razor template, with the suffix removed and converted to kebab-case. As this Tag Helper is called `SystemInfoTagHelper`, you must create a `<system-info>` element.

> **TIP If you want to customize the name of the element, for example to `<env-info>`, but want to keep the same class name, you can apply the `[HtmlTargetElement]` with the desired name, such as `[HtmlTargetElement("Env-Info")]`. HTML tags are not case sensitive, so you could use "`Env-Info`" or "`env-info`".**

Inject an `HtmlEncoder` into your Tag Helper so you can HTML-encode any data you write to the page. As you saw in chapter 18, you should always HTML-encode data you write to the page to avoid XSS vulnerabilities (and to ensure the data is displayed correctly).

You’ve defined two properties on your Tag Helper, `IncludeMachine` and `IncludeOS`, which you’ll use to control which data is written to the page. These are decorated with a corresponding `[HtmlAttributeName]`, which enables setting the properties from the Razor template. In Visual Studio, you’ll even get IntelliSense and type checking for these values, as shown in figure 20.2.



```
<footer>
    <system-info add-os="false" add-/>
</footer>
```

add-machine

bool CustomTagHelpers.SystemInfoTagHelper.IncludeMachine

Show the current System.Environment.MachineName. true by default

Figure 20.2 In Visual Studio, Tag Helpers are shown in a purple font and you get IntelliSense for properties decorated with `[HtmlAttributeName]`.

Finally, we come to the `Process()` method. The Razor engine calls this method to execute the Tag Helper when it identifies the target element in a view template. The `Process()` method defines the type of tag to render (`<div>`), whether it should render a start and end tag (or a self-closing tag—it depends on the type of tag you’re rendering), and the HTML content of the `<div>`. You set the HTML content to be rendered inside the tag by calling `Content.SetHtmlContent()` on the provided instance of `TagHelperOutput`.

> **WARNING Always HTML-encode your output before writing to your tag with `SetHtmlContent()`. Alternatively, pass unencoded input to `SetContent()` and the output will be automatically HTML-encoded for you.**

Before you can use your new Tag Helper in a Razor template, you need to register it. You can do this in the _ViewImports.cshtml file, using the `@addTagHelper` directive and specifying the fully qualified name of the Tag Helper and the assembly. For example,

```
@addTagHelper CustomTagHelpers.SystemInfoTagHelper, CustomTagHelpers
```

Alternatively, you can add all the Tag Helpers from a given assembly by using the wildcard syntax, `*`, and specifying the assembly name:

```
@addTagHelper *, CustomTagHelpers
```

With your custom Tag Helper created and registered, you're now free to use it in any of your Razor views, partial views, or layouts.

> **TIP If you're not seeing IntelliSense for your Tag Helper in Visual Studio, and the Tag Helper isn't rendered in the bold font used by Visual Studio, then you probably haven't registered your Tag Helpers correctly in __ViewImports.cshtml using** `@addTagHelper`**.**

The `SystemInfoTagHelper` is an example of a Tag Helper that generates content, but you can also use Tag Helpers to control how existing elements are rendered. In the next section, you'll create a simple Tag Helper that can control whether or not an element is rendered, based on an HTML attribute.

20.1.2 Creating a custom Tag Helper to conditionally hide elements

If you want to control whether an element is displayed in a Razor template based on some C# variable, then you'd typically wrap the element in a C# `if` statement:

```
@{
    var showContent = true;
}
@if(showContent)
{
    <p>The content to show</p>
}
```

Falling back to C# constructs like this can be useful, as it allows you to generate any markup you like. Unfortunately, it can be mentally disruptive having to switch back and forth between C# and HTML, and it makes it harder to use HTML editors that don't understand Razor syntax.

In this section, you'll create a simple Tag Helper to avoid the cognitive dissonance problem. You can apply this Tag Helper to existing elements to achieve the same result as shown previously, but without having to fall back to C#:

```
@{
    var showContent = true;
}
<p if="showContent">
    The content to show
</p>
```

Instead of creating a new *element*, as you did for SystemInfoTagHelper (<system-info>), you'll create a Tag Helper that you apply as an *attribute* to existing HTML elements. This Tag Helper does one thing: it controls the visibility of the element it's attached to. If the value passed in the if attribute is true, the element and its content is rendered as normal. If the value passed is false, the Tag Helper removes the element and its content from the template. Here's how you could achieve this.

Listing 20.2 Creating an IfTagHelper to conditionally render elements

```
[HtmlTargetElement(Attributes = "if")]        #A
public class IfTagHelper : TagHelper
{
    [HtmlAttributeName("if")]              #B
    public bool RenderContent { get; set; } = true;

    public override void Process(                           #C
        TagHelperContext context, TagHelperOutput output)    #C
    {
        if(RenderContent == false)             #D
        {
            output.TagName = null;          #E
            output.SuppressOutput();         #F
        }
    }

    public override int Order => int.MinValue;      #G
}
```

#A Setting the Attributes property ensures the Tag Helper is triggered by an if attribute.
#B Binds the value of the if attribute to the RenderContent property
#C The Razor engine calls Process() to execute the Tag Helper.
#D If the RenderContent property evaluates to false, removes the element
#E Sets the element the Tag Helper resides on to null, removing it from the page
#F Doesn't render or evaluate the inner content of the element
#G Ensures this Tag Helper runs before any others attached to the element

Instead of a standalone <if> element, the Razor engine executes the IfTagHelper whenever it finds an element with an if attribute. This can be applied to any HTML element: <p>, <div>, <input>, whatever you need. Define a Boolean property for whether you should render the content, which is bound to the value in the if attribute.

The Process() function is much simpler here. If RenderContent is false, then it sets the TagHelperOutput.TagName to null, which removes the element from the page. You also call SuppressOutput(), which prevents any content *inside* the attributed element from being rendered. If RenderContent is true, then you skip these steps and the content is rendered as normal.

One other point of note is the overridden Order property. This controls the order in which Tag Helpers run when multiple Tag Helpers are applied to an element. By setting Order to int.MinValue, you ensure IfTagHelper will run first, removing the element if required, before other Tag Helpers execute. There’s generally no point running other Tag Helpers if the element is going to be removed from the page anyway!

> **NOTE** **Remember to register your custom Tag Helpers in _ViewImports .cshtml with the** `@addTagHelper` **directive.**

With a simple HTML attribute, you can now conditionally render elements in Razor templates, without having to fall back to C#. This tag helper can show and hide content without needing to know what the content is. In the next section, we’ll create a Tag Helper that does *need* to know the content.

20.1.3 Creating a Tag Helper to convert Markdown to HTML

The two Tag Helpers shown so far are agnostic to the content written *inside* the Tag Helper, but it can also be useful to create Tag Helpers that inspect, retrieve, and modify this content. In this section you’ll see an example of one such Tag Helper that converts Markdown content written inside it into HTML.

> **DEFINITION** **Markdown is a commonly used text-based markup language that is easy to read but can also be converted into HTML. It is the common format used by README files on GitHub, and I use it to write blog posts, for example. For an introduction to Markdown, see https://guides.github.com/features/mastering-markdown/.**

We’ll use the popular Markdig library (https://github.com/lunet-io/markdig/) to create the Markdown Tag Helper. This library converts a `string` containing markdown into an HTML `string`. You can install Markdig using Visual Studio, by running `dotnet add package Markdig`, or by adding a `<PackageReference>` to your csproj file:

```
<PackageReference Include="Markdig" Version="0.20.0" />
```

The Markdown Tag Helper that we’ll create shortly can be used by adding `<markdown>` elements to your Razor Page, as shown in the following listing.

Listing 20.3 Using a Markdown Tag Helper in a Razor Page

```
@page
@model IndexModel

<markdown>                                                  #A
## This is a markdown title                                 #B

This is a markdown list:                                    #C

* Item 1                                                    #C
* Item 2                                                    #C

<div if="showContent">                                      #D
  Content is shown when showContent is true                 #D
</div>                                                      #D
```

```
</markdown>
```

#A The Markdown Tag Helper is added using the <markdown> element
#B Titles can be created in Markdown using # to denote h1, ## to denote h2, and so on
#C Markdown converts simple lists to HTML <ul> elements
#D Razor content can be nested inside other Tag Helpers

The Markdown Tag Helper renders content by:

1. Rendering any Razor content inside the Tag Helper. This includes executing any *nested* Tag Helpers and C# code inside the Tag Helper. The above example uses the `IfTagHelper`, for example.
2. Converting the resulting `string` to HTML using the Markdig library.
3. Replacing the content with the rendered HTML and removing the Tag Helper `<markdown>` element.

The following listing shows a simple approach to implementing a Markdown Tag Helper using Markdig. Markdig supports many additional extensions and features that you could enable, but the overall pattern of the Tag Helper would be the same.

Listing 20.4 Implementing a Markdown Tag Helper using Markdig

```
public class MarkdownTagHelper: TagHelper                           #A
{
    public override async Task ProcessAsync(
        TagHelperContext context, TagHelperOutput output)
    {
        TagHelperContent markdownRazorContent = await               #B
            output.GetChildContentAsync(NullHtmlEncoder.Default);   #B
        string markdown =                                           #C
            markdownRazorContent.GetContent(NullHtmlEncoder.Default);    #C

        string html = Markdig.Markdown.ToHtml(markdown);            #D

        output.Content.SetHtmlContent(html);                        #E
        output.TagName = null;                                      #F
    }
}
```

#A The Markdown Tag Helper will use the <markdown> element
#B Retrieve the contents of the <markdown> element
#C Render the Razor contents to a string
#D Convert the markdown string to HTML using Markdig
#E Write the HTML content to the output
#F Remove the <markdown> element from the content

When rendered to HTML, the Markdown content in listing 20.3 (when the `showContent` variable is `true`) becomes:

```
<h2>This is a markdown title</h2>
<p>This is a markdown list:</p>
<ul>
<li>Item 1</li>
```

```
<li>Item 2</li>
</ul>
<div>
  Content is shown when showContent is true
</div>
```

> **NOTE** In Listing 20.4 we implemented `ProcessAsync()` instead of `Process()`. That is because we call the `async` method, `GetChildContentAsync()`. You must only call `async` methods from other `async` methods, as otherwise you can get issues such as thread starvation. For more details, see https://docs.microsoft.com/aspnet/core/performance/performance-best-practices.

The Tag Helpers in this section represent a small sample of possible avenues you could explore,[100] but they cover the two broad categories: Tag Helpers for rendering new content, and Tag Helpers for controlling the rendering of other elements.

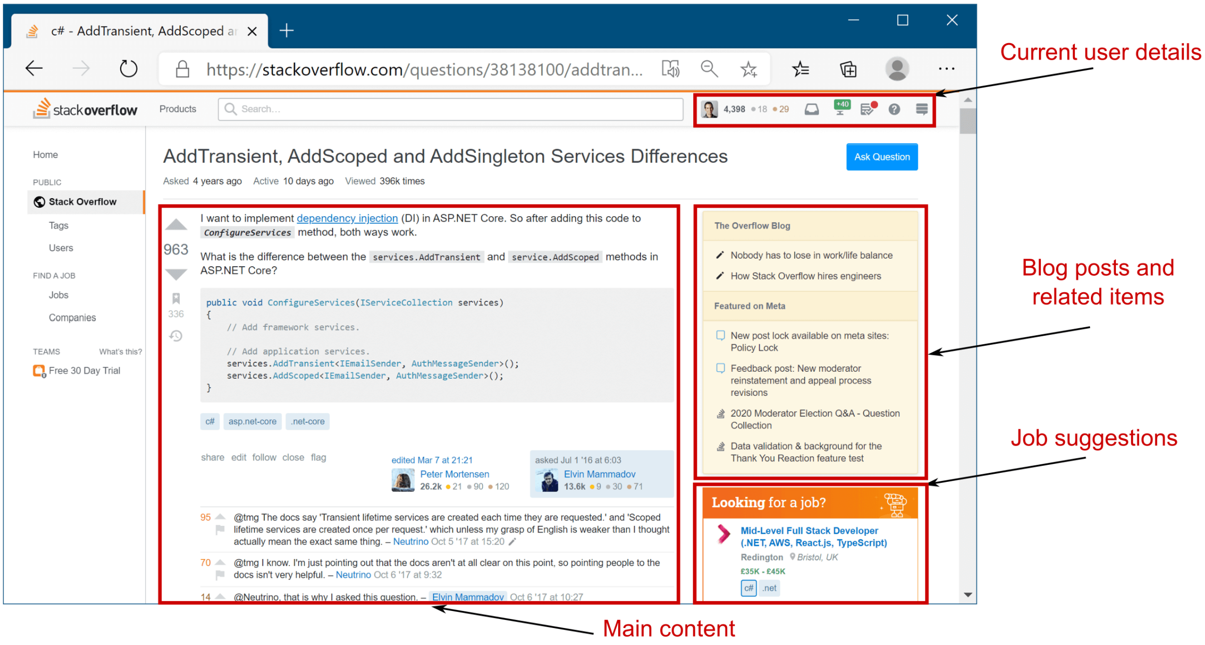
Tag Helpers can be useful for providing small pieces of isolated, reusable functionality like this, but they're not designed to provide larger, application-specific sections of an app or to make calls to business-logic services. Instead, you should use view components, as you'll see in the next section.

20.2 View components: adding logic to partial views

In this section you'll learn about view components. View components operate independently of the main Razor Page and can be used to encapsulate complex business logic. You can use view components to keep your main Razor Page focused on a single task, rendering the main content, instead of also being responsible for other sections of the page.

If you think about a typical website, you'll notice that they often have multiple independent dynamic sections, in addition to the main content. Consider Stack Overflow, shown in figure 20.3, for example. As well as the main body of the page showing questions and answers, there's a section showing the current logged-in user, a panel for blog posts and related items, and a section for job suggestions.

[100] For further details and examples, see the documentation at http://mng.bz/Idb0.



AddTransient, AddScoped and AddSingleton Services Differences

Asked 4 years ago Active 10 days ago Viewed 396k times

I want to implement dependency injection (DI) in ASP.NET Core. So after adding this code to `ConfigureServices` method, both ways work.

What is the difference between the `services.AddTransient` and `service.AddScoped` methods in ASP.NET Core?

```
public void ConfigureServices(IServiceCollection services)
{
    // Add framework services.

    // Add application services.
    services.AddTransient<IEmailSender, AuthMessageSender>();
    services.AddScoped<IEmailSender, AuthMessageSender>();
}
```

edited Mar 7 at 21:21
Peter Mortensen
26.2k •21 •90 •120

asked Jul 1 '16 at 6:03
Elvin Mammadov
13.6k •9 •30 •71

95 @tmg The docs say 'Transient lifetime services are created each time they are requested.' and 'Scoped lifetime services are created once per request.' which unless my grasp of English is weaker than I thought actually mean the exact same thing. – Neutrino Oct 5 '17 at 15:20

70 @tmg I know. I'm just pointing out that the docs aren't at all clear on this point, so pointing people to the docs isn't very helpful. – Neutrino Oct 6 '17 at 9:32

14 @Neutrino, that is why I asked this question. – Elvin Mammadov Oct 6 '17 at 10:27

The Overflow Blog

- Nobody has to lose in work/life balance
- How Stack Overflow hires engineers

Featured on Meta

- New post lock available on meta sites: Policy Lock
- Feedback post: New moderator reinstatement and appeal process revisions
- 2020 Moderator Election Q&A - Question Collection
- Data validation & background for the Thank You Reaction feature test

Looking for a job?

Mid-Level Full Stack Developer (.NET, AWS, React.js, TypeScript)
Redington Bristol, UK
£35K - £45K
c# .net

Figure 20.3 The Stack Overflow website has multiple sections that are independent of the main content, but which contain business logic and complex rendering logic. Each of these sections could be rendered as a view component in ASP.NET Core.

Each of these sections is effectively independent of the main content. Each section contains business logic (deciding which posts or ads to show), database access (loading the details of the posts), and rendering logic for how to display the data. In chapter 7, you saw that you can use layouts and partial views to split up the rendering of a view template into similar sections, but partial views aren’t a good fit for this example. Partial views let you encapsulate *view rendering* logic, but not *business* logic that’s independent of the main page content.

Instead, *view components* provide this functionality, encapsulating both the business logic and rendering logic for displaying a small section of the page. You can use DI to provide access to a database context, and you can test them independently of the view they generate, much like MVC and API controllers. Think of them a bit like mini-MVC controllers, or mini-Razor Pages, but you invoke them directly from a Razor view, instead of in response to an HTTP request.

TIP View components are comparable to *child actions* from the previous version of ASP.NET, in that they provide similar functionality. Child actions don’t exist in ASP.NET Core.

View components versus Razor Components and Blazor

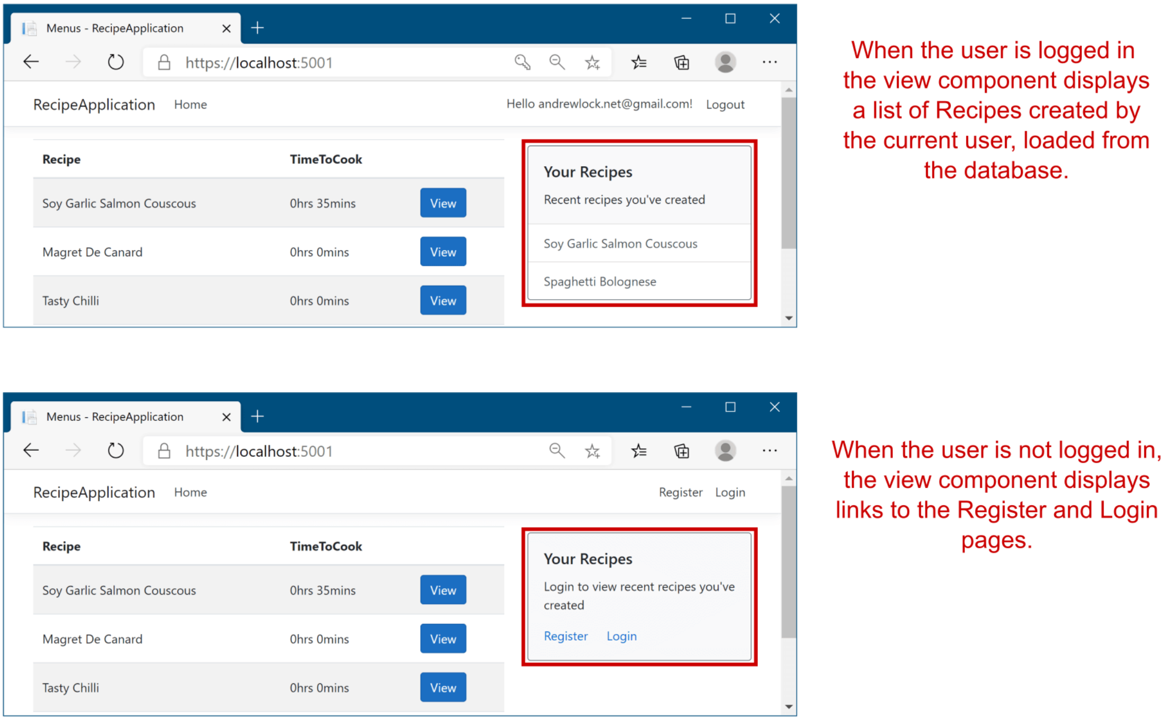
In this book I am focusing on server-side rendered applications using Razor Pages and API applications using API controllers. .NET Core 3.0 introduced a completely new approach to building ASP.NET Core applications: Blazor. I don't cover Blazor in this book, so I recommend reading *Blazor in Action* by Chris Sainty (Manning, 2021).

Blazor has two programming models, client-side and server-side, but both approaches use *Blazor components* (confusingly, officially called *Razor components*). Blazor components have a lot of parallels with view components, but they live in a fundamentally different world. Blazor components can interact with each other easily, but you can't use them with Tag Helpers or view components, and it's hard to combine them with Razor Page form posts.

Nevertheless, if you need an "island" of rich client-side interactivity in a single Razor Page, you can embed a Blazor component inside a Razor Page, as shown in the documentation: https://docs.microsoft.com/aspnet/core/blazor/components/integrate-components. You could also use Blazor components as a way to replace AJAX calls in your Razor Pages, as I show in https://andrewlock.net/replacing-ajax-calls-in-razor-pages-using-razor-components-and-blazor/.

If you don't need the client-side interactivity of Blazor, then view components are still the best option for isolated sections in Razor Pages. They interoperate cleanly with your Razor Pages, have no additional operational overhead, and use familiar concepts like layouts, partial views and Tag Helpers. For more details on why you should continue to use view components see https://andrewlock.net/dont-replace-your-view-components-with-razor-components/.

In this section, you'll see how to create a custom view component for the recipe app you built in previous chapters, as shown in figure 20.4. If the current user is logged in, the view component displays a panel with a list of links to the user's recently created recipes. For unauthenticated users, the view component displays links to the login and register actions.



Menus - RecipeApplication

https://localhost:5001

RecipeApplication Home Hello andrewlock.net@gmail.com! Logout

Recipe	TimeToCook	
Soy Garlic Salmon Couscous	0hrs 35mins	View
Magret De Canard	0hrs 0mins	View
Tasty Chilli	0hrs 0mins	View

Your Recipes

Recent recipes you've created

Soy Garlic Salmon Couscous

Spaghetti Bolognese

When the user is logged in the view component displays a list of Recipes created by the current user, loaded from the database.

Menus - RecipeApplication

https://localhost:5001

RecipeApplication Home Register Login

Recipe	TimeToCook	
Soy Garlic Salmon Couscous	0hrs 35mins	View
Magret De Canard	0hrs 0mins	View
Tasty Chilli	0hrs 0mins	View

Your Recipes

Login to view recent recipes you've created

Register Login

When the user is not logged in, the view component displays links to the Register and Login pages.

Figure 20.4 The view component displays different content based on the currently logged-in user. It includes both business logic (which recipes to load from the database) and rendering logic (how to display the data).

This component is a great candidate for a view component as it contains database access and business logic (choosing which recipes to display), as well as rendering logic (how the panel should be displayed).

> **TIP** Use partial views when you want to encapsulate the rendering of a specific view model, or part of a view model. When you have rendering logic that requires business logic or database access, or where the section is logically distinct from the main page content, consider using a view component.

You invoke view components directly from Razor views and layouts using a Tag Helper-style syntax, using a `vc:` prefix:

```
<vc:my-recipes number-of-recipes="3">
</vc:my-recipes>
```

Custom view components typically derive from the `ViewComponent` base class, and implement an `InvokeAsync()` method, as shown in listing 20.5. Deriving from this base class allows access to useful helper methods, in much the same way that deriving from the

ControllerBase class does for API controllers. Unlike API controllers, the parameters passed to InvokeAsync don’t come from model binding. Instead, you pass the parameters to the view component using properties on the Tag Helper element in your Razor view.

Listing 20.5 A custom view component to display the current user’s recipes

```
public class MyRecipesViewComponent : ViewComponent              #A
{
    private readonly RecipeService _recipeService;               #B
    private readonly UserManager<ApplicationUser> _userManager;   #B
    public MyRecipesViewComponent(RecipeService recipeService,    #B
        UserManager<ApplicationUser> userManager)                 #B
    {                                                             #B
        _recipeService = recipeService;                           #B
        _userManager = userManager;                               #B
    }                                                             #B

    public async Task<IViewComponentResult> InvokeAsync(          #C
        int numberOfRecipes)                                      #D
    {
        if(!User.Identity.IsAuthenticated)
        {
            return View("Unauthenticated");                       #E
        }

        var userId = _userManager.GetUserId(HttpContext.User);    #F
        var recipes = await _recipeService.GetRecipesForUser(     #F
            userId, numberOfRecipes);

        return View(recipes);                                     #G
    }
}
```

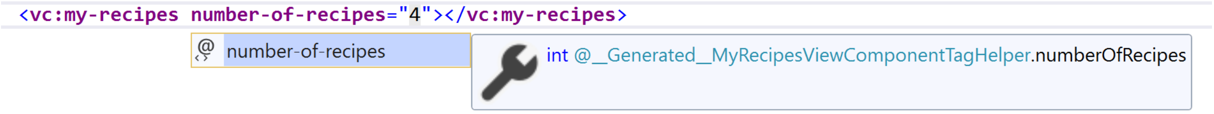
#A Deriving from the ViewComponent base class provides useful methods like View().
#B You can use DI in a view Component.
#C InvokeAsync renders the view component. It should return a Task<IViewComponentResult>
#D You can pass parameters to the component from the view.
#E Calling View() will render a partial view with the provided name.
#F You can use async external services, allowing you to encapsulate logic in your business domain.
#G You can pass a view model to the partial view. Default.cshtml is used by default.

This custom view component handles all the logic you need to render a list of recipes when the user is logged in, or a different view if the user isn’t authenticated. The name of the view component is derived from the class name, like Tag Helpers. Alternatively, you can apply the [ViewComponent] attribute to the class and set a different name entirely.

The InvokeAsync method must return a Task<IViewComponentResult>. This is similar to the way you can return IActionResult from an action method or a page handler, but it’s more restrictive; view components *must* render some sort of content, so you can’t return status codes or redirects. You’ll typically use the View() helper method to render a partial view template (as in the previous listing) though you can also return a string directly using the

Content() helper method, which will HTML-encode the content and render it to the page directly.

You can pass any number of parameters to the InvokeAsync method. The name of the parameters (in this case, numberOfRecipes) is converted to kebab-case and exposed as a property in the view component's Tag Helper (<number-of-recipes>). You can provide these parameters when you invoke the view component from a view, and you'll get IntelliSense support, as show in figure 20.5.



```
<vc:my-recipes number-of-recipes="4"></vc:my-recipes>
```

number-of-recipes
int @__Generated__MyRecipesViewComponentTagHelper.numberOfRecipes

Figure 20.5 Visual Studio provides IntelliSense support for the method parameters of a view component's InvokeAsync method. The parameter name, in this case numberOfRecipes, is converted to kebab-case for use as an attribute in the Tag Helper.

View components have access to the current request and HttpContext. In listing 20.5, you can see that we're checking whether the current request was from an authenticated user. You can also see that we've used some conditional logic: if the user isn't authenticated, render the "Unauthenticated" Razor template, if they're authenticated, render the default Razor template and pass in the view models loaded from the database.

> **NOTE If you don't specify a specific Razor view template to use in the View() function, view components use the template name, "Default.cshtml."**

The partial views for view components work similarly to other Razor partial views that you learned about in chapter 7, but they're stored separately from them. You must create partial views for view components at either:

- Views/Shared/Components/ComponentName/TemplateName, or
- Pages/Shared/Components/ComponentName/TemplateName

Both locations work, so for Razor Pages app, I typically use the Pages/ folder. For the view component in listing 20.5, for example, you'd create your view templates at

- Pages/Shared/Components/MyRecipes/Default.cshtml
- Pages/Shared/Components/MyRecipes/Unauthenticated.cshtml

This was only a quick introduction to view components, but it should get you a long way. View components are a simple method to embed pockets of isolated, complex logic in your Razor layouts. Having said that, be mindful of these caveats:

- View component classes must be public, non-nested, and non-abstract classes.
- Although similar to MVC controllers, you can't use filters with view components.

- You can use Layouts in your view components views, to extract rendering logic common to a specific view component. This layout may contain @sections, as you saw in chapter 7, but these sections are independent of the "main" Razor view's layout.
- View components are isolated from the Razor Page they're rendered in, so you can't, for example, define a @section in a Razor Page layout, and then add that content from a view component; the contexts are completely separate
- When using the <vc:my-recipes> Tag Helper syntax to invoke your view component, you must import it as a custom Tag Helper, as you saw in section 20.1.
- Instead of using the Tag Helper syntax, you may invoke the view component from a view directly by using IViewComponentHelper Component, though I don't recommend using this syntax. For example:

```
@await Component.InvokeAsync("MyRecipes", new { numberOfRecipes = 3 })
```

We've covered Tag Helpers and view components, which are both features of the Razor engine in ASP.NET Core. In the next section, you'll learn about a different, but related, topic: how to create a custom DataAnnotations attribute. If you've used previous versions of ASP.NET, then this will be familiar, but ASP.NET Core has a couple of tricks up its sleeve to help you out.

20.3 Building a custom validation attribute

In this section you'll learn how to create a custom DataAnnotations validation attribute that specifies specific values a string property may take. You'll then learn how you can expand the functionality to be more generic by delegating to a separate service that is configured in your DI controller. This will allow you to create custom domain-specific validations for your apps.

We looked at model binding in chapter 6, where you saw how to use the built-in DataAnnotations attributes in your binding models to validate user input. These provide several built-in validations, such as

- [Required]—The property isn't optional and must be provided.
- [StringLength(min, max)]—The length of the string value must be between min and max characters.
- [EmailAddress]—The value must be a valid email address format.

But what if these attributes don't meet your requirements? Consider the following listing, which shows a binding model from a currency converter application. The model contains three properties: the currency to convert from, the currency to convert to, and the quantity.

Listing 20.6 Currency converter initial binding model

```
public class CurrencyConverterModel
{
    [Required]                                    #A
    [StringLength(3, MinimumLength = 3)]          #B
    public string CurrencyFrom { get; set; }
    [Required]                              #A
    [StringLength(3, MinimumLength = 3)]    #B
    public string CurrencyTo { get; set; }

    [Required]                              #A
    [Range(1, 1000)]                        #C
    public decimal Quantity { get; set; }
}
```

#A All the properties are required.
#B The strings must be exactly 3 characters.
#C The quantity can be between 1 and 1000.

There's some basic validation on this model, but during testing you identify a problem: users can enter any three-letter string for the `CurrencyFrom` and `CurrencyTo` properties. Users should only be able to choose a valid currency code, like `"USD"` or `"GBP"`, but someone attacking your application could easily send `"XXX"` or `"£$%"`!

Assuming you support a limited set of currencies, say GBP, USD, EUR, and CAD, you could handle the validation in a few different ways. One way would be to validate the `CurrencyFrom` and `CurrencyTo` values within the Razor Page handler method, after model binding and attribute validation has already occurred.

Another way would be to use a `[RegularExpresssion]` attribute to look for the allowed strings. The approach I'm going to take here is to create a custom `ValidationAttribute`. The goal is to have a custom validation attribute you can apply to the `CurrencyFrom` and `CurrencyTo` attributes, to restrict the range of valid values. This will look something like the following example.

Listing 20.7 Applying custom validation attributes to the binding model

```
public class CurrencyConverterModel
{
    [Required]
    [StringLength(3, MinimumLength = 3)]
    [CurrencyCode("GBP", "USD", "CAD", "EUR")]      #A
    public string CurrencyFrom { get; set; }

    [Required]
    [StringLength(3, MinimumLength = 3)]
    [CurrencyCode("GBP", "USD", "CAD", "EUR")]      #A

    [Required]
    [Range(1, 1000)]
    public decimal Quantity { get; set; }
}
```

#A CurrencyCodeAttribute validates that the property has one of the provided values

Creating a custom validation attribute is simple, as you can start with the `ValidationAttribute` base class and you only have to override a single method. The next listing shows how you could implement CurrencyCodeAttribute to ensure that the currency codes provided match the expected values.

Listing 20.8 Custom validation attribute for currency codes

```
public class CurrencyCodeAttribute : ValidationAttribute          #A
{
    private readonly string[] _allowedCodes;                      #B
    public CurrencyCodeAttribute(params string[] allowedCodes)    #B
    {                                                             #B
        _allowedCodes = allowedCodes;                             #B
    }                                                             #B

    protected override ValidationResult IsValid(                  #C
        object value, ValidationContext context)                  #C
    {
        var code = value as string;
        if(code == null || !_allowedCodes.Contains(code))              #D
        {
            return new ValidationResult("Not a valid currency code");    #D
        }
        return ValidationResult.Success;        #E
    }
}
```

#A Derives from ValidationAttribute to ensure your attribute is used during validation
#B The attribute takes in an array of allowed currency codes.
#C The IsValid method is passed the value to validate and a context object.
#D If the value provided isn't a string, is null, or isn't an allowed code, then return an error . . .
#E . . . otherwise, return a success result

Validation occurs in the action filter pipeline after model binding, before the action or Razor Page handler is executed. The validation framework calls IsValid() for each instance of ValidationAttribute on the model property being validated. The framework passes in value (the value of the property being validated) and the ValidationContext to each attribute in turn. The context object contains details that you can use to validate the property.

Of particular note is the ObjectInstance property. You can use this to access the top-level model being validated when you validate a sub-property. For example, if the CurrencyFrom property of the CurrencyConvertModel is being validated, you can access the top-level object from the ValidationAttribute using:

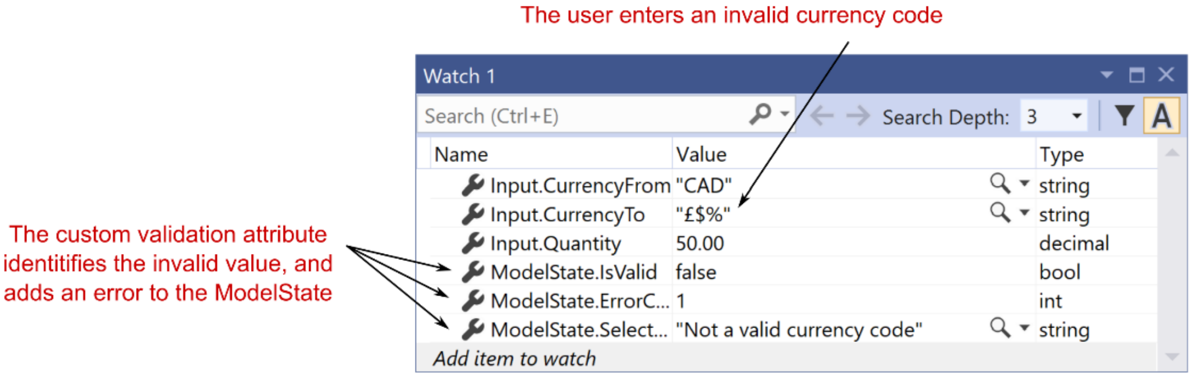
```
var model = validationContext.ObjectInstance as CurrencyConverterModel;
```

This can be useful if the validity of a property depends on the value of another property of the model. For example, you might want a validation rule that says that GBP is a valid value for CurrencyTo, *except* when CurrencyFrom is *also* GBP. The ObjectInstance makes these sorts of comparison validations easy.

NOTE Although using `ObjectInstance` makes it easy to make "model-level" comparisons like these, it reduces the portability of your validation attribute. In this case, you would only be able to use the attribute in the application that defines `CurrencyConverterModel`.

Within the `IsValid` method, you can cast the `value` provided to the required data type (in this case, `string)` and check against the list of allowed codes. If the code isn't allowed, then the attribute returns a `ValidationResult` with an error message indicating there was a problem. If the code *is* allowed, then `ValidationResult.Success` is returned, and the validation succeeds.

Putting your attribute to the test in figure 20.6 shows that when `CurrencyTo` is an invalid value (`£$%`), the validation for the property fails and an error is added to the `ModelState`. You could do some tidying up of this attribute to let you set a custom message, to allow nulls, or to display the name of the property that's invalid, but the important features are all there.



The user enters an invalid currency code

The custom validation attribute identitifies the invalid value, and adds an error to the ModelState

Name	Value	Type
Input.CurrencyFrom	"CAD"	string
Input.CurrencyTo	"£$%"	string
Input.Quantity	50.00	decimal
ModelState.IsValid	false	bool
ModelState.ErrorC...	1	int
ModelState.Select...	"Not a valid currency code"	string

Figure 20.6 The Watch window of Visual Studio showing the result of validation using the custom `ValidationAttribute`. The user has provided an invalid `currencyTo` value, `£$%`. Consequently, `ModelState` isn't valid and contains a single error with the message "Not a valid currency code."

The main feature missing from this custom attribute is client-side validation. You've seen that the attribute works well on the server side, but if the user entered an invalid value they wouldn't be informed until after the invalid value had been sent to the server. That's safe, and so is as much as you *need* to do for security and data-consistency purposes, but client-side validation can improve the user experience by providing immediate feedback.

You can implement client-side validation in several ways, but it's heavily dependent on the JavaScript libraries you use to provide the functionality. Currently ASP.NET Core Razor templates rely on jQuery for client-side validation. See the documentation for an example of creating a jQuery Validation adapter for your attributes: https://docs.microsoft.com/aspnet/core/mvc/models/validation#custom-client-side-validation.

Another improvement to your custom validation attribute would be to load the list of currencies from a DI service, such as an ICurrencyProvider. Unfortunately, you can't use constructor DI in your CurrencyCodeAttribute as you can only pass *constant* values to the constructor of an Attribute in .NET. In chapter 13, we worked around this limitation for filters by using [TypeFilter] or [ServiceFilter], but there's no such solution for ValidationAttribute.

Instead, for validation attributes, you must use the service locator pattern. As I discussed in chapter 10, this antipattern is best avoided where possible, but unfortunately, it's necessary in this case. Instead of declaring an explicit dependency via a constructor, you must ask the DI container directly for an instance of the required service.

Listing 20.9 shows how you could rewrite listing 20.8 to load the allowed currencies from an instance of ICurrencyProvider, instead of hardcoding the allowed values in the attribute's constructor. The attribute calls the GetService<T>() method on ValidationContext to resolve an instance of ICurrencyProvider from the DI container. Note that ICurrencyProvider is a hypothetical service, that would need to be registered in your application's ConfigureServices() method in Startup.cs.

Listing 20.9 Using the service-locator pattern to access services

```
public class CurrencyCodeAttribute : ValidationAttribute
{
    protected override ValidationResult IsValid(
        object value, ValidationContext context)
    {
        var provider = context.GetService<ICurrencyProvider>();          #A
        var allowedCodes = provider.GetCurrencies();                           #B

        var code = value as string;                                      #C
        if(code == null || !_allowedCodes.Contains(code))                #C
        {                                                                #C
            return new ValidationResult("Not a valid currency code");    #C
        }                                                                #C
        return ValidationResult.Success;                                 #C
    }
}
```

#A Retrieves an instance of ICurrencyProvider directly from the DI container
#B Fetches the currency codes using the provider
#C Validates the property as before

> **TIP** **The generic** GetService<T> **method is an extension method available in the** Microsoft.Extensions.DependencyInjection **namespace. As an alternative, you can use the** GetService(Type type) **method.**

The default DataAnnotations validation system can be convenient due to its declarative nature, but this has trade-offs, as shown by the dependency injection problem above. Luckily, you can completely replace the validation system your application uses, as shown in the following section.

20.4 Replacing the validation framework with FluentValidation

In this section you'll learn how to replace the DataAnnotations-based validation framework that's used by default in ASP.NET Core. You'll see the arguments for why you might want to do this and learn how to use a third-party alternative: FluentValidation. This open source project allows you to define the validation requirements of your models separately from the models themselves. This separation can make some types of validation easier and ensures each class in your application has a single responsibility.

Validation is an important part of the model-binding process in ASP.NET Core. Up to now, we've been using DataAnnotation attributes applied to properties of your binding model, to define your requirements. In section 20.3 we even created a custom validation attribute.

By default, ASP.NET Core is configured to use these attributes to drive the validation portion of model-binding. But the ASP.NET Core framework is very flexible and allows you to replace whole chunks of the framework if you like. The validation system is one such area that many people choose to replace.

FluentValidation (https://fluentvalidation.net/) is a popular alternative validation framework for ASP.NET Core. It is a mature library, with its roots going back well before ASP.NET Core was conceived of. With FluentValidation you write your validation code *separately* from your binding model code. This gives several advantages:

- You're not restricted to the limitations of Attributes, such as the dependency injection problem we had to work around in listing 20.9.
- It's much easier to create validation rules that apply to multiple properties, for example to ensure an EndDate property contains a later value than a StartDate property. Achieving this with DataAnnotation attributes is possible, but difficult.
- It's generally easier to test FluentValidation validators than DataAnnotation attributes.
- The validation is strongly-typed, compared to DataAnnotations attributes where it's possible to apply attributes in ways that don't make sense, such as applying an [EmailAddress] attribute to an int property, for example.
- Separating your validation logic from the model itself arguably better conforms to the single-responsibility-principle (SRP) [101].

That final point is often given as a reason *not* to use FluentValidation: FluentValidation separates a binding model from its validation rules. Some people are happy to accept the limitations of DataAnnotations to keep the model and validation rules together. Before I show how to add FluentValidation to your application, let's see what FluentValidation validators look like.

[101] The SRP is one of the SOLID design principles: https://en.wikipedia.org/wiki/SOLID.

20.4.1 Comparing FluentValidation to DataAnnotation attributes

To better understand the difference between the `DataAnnotations` approach and FluentValidation, we'll convert the binding models from section 20.3 to use FluentValidation. The following listing shows what the binding model from listing 20.7 would look like when used with FluentValidation. It is structurally identical but has no validation attributes.

Listing 20.10 Currency converter initial binding model for use with FluentValidation

```
public class CurrencyConverterModel
{
    public string CurrencyFrom { get; set; }
    public string CurrencyTo { get; set; }
    public decimal Quantity { get; set; }
}
```

In FluentValidation you define your validation rules in a separate class, with a class per model to be validated. Typically, these derive from the `AbstractValidator<>` base class, which provides a set of extension methods for defining your validation rules.

The following listing shows a validator for the `CurrencyConverterModel`, which matches the validations added using attributes in listing 20.7. You create a set of validation rules for a property by calling `RuleFor()`, and chaining method calls such as `NotEmpty()` from it. This style of method chaining is called a "fluent" interface, hence the name.

Listing 20.11 Currency converter initial binding model for use with FluentValidation

```
public class CurrencyConverterModelValidator                   #A
    : AbstractValidator<CurrencyConverterModel>                #A
{
    private readonly string[] _allowedValues                   #B
        = new []{ "GBP", "USD", "CAD", "EUR" };                #B

    public InputValidator()                                    #C
    {
        RuleFor(x => x.CurrencyFrom)                           #D
            .NotEmpty()                                        #E
            .Length(3)                                         #E
            .Must(value => _allowedValues.Contains(value))     #F
            .WithMessage("Not a valid currency code");         #F

        RuleFor(x => x.CurrencyTo)
            .NotEmpty()
            .Length(3)
            .Must(value => _allowedValues.Contains(value))
            .WithMessage("Not a valid currency code");

        RuleFor(x => x.Quantity)
            .NotNull()
            .InclusiveBetween(1, 1000);                        #G
    }
}
```

#A The validator inherits from AbstractValidator
#B Defines the static list of currency codes that are supported

#C You define validation rules in the validator's constructor
#D RuleFor is used to add a new validation rule. The lambda syntax allows for strong typing
#E There are equivalent rules for common DataAnnotation validation attributes
#F You can easily add custom validation rules, without having to create separate classes
#G Thanks to strong typing, the rules available depend on the property being validated.

Your first impression of this code might be that it's quite verbose compared to listing 20.7 but remember that listing 20.7 used a custom validation attribute, `[CurrencyCode]`. The validation in listing 20.11 doesn't require anything else—the logic implemented by the `[CurrencyCode]` attribute is right there in the validator, making it easy to reason about. The `Must()` method can be used to perform arbitrarily complex validations, without having the additional layers of indirection required by custom `DataAnnotations` attributes.

On top of that, you'll notice that you can only define validation rules that make sense for the property being validated. Previously, there was nothing to stop us applying the `[CurrencyCode]` attribute to the `Quantity` property; that's just not possible with FluentValidation.

Of course, just because you *can* write the custom `[CurrencyCode]` logic in-line, doesn't necessarily mean you have to. If a rule is used in multiple parts of your application, it may make sense to extract it into a helper class. The following listing shows how you could extract the currency code logic into an extension method, which can be used in multiple validators.

Listing 20.12 An extension method for currency validation

```
public static class ValidationExtensions
{
    public static IRuleBuilderOptions<T, string>                       #A
        MustBeCurrencyCode<T>(                                         #A
            this IRuleBuilder<T, string> ruleBuilder)                  #A
    {
        return ruleBuilder                                             #B
            .Must(value => _allowedValues.Contains(value))             #B
            .WithMessage("Not a valid currency code");                 #B
    }

    private static readonly string[] _allowedValues =                  #C
        new []{ "GBP", "USD", "CAD", "EUR" };                          #C
}
```

#A Creates an extension method that can be chained from RuleFor() for string properties
#B Applies the same validation logic as before
#C The currency code values to allow

You can then update your `CurrencyConverterModelValidator` to use the new extension method, removing the duplication in your validator, and ensuring consistency across "country code" fields:

```
RuleFor(x => x.CurrencyTo)
    .NotEmpty()
    .Length(3)
    .MustBeCurrencyCode();
```

Another advantage of the FluentValidation approach of using standalone validation classes, is that they are created using dependency injection, so you can inject services into them. As an example, consider the `[CurrencyCode]` validation attribute from listing 20.9 which used a service, `ICurrencyProvider` from the DI container. This requires using service location to obtain an instance of `ICurrencyProvider` using an injected “context” object.

With the FluentValidation library, you can just inject the `ICurrencyProvider` directly into your validator, as shown in the following listing. This requires fewer gymnastics to get the desired functionality and makes your validator’s dependencies explicit.

Listing 20.13 Currency converter validator using dependency injection

```
public class CurrencyConverterModelValidator
    : AbstractValidator< CurrencyConverterModel>
{
    public InputValidator(ICurrencyProvider provider)         #A
    {
        RuleFor(x => x.CurrencyFrom)
            .NotEmpty()
            .Length(3)
            .Must(value => provider                           #B
                .GetCurrencies()                              #B
                .Contains(value))                             #B
            .WithMessage("Not a valid currency code");

        RuleFor(x => x.CurrencyTo)
            .NotEmpty()
            .Length(3)
            .MustBeCurrencyCode(provider.GetCurrencies());    #C

        RuleFor(x => x.Quantity)
            .NotNull()
            .InclusiveBetween(1, 1000);
    }
}
```

#A Injecting the service using standard constructor dependency injection
#B Using the injected service in a Must() rule
#C Using the injected service with an extension method

The final feature I’ll show demonstrates how much easier it is to write validators that span multiple properties with FluentValidation. For example, imagine we want to validate that the value of `CurrencyTo` is different to `CurrencyFrom`. Using FluentValidation you can implement this with an overload of `Must()`, which provides both the model and the property being validated, as shown in the following listing.

Listing 20.14 Using `Must ()` to validate that two properties are different

```
RuleFor(x => x.CurrencyTo)                                     #A
    .NotEmpty()
    .Length(3)
    .MustBeCurrencyCode()
    .Must((InputModel model, string currencyTo)                #B
        => currencyTo != model.CurrencyFrom)                   #C
    .WithMessage("Cannot convert currency to itself");         #D
```

#A The error message will be associated with the CurrencyTo property
#B The Must function passes the top-level model being validated and the current property
#C Perform the validation—the currencies must be different
#D Use the provided message as the error message

Creating a validator like this is certainly possible with `DataAnnotation` attributes, but it requires far more ceremony than the FluentValidation equivalent, and is generally harder to test. FluentValidation has many more features for making it easier to write and test your validators too, for example:

- *Complex property validations*. Validators can be applied to complex types, as well as primitive types like `string` and `int` shown here in this section.
- *Custom property validators*. In addition to simple extension methods, you can create your own property validators for complex validation scenarios.
- *Collection rules*. When types contain collections, such as `List<T>`, you can apply validation to each item in the list, as well as the overall collection.
- *RuleSets*. Create multiple collections of rules that can be applied to an object in different circumstances. These can be especially useful if you're using FluentValidation in additional areas of your application.
- *Client-side validation*. FluentValidation is a server-side framework, but it emits the same attributes as `DataAnnotation` attributes to enable client-side validation using jQuery.

There are many more features in addition to these, so be sure to browse the documentation at https://docs.fluentvalidation.net/ for details. In the next section you'll see how to add FluentValidation to your ASP.NET Core application.

20.4.2 Adding FluentValidation to your application

Replacing the whole validation system of ASP.NET Core sounds like a big step, but the FluentValidation library makes it easy to add to your application. Simply follow these steps:

1. Install the FluentValidation.AspNetCore NuGet package using Visual Studio's NuGet package manager, using the CLI by running `dotnet add package FluentValidation.AspNetCore` or by adding a `<PackageReference>` to your csproj file:

   ```
   <PackageReference Include="FluentValidation.AspNetCore" Version="9.0.1" />
   ```

2. Configure the FluentValidation library in the `ConfigureServices` method of your `Startup` class by calling `AddFluentValidation()`. You can further configure the library, as shown in listing 20.15 below.

3. Register your validators (such as the `CurrencyConverterModelValidator` from listing 20.13) with the DI container. These can be registered manually, using any scope you choose, for example:

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddRazorPages()
        .AddFluentValidation();

    services.AddScoped<
        IValidator<CurrencyConverterModelValidator>,
        CurrencyConverterModelValidator>();
}
```

   Alternatively, you can allow FluentValidation to automatically register all your validators using the options shown in listing 20.15.

For such a mature library, FluentValidation has relatively few configuration options to decipher. The following listing shows some of the options available, in particular it shows how to automatically register all the custom validators in your application, and how to disable `DataAnnotation` validation entirely.

Listing 20.15 Configuring FluentValidation in an ASP.NET Core application

```
public void ConfigureServices(IServiceCollection services)
{
  services.AddRazorPages()
    .AddFluentValidation(opts =>
    {
      opts.RegisterValidatorsFromAssemblyContaining<Startup>();     #A
      opts.ImplicitlyValidateChildProperties = true;                #B
      opts.LocalizationEnabled = false;                             #C
      opts.RunDefaultMvcValidationAfterFluentValidationExecutes     #D
        = false;                                                    #D
    });
}
```

#A Instead of manually registering validators, FluentValidation can auto-register them for you
#B Ensure that complex (nested) properties are validated, not just “top-level” properties
#C FluentValidation has full localization support, but you can disable it if you don’t need it
#D Setting to false disables DataAnnotation validation completely for model binding

It’s important to understand that final point. If you don’t set it to `false`, ASP.NET Core will run validation with *both* `DataAnnotations` and with FluentValidation. That may be useful if you’re in the process of migrating from one system to the other, but otherwise I recommend disabling it. Having your validation split between both places seems like it would be the worst of both worlds!

One final thing to consider is where to put your validators in your solution. There are no technical requirements on this—if you’ve registered your validator with the DI container it will be used correctly—so the choice is up to you. Personally, I prefer to place validators close to the models they’re validating.

For Razor Pages binding model validators, I create the validator as a nested class of the `PageModel`, in the same place as I create the `InputModel`, as I described in chapter 6. That gives a class hierarchy in the Razor Page similar to the following:

```
public class IndexPage : PageModel
{
    public class InputModel { }
    public class InputModelValidator: AbstractValidator<InputModel> { }
}
```

That's just my preference of course, you're free to adopt another approach if you prefer!

That brings us to the end of this chapter on custom Razor Pages components. When combined with the components in the previous chapter, you've got a great base for extending your ASP.NET Core applications to meet your needs. It's a testament to ASP.NET Core's design that you can swap out whole sections like the Validation framework entirely. If you don't like how some part of the framework works, see if someone has written an alternative!

20.5 Summary

- With Tag Helpers, you can bind your data model to HTML elements, making it easier to generate dynamic HTML. Tag Helpers can customize the elements they're attached to, add additional attributes, and customize how they're rendered to HTML. This can greatly reduce the amount of markup you need to write.
- The name of a Tag Helper class dictates the name of the element in the Razor templates, so the `SystemInfoTagHelper` corresponds to the `<system-info>` element. You can choose a different element name by adding the `[HtmlTargetElement]` attribute to your Tag Helper.
- You can set properties on your Tag Helper object from Razor syntax by decorating the property with an `[HtmlAttributeName("name")]` attribute and providing a name. You can set these properties from Razor using HTML attributes, `<system-info name="value">`, for example.
- The `TagHelperOutput` parameter passed to the `Process` or `ProcessAsync` methods control the HTML that's rendered to the page. You can set the element type with the `TagName` property, and set the inner content using `Content.SetContent()` or `Content.SetHtmlContent()`.
- You can prevent inner Tag Helper content being processed by calling `SupressOutput()` and you can remove the element entirely by setting `TagName=null`. This is useful if you only want to conditionally render elements to the response.
- You can retrieve the contents of a Tag Helper by calling `GetChildContentAsync()` on the `TagHelperOutput` parameter. You can then Render this content to a `string` by calling `GetContent()`. This will render any Razor expressions and Tag Helpers to HTML, allowing you to manipulate the contents.
- View components are like partial views, but they allow you to use complex business and rendering logic. You can use them for sections of a page, such as the shopping

cart, a dynamic navigation menu, or suggested articles.

- Create a view component by deriving from the `ViewComponent` base class, and implement `InvokeAsync()`. You can pass parameters to this function from the Razor view template using HTML attributes, in a similar way to Tag Helpers.
- View components can use DI, have access to the `HttpContext`, and can render partial views. The partial views should be stored in the Pages/Shared/Components/<Name>/ folder, where Name is the name of the view component. If not specified, view components will look for a default view named Default.cshtml.
- You can create a custom `DataAnnotations` attribute by deriving from `ValidationAttribute` and overriding the `IsValid` method. You can use this to decorate your binding model properties and perform arbitrary validation.
- You can't use constructor DI with custom validation attributes. If the validation attribute needs access to services from the DI container, you must use the service locator pattern to load them from the validation context, using the `GetService<T>` method.
- FluentValidation is an alternative validation system that can replace the default `DataAnnotations` validation system. It is not based on attributes, which makes it easier to write custom validations for your validation rules and makes those rules easier to test.
- To create a validator for a model, create a class derived from `AbstractValidator<>` and call `RuleFor<>()` in the constructor to add validation rules. You can chain multiple requirements on `RuleFor<>()` in the same way that you could add multiple `DataAnnotation` attributes to a model.
- If you need to create a custom validation rule, you can use the `Must()` method to specify a predicate. If you wish to re-use the validation rule across multiple models, encapsulate the rule as an extension method, to reduce duplication.
- To add FluentValidation to your application, install the FluentValidation.AspNetCore NuGet package, call `AddFluentValidation()` after your call to `AddRazorPages()` or `AddControllers()`, and register your validators with the DI container. This will add FluentValidation validations in addition to the built-in `DataAnnotations` system.
- To remove the `DataAnnotations` validation system, and use FluentValidation only, set the `RunDefaultMvcValidationAfterFluentValidationExecutes` option to `false` in your call to `AddFluentValidation()`. Favor this approach where possible, to avoid receiving validation methods from two different systems.
- You can allow FluentValidation to automatically discover and register all the validators in your application by calling `RegisterValidatorsFromAssemblyContaining<T>()`, where `T` is a type in the assembly to scan. This means you don't have to register each validator in your application with the DI container individually.

21 Calling remote APIs with IHttpClientFactory

This chapter covers

- **Problems caused by using** `HttpClient` **incorrectly to call HTTP APIs**
- **Using** `IHttpClientFactory` **to manage** `HttpClient` **lifetimes**
- **Encapsulating configuration and handling transient errors with** `IHttpClientFactory`

So far in this book we've focused on creating web pages and exposing APIs for others to consume. Whether that's customers browsing a Razor Pages application, or client-side SPAs and mobile apps consuming your APIs, we've been writing the APIs for others to consume.

However, it's very common for your application to interact with third-party-services by consuming *their* APIs. For example, an eCommerce site needs to take payments, send email and SMS messages, and retrieve exchange rates from a third-party service. The most common approach for interacting with services is using HTTP. So far in this book we've looked at how you can *expose* HTTP services, using API controllers, but we haven't looked at how you can *consume* HTTP services.

In section 21.1, you'll learn the best way to interact with HTTP services using `HttpClient`. If you have any experience with C#, it's very likely you've used this class to send HTTP requests, but there are two "gotchas" to think about, otherwise your app could run into difficulties.

`IHttpClientFactory` was introduced in .NET Core 2.1; it makes creating and managing `HttpClient` instances easier and avoids the common pitfalls. In section 21.2 you'll learn how `IHttpClientFactory` achieves this by managing the `HttpClient` handler pipeline. You'll learn how to create *named clients* to centralize the configuration for calling remote APIs, and how to use *typed clients* to encapsulate the remote service's behavior.

Network glitches are a fact of life when you're working with HTTP APIs, so it's important for you to handle them gracefully. In section 21.3 you'll learn how to use the open source resilience and fault-tolerance library Polly to handle common transient errors using simple retries, with the possibility for more complex policies.

Finally, in section 21.4 you'll see how you can create your own custom `HttpMessageHandler` handler managed by `IHttpClientFactory`. You can use custom handlers to implement cross cutting concerns such as logging, metrics, or authentication, where a function needs to execute every time you call an HTTP API. In section 21.4 you'll see how to create a handler that automatically adds an API key to all outgoing requests to an API.

To misquote John Donne, "no app is an island", and the most common way of interacting with other apps and services is over HTTP. In .NET Core, that means using `HttpClient`.

21.1 Calling HTTP APIs: the problem with HttpClient

In this section you'll learn how to use `HttpClient` to call HTTP APIs. I focus on two common pitfalls in using `HttpClient`, socket exhaustion and DNS rotation problems, and show why they occur. In section 21.2 you'll see how to avoid these issues by using `IHttpClientFactory`.

It's very common for an application to need to interact with other services to fulfill its duty. Take a typical ecommerce store for example. In even the most basic version of the application, you will likely need to send emails and take payments using credit cards or other services. You *could* try and build that functionality yourself, but it probably wouldn't be worth the effort.

Instead, it makes far more sense to delegate those responsibilities to third-party services which specialize in that functionality. Whichever service you use, they will almost certainly expose an HTTP API for interacting with the service. For many services, that will be the *only* way.

HTTP vs gRPC vs GraphQL

There are many ways to interact with third-party services, but HTTP RESTful services are still the king, decades after HTTP was first proposed. Every platform and programming language you can think of includes support for making HTTP requests and handling responses. That ubiquity makes it the go-to option for most services.

Despite their ubiquity, RESTful services are not perfect. They are relatively verbose, which means more data ends up being sent and received than some other protocols. It can also be difficult to evolve RESTful APIs after you have deployed them. These limitations have spurred interest in two alternative protocols in particular: gRPC and GraphQL.

gRPC is intended to be an efficient mechanism for server-to-server communication. It builds on top of HTTP/2, but typically provides much higher performance than traditional RESTful APIs. gRPC support was added in .NET Core 3.0 and is receiving many performance and feature updates. For a comprehensive view of .NET support, see the documentation at https://docs.microsoft.com/aspnet/core/grpc.

While gRPC is primarily intended for server-to-server communication, GraphQL is best used to provide evolvable APIs to mobile and SPA apps. It has become very popular among front-end developers, as it can reduce the friction involved in deploying and using new APIs. For details, I recommend *GraphQL in Action* by Samer Buna (Manning, 2020).

Despite the benefits and improvements gRPC and GraphQL can bring, RESTful HTTP services are here to stay for the foreseeable future, so it's worth making sure you understand how to use them with `HttpClient`.

In .NET we use the `HttpClient` class for calling HTTP APIs. You can use it to make HTTP calls to APIs, providing all the headers and body to send in a request, and reading the response headers and data you get back. Unfortunately, it's hard to use correctly, and even when you do, it has limitations.

The source of the difficultly with `HttpClient` stems partly from the fact it implements the `IDisposable` interface. In general, when you use a class that implements `IDisposable`, you should wrap the class with a `using` statement whenever you create a new instance. This ensures that unmanaged resources used by the type are cleaned-up when the class is removed.

```
using (var myInstance = new MyDisposableClass())
{
    // use myInstance
}
```

That might lead you to think that the correct way to create an `HttpClient` is shown in the following listing. This shows a simple example where an API controller calls an external API to fetch the latest currency exchange rates and returns them as the response.

> **WARNING** Do not use `HttpClient` like what's shown in listing 21.1. Using it this way could cause your application to become unstable, as you'll see shortly.

Listing 21.1 The incorrect way to use `HttpClient`

```
[ApiController]
public class ValuesController : ControllerBase
{
    [HttpGet("values")]
    public async Task<string> GetRates()
    {
        using (HttpClient client = new HttpClient())              #A
        {
            client.BaseAddress                                    #B
                = new Uri("https://api.exchangeratesapi.io");     #B

            var response = await client.GetAsync("latest");       #C

            response.EnsureSuccessStatusCode();                   #D
            return await response.Content.ReadAsStringAsync();    #E
        }
    }
}
```

#A Wrapping the HttpClient in a using statement means it is disposed at the end of the using block
#B Configure the base URL used to make requests using the HttpClient
#C Make a GET request to the exchange rates API
#D Throws an exception if the request was not successful

#E Read the result as a string and return it from the action method

However, `HttpClient` is special, and you *shouldn't* use it like this! The problem is primarily due to the way the underlying protocol implementation works. Whenever your computer needs to send a request to an HTTP server, you must create a *connection* between your computer and the server. To create a connection, your computer opens a port, which has a random number between 0 and 65535, and connects to the HTTP server's IP address and port, as shown in figure 21.1. Your computer can then send HTTP requests to the server.

> **DEFINITION** The combination of IP address and port is called a *socket*.

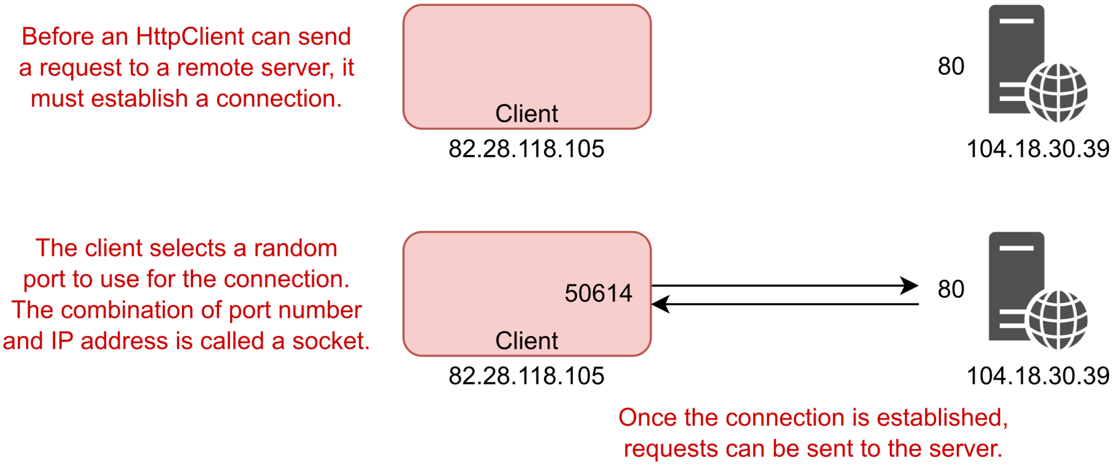

Before an HttpClient can send a request to a remote server, it must establish a connection.
Client
82.28.118.105
80
104.18.30.39
The client selects a random port to use for the connection. The combination of port number and IP address is called a socket.
50614
Client
82.28.118.105
80
104.18.30.39
Once the connection is established, requests can be sent to the server.

Figure 21.1 To create a connection, a client selects a random port and connects to the HTTP server's port and IP address. The combination of a port number and IP address is called a socket. The client can then send HTTP requests to the server.

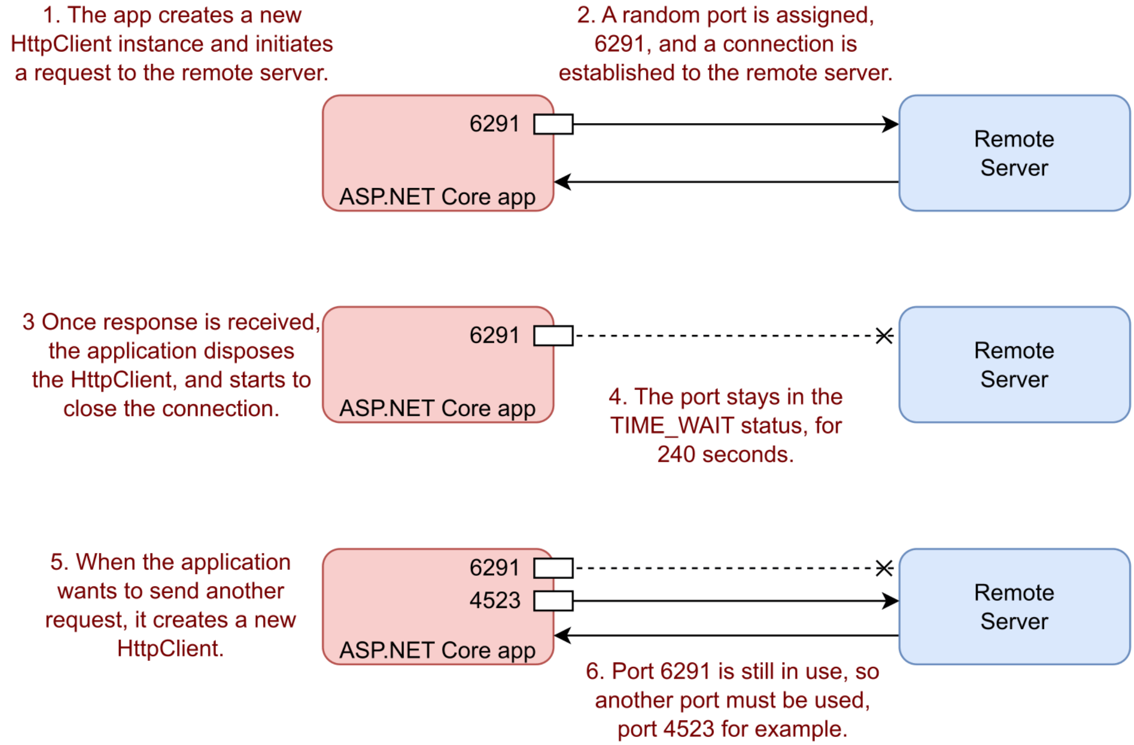
The main problem with the `using` statement and `HttpClient` is that it can lead to a problem called *socket exhaustion*, as illustrated in figure 21.2. This happens when all the ports on your computer have been used up making other HTTP connections, so your computer can't make any more requests. At that point, your application will hang, waiting for a socket to become free. A very bad experience!

Given that I said there are 65536 different port numbers, you might think that's an unlikely situation. It's true, you will likely only run into this problem on a server that is making a lot of connections, but it's not as rare as you might think.

The problem is that when you dispose an `HttpClient`, *it doesn't close the socket immediately*. The design of the TCP/IP protocol used for HTTP requests means that after trying to close a connection, the connection moves to a state called TIME_WAIT. The connection then waits for a specific period (240 seconds on Windows) before closing the socket completely.

Until the TIME_WAIT period has elapsed, you can't reuse the socket in another `HttpClient` to make HTTP requests. If you're making a lot of requests, that can quickly lead to socket exhaustion, as shown in figure 21.2

TIP **You can view the state of active ports/sockets in Windows and Linux by running the command** `netstat` **from the command line or a terminal window.**


1. The app creates a new HttpClient instance and initiates a request to the remote server.

2. A random port is assigned, 6291, and a connection is established to the remote server.

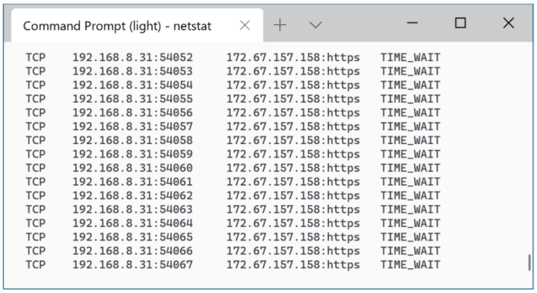
3 Once response is received, the application disposes the HttpClient, and starts to close the connection.

4. The port stays in the TIME_WAIT status, for 240 seconds.

5. When the application wants to send another request, it creates a new HttpClient.

6. Port 6291 is still in use, so another port must be used, port 4523 for example.

7. With sufficient numbers of requests, the machine running your app can run out of ports as they're all stuck, in TIME_WAIT, and you can no longer send or receive new requests.



```
TCP    192.168.8.31:54052     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54053     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54054     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54055     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54056     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54057     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54058     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54059     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54060     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54061     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54062     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54063     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54064     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54065     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54066     172.67.157.158:https   TIME_WAIT
TCP    192.168.8.31:54067     172.67.157.158:https   TIME_WAIT
```

Figure 21.2 Disposing of `HttpClient` **can lead to socket exhaustion. Each new connection requires the**

operating system to assign a new socket. Closing a socket doesn’t make it available until the TIME_WAIT period of 240 seconds has elapsed. Eventually you can run out of sockets, at which point you can’t make any outgoing HTTP requests.

Instead of disposing `HttpClient`, the general advice (before `IHttpClientFactory` was introduced in .NET Core 2.1) was to use a single instance of the `HttpClient`, as shown in the following listing.

Listing 21.2 Using a singleton `HttpClient` to avoid socket exhaustion

```
[ApiController]
public class ValuesController : ControllerBase
{
    private static readonly HttpClient _client = new HttpClient        #A
    {                                                                  #A
        BaseAddress = new Uri("https://api.exchangeratesapi.io")       #A
    };                                                                 #A

    [HttpGet("values")]
    public async Task<string> GetRates()
    {
        var response = await _client.GetAsync("latest");          #B

        response.EnsureSuccessStatusCode();
        return await response.Content.ReadAsStringAsync();
    }
}
```

#A A single instance of the HttpClient is created and stored as a static field
#B Multiple requests use the same instance of HttpClient

This solves the problem of socket exhaustion. As you’re not disposing the `HttpClient`, the socket is not disposed, so you can re-use the same port for multiple requests. No matter how many times you call `GetRates()` in the example above, you will only use a single socket. Problem solved!

Unfortunately, this introduces a different problem, primarily around DNS. DNS is how the friendly host names we use, such as manning.com, are converted into the IP addresses that computers need. When a new connection is required, the `HttpClient` first checks the DNS record for a host to find the IP address, and then makes the connection. For subsequent requests, the connection is already established, so it doesn’t make another DNS call.

For singleton `HttpClient` instances this can be a problem, as the `HttpClient` won’t detect DNS changes. DNS is often used in cloud environments for load balancing to do graceful rollouts of deployments.[102] If the DNS record of a service you’re calling changes during the

[102] Azure Traffic Manager, for example, uses DNS to route requests. You can read more about how it works at https://azure.microsoft.com/en-gb/services/traffic-manager/.

lifetime of your application, a singleton `HttpClient` will keep calling the old service, as shown in figure 21.3.

> **NOTE** `HttpClient` **won't respect a DNS change while the original connection exists. If the original connection is closed, for example if the original server goes offline, then it will respect the DNS change as it must establish a new connection.**

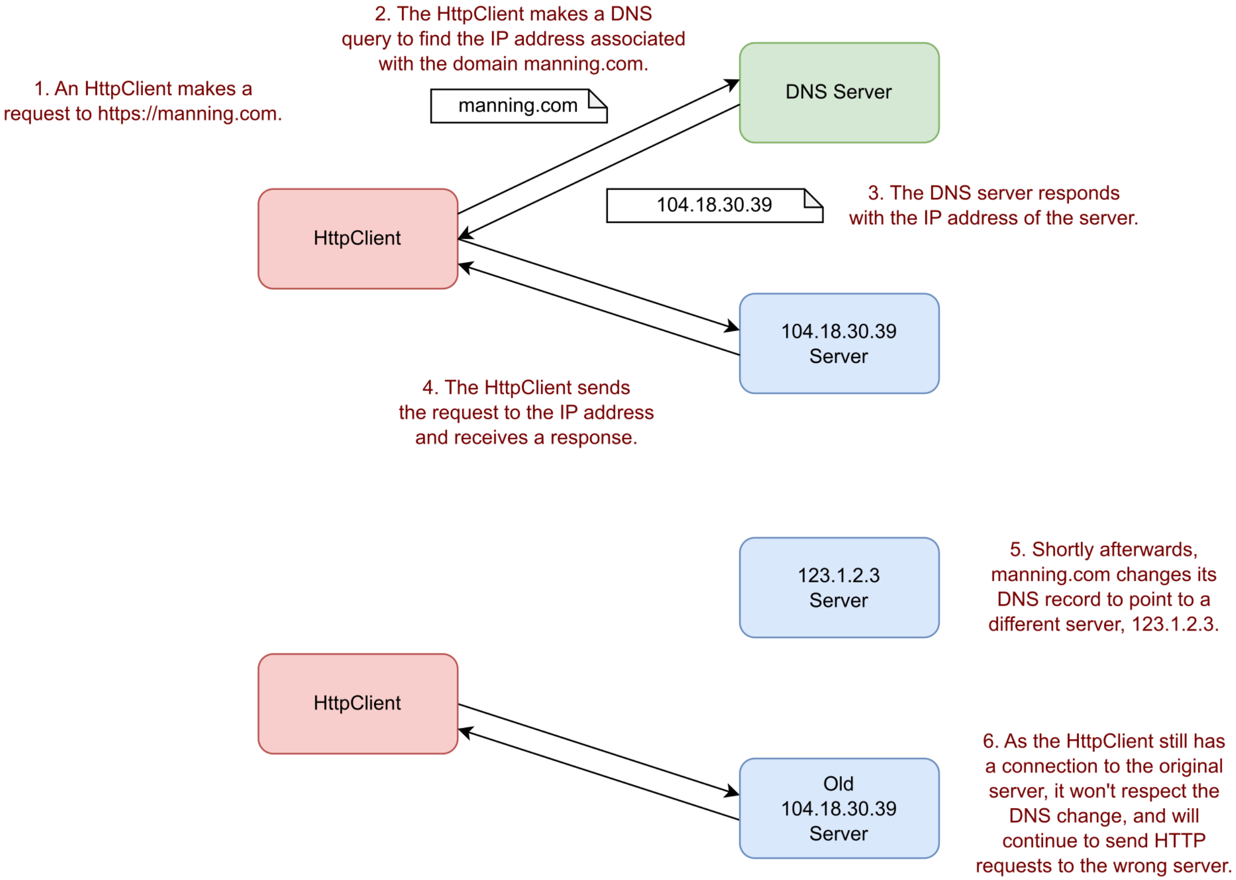

2. The HttpClient makes a DNS query to find the IP address associated with the domain manning.com.
1. An HttpClient makes a request to https://manning.com.
manning.com
DNS Server
HttpClient
104.18.30.39
3. The DNS server responds with the IP address of the server.
104.18.30.39 Server
4. The HttpClient sends the request to the IP address and receives a response.
123.1.2.3 Server
5. Shortly afterwards, manning.com changes its DNS record to point to a different server, 123.1.2.3.
HttpClient
Old 104.18.30.39 Server
6. As the HttpClient still has a connection to the original server, it won't respect the DNS change, and will continue to send HTTP requests to the wrong server.

Figure 21.3. `HttpClient` **does a DNS lookup before establishing a connection, to determine the IP address associated with a hostname. If the DNS record for a hostname changes, a singleton** `HttpClient` **will not detect it, and will continue sending requests to the original server it connected to.**

It seems like you're damned if you, and you're damned if you don't! Luckily, `IHttpClientFactory` can take care of all this for you.

21.2 Creating HttpClients with IHttpClientFactory

In this section you'll learn how you can use IHttpClientFactory to avoid the common pitfalls of HttpClient. I'll show several patterns you can use to create HttpClients:

- Using the CreateClient() as a drop-in replacement for HttpClient
- Using "named clients" centralize the configuration of an HttpClient used to call a specific third-party API.
- Using "typed clients" to encapsulate the interaction with a third-party API for easier consumption by your code.

IHttpClientFactory was introduced in .NET Core 2.1. It makes it easier to create HttpClient instances *correctly*, instead of relying on either of the faulty approaches I showed in section 21.1. It also makes it easier to configure multiple HttpClients and allows you to create a "middleware pipeline" for outgoing requests.

Before we look at how IHttpClientFactory achieves all that, we will look a little closer at how HttpClient works under the hood.

21.2.1 Using IHttpClientFactory to manage HttpClientHandler lifetime

In this section I describe the handler pipeline used by HttpClient. You'll see how IHttpClientFactory manages the lifetime of the handler pipeline and how this enables the factory to avoid both socket exhaustion and DNS issues.

The HttpClient class you typically use to make HTTP requests is responsible for orchestrating requests, but it isn't responsible for making the raw connection itself. Instead, the HttpClient calls into a pipeline of HttpMessageHandler, at the end of which is an HttpClientHandler, which makes the actual connection, and sends the HTTP request, as shown in figure 21.4.

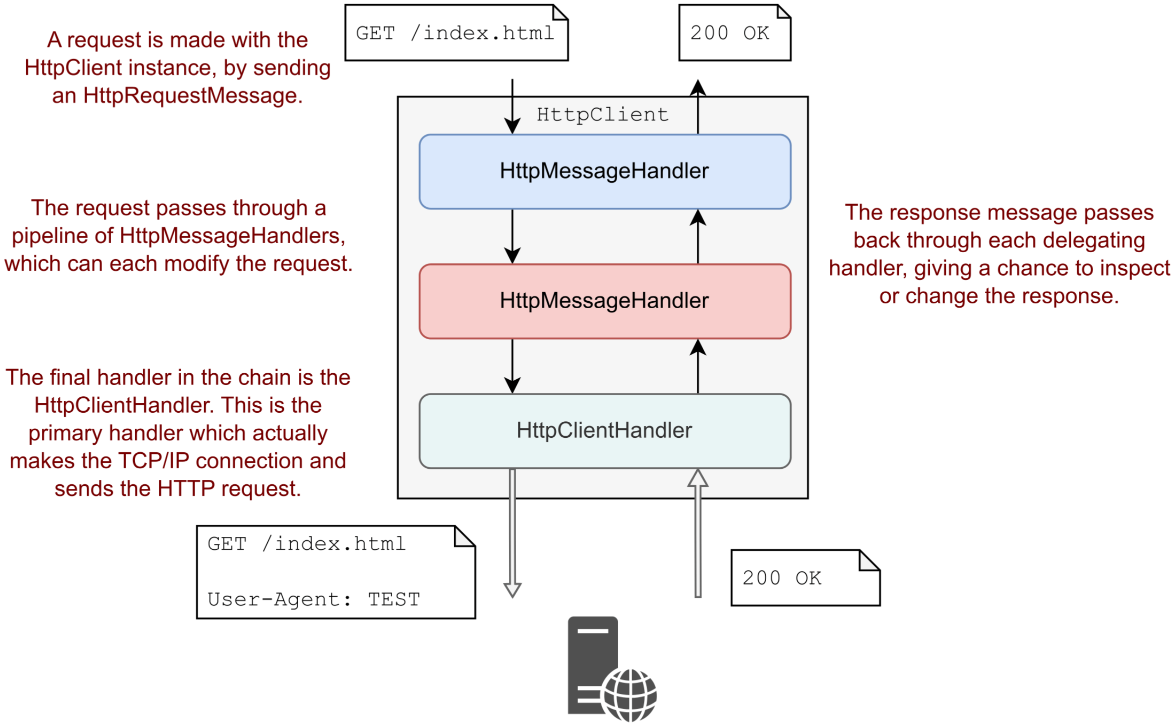

A request is made with the HttpClient instance, by sending an HttpRequestMessage.
GET /index.html
200 OK
HttpClient
HttpMessageHandler
The request passes through a pipeline of HttpMessageHandlers, which can each modify the request.
HttpMessageHandler
The response message passes back through each delegating handler, giving a chance to inspect or change the response.
The final handler in the chain is the HttpClientHandler. This is the primary handler which actually makes the TCP/IP connection and sends the HTTP request.
HttpClientHandler
GET /index.html
User-Agent: TEST
200 OK

Figure 21.4. Each `HttpClient` contains a pipeline of `HttpMessageHandlers`. The final handler is an `HttpClientHandler`, which makes the connection to the remote server and sends the HTTP request. This configuration is similar to the ASP.NET Core middleware pipeline and allows you to make cross-cutting adjustments to outgoing requests.

This configuration is very reminiscent of the middleware pipeline used by ASP.NET Core applications, but this is an *outbound* pipeline. When an `HttpClient` makes a request, each handler gets a chance to modify the request, before the final `HttpClientHandler` makes the real HTTP request. Each handler in turn then gets a chance to view the response after it's received.

> **TIP** You'll see an example of using this handler pipeline for cross-cutting concerns in section 21.2.4 when we add a transient error handler.

The issues of socket exhaustion and DNS I described in section 21.1 are both related to the disposal of the `HttpClientHandler` at the end of the handler pipeline. By default, when you dispose an `HttpClient`, you dispose the handler pipeline too. `IHttpClientFactory` separates the lifetime of the `HttpClient` from the underlying `HttpClientHandler`.

Separating the lifetime of these two components enables the IHttpClientFactory to solve the problems of socket exhaustion and DNS rotation. It achieves this in two ways:

- *Creating a pool of available handlers*. Socket exhaustion occurs when you dispose an HttpClientHandler, due to the TIME_WAIT problem described previously. IHttpClientFactory solves this by creating a "pool" of handlers.

  IHttpClientFactory maintains an "active" handler, that is used to create all HttpClients for two minutes. When the HttpClient is disposed, the underlying handler *isn't* disposed. As the handler isn't disposed, the connection isn't closed, and socket exhaustion isn't a problem.

- *Periodically disposing handlers*. Sharing handler pipelines solves the socket exhaustion problem, but it doesn't solve the DNS issue. To work around this, the IHttpClientFactory periodically (every two minutes) creates a new "active" HttpClientHandler that is used for each HttpClient created subsequently. As these HttpClients are using a new handler, they make a new TCP/IP connection, and so DNS changes are respected.

  IHttpClientFactory disposes "expired" handlers periodically in the background—once they are no longer used by an HttpClient. This ensures there are only ever a limited number of connections in use by your application's HttpClients.[103]

Rotating handlers with IHttpClientFactory solves both the issues we've discussed. Another bonus is that it's easy to replace existing usages of HttpClient with IHttpClientFactory.

IHttpClientFactory is included by default in ASP.NET Core, you just need to add it to your application's services in the ConfigureServices() method of Startup.cs:

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddHttpClient()
}
```

This registers the IHttpClientFactory as a singleton in your application, so you can inject it into any other service. For example, the following listing shows how you can replace the HttpClient approach from listing 21.2 with a version that uses IHttpClientFactory.

Listing 21.3 Using IHttpClientFactory to create an HttpClient

```
[ApiController]
public class ValuesController : ControllerBase
{
    private readonly IHttpClientFactory _factory;          #A
    public ValuesController(IHttpClientFactory factory)    #A
    {
```

[103] I looked in depth about how IHttpClientFactory achieves this rotation. This is a detailed post, but may be of interest to those who like to know how things are implemented behind the scenes: https://andrewlock.net/exporing-the-code-behind-ihttpclientfactory/.

```
        _factory = factory;
    }

    [HttpGet("values")]
    public async Task<string> GetRates()
    {
        HttpClient client = _factory.CreateClient();            #B

        client.BaseAddress =                                   #C
            new Uri("https://api.exchangeratesapi.io");        #C
        client.DefaultRequestHeaders.Add(                      #C
            HeaderNames.UserAgent, "ExchangeRateViewer");      #C

        var response = await client.GetAsync("latest");        #D

        response.EnsureSuccessStatusCode();                    #D
        return await response.Content.ReadAsStringAsync();     #D
    }
}
```

#A Inject the IHttpClientFactory using DI
#B Create an HttpClient instance with an HttpClientHandler managed by the factory
#C Configure the HttpClient for calling the API as before
#D Use the HttpClient in exactly the same way as you would otherwise

The immediate benefit of using `IHttpClientFactory` in this way is efficient socket and DNS handling. Minimal changes should be required to take advantage of this pattern, as the bulk of your code stays the same. This makes it a good option if you're refactoring an existing app.

21.2.2 Configuring named clients at registration time

In this section you'll learn how to use the "named client" pattern with `IHttpClientFactory`. This pattern encapsulates the logic for calling a third-party API in a single location, making it easier to use the `HttpClient` in your consuming code.

Using `IHttpClientFactory` solves the technical issues I described in section 21.1, but the code in listing 21.3 is still pretty messy in my eyes. That's primarily because you must configure the `HttpClient` to point to your service before you use it. If you use need to create an `HttpClient` to call the API in more than one place in your application, you must *configure* it more than one place too.

`IHttpClientFactory` provides a convenient solution to this problem by allowing you to centrally configure *named clients*. These clients have a `string` name, and a configuration function which runs whenever an instance of the named client is requested. You can define multiple configuration functions which run in sequence to configure your new `HttpClient`.

For example, the following listing shows how to register a named client called `"rates"`. This client is configured with the correct `BaseAddress` and sets default headers that are to be sent with each outbound request.

Listing 21.4 Configuring a named client using `IHttpClientFactory` in Startup.cs

```
public void ConfigureServices(IServiceCollection services)
```

```
{
    services.AddHttpClient("rates", (HttpClient client) =>           #A
    {
        client.BaseAddress =                                         #B
            new Uri("https://api.exchangeratesapi.io");              #B
        client.DefaultRequestHeaders.Add(                            #B
            HeaderNames.UserAgent, "ExchangeRateViewer");            #B
    })
    .ConfigureHttpClient((HttpClient client) => {})                  #C
    .ConfigureHttpClient(
        (IServiceProvider provider, HttpClient client) => {});       #D
}
```

#A Provide a name for the client, and a configuration function
#B The configuration function runs every time the named HttpClient is requested
#C You can add additional configuration functions for the named client, which run in sequence
#D Additional overloads exist that allow access to the DI container when creating a named client

Once you have configured this named client, you can create it from an `IHttpClientFactory` instance using the name of the client, `"rates"`. The following listing shows how you could update listing 21.3 to use the named client configured in listing 21.4.

Listing 21.5 Using `IHttpClientFactory` to create a named `HttpClient`

```
[ApiController]
public class ValuesController : ControllerBase
{
    private readonly IHttpClientFactory _factory;                 #A
    public ValuesController(IHttpClientFactory factory)           #A
    {
        _factory = factory;
    }

    [HttpGet("values")]
    public async Task<string> GetRates()
    {
        HttpClient client = _factory.CreateClient("rates");          #B

        var response = await client.GetAsync("latest");              #C

        response.EnsureSuccessStatusCode();                          #C
        return await response.Content.ReadAsStringAsync();           #C
    }
}
```

#A Inject the IHttpClientFactory using DI
#B Request the named client called "rates" and configure it as defined in ConfigureServices()
#C Use the HttpClient in the same way as before

> **NOTE** **You can still create "unconfigured" clients using `CreateClient()` without a name. Be aware that if you pass an unconfigured name, for example `CreateClient("MyRates")`, then the client returned will be unconfigured. Take care—client names are case sensitive, so `"rates"` is a different client to `"Rates"`!**

Named clients allow you to centralize your `HttpClient` configuration in one place, removing the responsibility of *configuring* the client from your consuming code. But you're still working with "raw" HTTP calls at this point, for example providing the relative URL to call (`"/latest"`) and parsing the response. `IHttpClientFactory` includes a feature that makes it easier to clean up this code.

21.2.3 Using Typed clients to encapsulate HTTP calls

In this section I teach about "typed clients." These take the "named client" approach one step further—as well as encapsulating the configuration for calling a third-party API, they also encapsulate the HTTP details, such as which URLs to call, what HTTP verbs to use, and what data is returned. Encapsulating these details in a single location makes the API easier to consumer in your code.

A common pattern when you need to interact with an API is to encapsulate the mechanics of that interaction into a separate service. You could easily do this with the `IHttpClientFactory` features you've already seen, by extracting the body of the `GetRates()` function from listing 21.5 into a separate service. But `IHttpClientFactory` has deeper support for this pattern too.

`IHttpClientFactory` supports *typed clients*. A typed client is a class that accepts a configured `HttpClient` in its constructor. It uses the `HttpClient` to interact with the remote API and exposes a clean interface for consumers to call. All of the logic for interacting with the remote API is encapsulated in the typed client, such as which URL paths to call, which HTTP verbs to use, and the types of response the API returns. This encapsulation makes it easier to call the third-party API from multiple places in your app by using the typed client.

For example, the following listing shows an example typed client for the exchange rates API shown in previous listings. It accepts an `HttpClient` in its constructor, and exposes a `GetLatestRates()` method that encapsulates the logic for interacting with the third-party API.

Listing 21.6 Creating a typed client for the exchange rates API

```
public class ExchangeRatesClient
{
    private readonly HttpClient _client;                   #A
    public ExchangeRatesClient(HttpClient client)          #A
    {
        _client = client;
    }

    public async Task<string> GetLatestRates()             #B
    {
        var response = await _client.GetAsync("latest");   #C
        response.EnsureSuccessStatusCode();                #C

        return await response.Content.ReadAsString();      #C
    }
}
```

#A Inject an HttpClient using DI instead of an IHttpClientFactory

#B The GetLatestRates() logic encapsulates the logic for interacting with the API
#C Use the HttpClient the same way as before

We can then inject this ExchangeRatesClient into consuming services, and they don't need to know anything about how to make HTTP requests to the remote service, they just need to interact with the typed client. We can update listing 21.3 to use the typed client as shown in the following listing, at which point the GetRates() action method becomes trivial.

Listing 21.7 Consuming a typed client to encapsulate calls to a remote HTTP server

```
[ApiController]
public class ValuesController : ControllerBase
{
    private readonly ExchangeRatesClient _ratesClient;            #A
    public ValuesController(ExchangeRatesClient ratesClient)      #A
    {
        _ratesClient = ratesClient;
    }

    [HttpGet("values")]
    public async Task<string> GetRates()
    {
        return await _ratesClient.GetLatestRates();          #B
    }
}
```

#A Inject the typed client in the constructor
#B Call the typed client's API. The typed client handles making the correct HTTP requests

You may be a little confused at this point: I haven't mentioned how IHttpClientFactory is involved yet!

The ExchangeRatesClient takes an HttpClient in its constructor. IHttpClientFactory is responsible for creating the HttpClient, configuring it to call the remote service, and injecting it into a new instance of the typed client.

You can register the ExchangeRatesClient as a typed client and configure the HttpClient that is injected in ConfigureServices, as shown in the following listing. This is very similar to configuring a named client, so you can register additional configuration for the HttpClient that will be injected into the typed client

Listing 21.8 Registering a typed client with HttpClientFactory in Startup.cs

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddHttpClient<ExchangeRatesClient>                      #A
        (HttpClient client) =>                                       #B
    {
        client.BaseAddress =                                         #B
            new Uri("https://api.exchangeratesapi.io");              #B
        client.DefaultRequestHeaders.Add(                            #B
            HeaderNames.UserAgent, "ExchangeRateViewer");            #B
    })
    .ConfigureHttpClient((HttpClient client) => {});                 #C
```

```
}
```

#A Register a typed client using the generic AddHttpClient method
#B You can provide an additional configuration function for the HttpClient that will be injected
#C As for named clients, you can provide multiple configuration methods

> **TIP** You can think of a typed client as a wrapper around a named client. I'm a big fan of this approach as it encapsulates all the logic for interacting with a remote service in one place. It also avoids the "magic strings" that you use with named clients, removing the possibility of typos.

Another option when registering typed clients is to register an interface, in addition to the implementation. This is often a good practice, as it makes it much easier to test consuming code. For example, if the typed client in listing 21.6 implemented the interface `IExchangeRatesClient`, you could register the interface and typed client implementation using

```
services.AddHttpClient<IExchangeRatesClient, ExchangeRatesClient>()
```

You could then inject this into consuming code using the interface type, for example:

```
public ValuesController(IExchangeRatesClient ratesClient)
```

Another commonly used pattern is to not provide any configuration for the typed client in `ConfigureServices()`. Instead, you could place that logic in the constructor of your `ExchangeRatesClient` using the injected `HttpClient`:

```
public class ExchangeRatesClient
{
    private readonly HttpClient _client;
    public ExchangeRatesClient(HttpClient client)
    {
        _client = client;
        _client.BaseAddress = new Uri("https://api.exchangeratesapi.io");
    }
}
```

This is functionally equivalent to the approach shown in listing 21.8, it's a matter of taste where you'd rather put the configuration for your `HttpClient`. If you take this approach, you don't need to provide a configuration lambda in `ConfigureServices`:

```
services.AddHttpClient<ExchangeRatesClient>();
```

Named clients and typed clients are convenient for managing and encapsulating `HttpClient` configuration, but `IHttpClientFactory` brings another advantage we haven't looked at yet: it's easier to extend the `HttpClient` handler pipeline.

21.3 Handling transient HTTP errors with Polly

In this section you'll learn how to handle a very common scenario: "transient" errors when you make calls to a remote service, caused by an error in the remote server, or temporary network issues. You’ll see how to use IHttpClientFactory to handle cross-cutting concerns like this by adding handlers to the HttpClient handler pipeline.

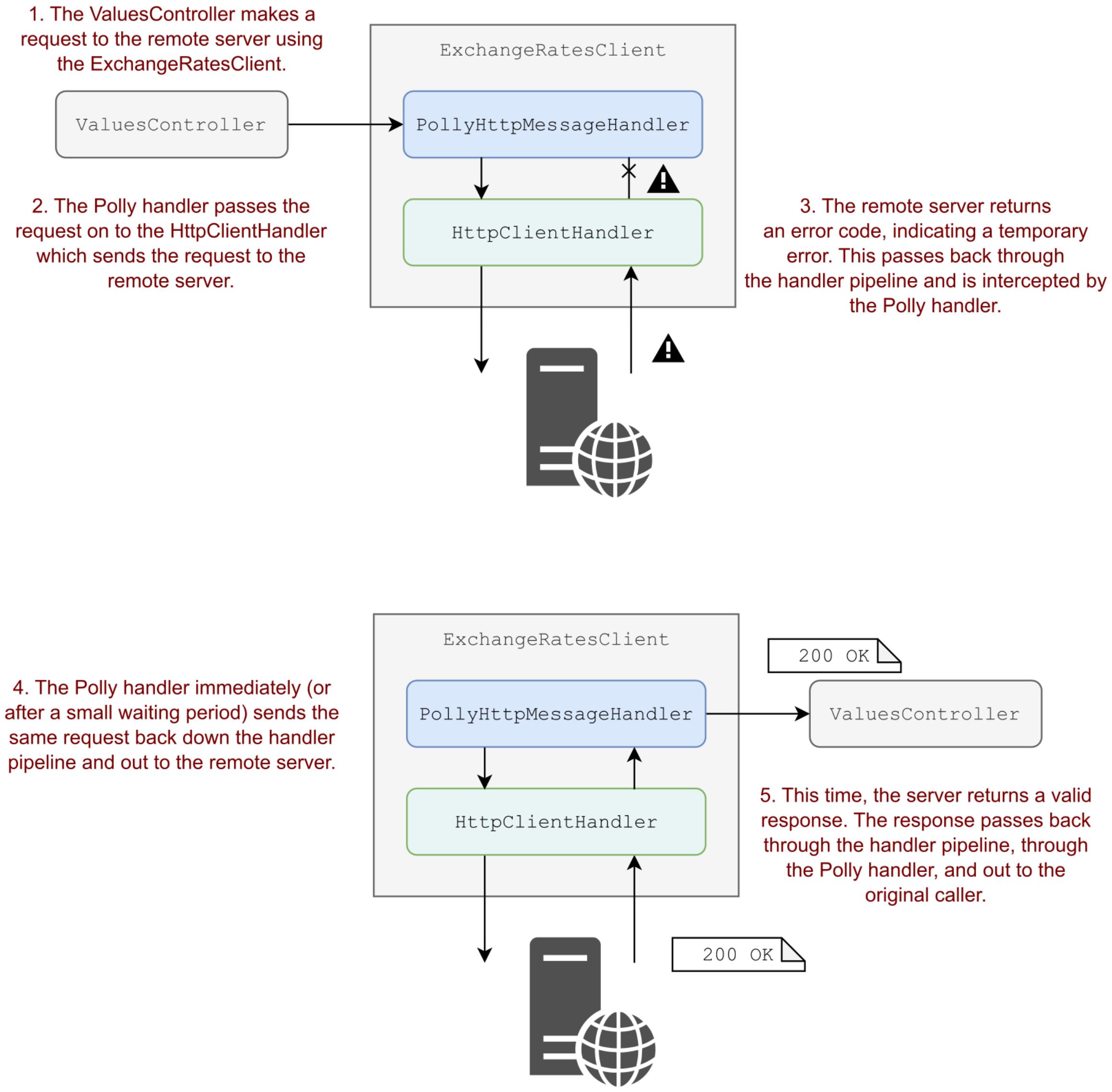
In section 21.2.1 I described HttpClient as consisting of a “pipeline” of handlers. The big advantage of this pipeline, much like the middleware pipeline of your application, is it allows you to add cross-cutting concerns to all requests. For example, IHttpClientFactory automatically adds a handler to each HttpClient that logs the status code and duration of each outgoing request.

As well as logging, another very common requirement is to handle transient errors when calling an external API. Transient errors can happen when the network drops out, or if a remote API goes offline temporarily. For transient errors, simply trying the request again can often succeed, but having to *manually* write the code to do so is cumbersome.

ASP.NET Core includes a library called Microsoft.Extensions.Http.Polly that makes handling transient errors easier. It uses the popular open source library Polly (www.thepollyproject.org) to automatically retry requests that fail due to transient network errors.

Polly is a mature library for handling transient errors that includes a variety of different error handling strategies, such as simple retries, exponential back off, circuit breaking, bulkhead isolation, and many more. Each strategy is explained in detail at https://github.com/App-vNext/Polly, so be sure to read the benefits and trade-offs when selecting a strategy.

To provide a taste of what’s available, we’ll add a simple retry policy to the ExchangeRatesClient shown in section 21.2. If a request fails due to a network problem such as a timeout or a server error, we’ll configure Polly to automatically retry the request as part of the handler pipeline, as shown in figure 21.5.



1. The ValuesController makes a request to the remote server using the ExchangeRatesClient.

2. The Polly handler passes the request on to the HttpClientHandler which sends the request to the remote server.

3. The remote server returns an error code, indicating a temporary error. This passes back through the handler pipeline and is intercepted by the Polly handler.

4. The Polly handler immediately (or after a small waiting period) sends the same request back down the handler pipeline and out to the remote server.

5. This time, the server returns a valid response. The response passes back through the handler pipeline, through the Polly handler, and out to the original caller.

Figure 21.5 Using the `PolicyHttpMessageHandler` to handle transient errors. If an error occurs when calling the remote API, the Polly handler will automatically retry the request. If the request then succeeds, the result is passed back to the caller. The caller didn't have to handle the error themselves, making it simpler to use the `HttpClient` while remaining resilient to transient errors.

To add transient error handling to a named or `HttpClient`, you must:

1. Install the Microsoft.Extensions.Http.Polly NuGet package in your project by running `dotnet add package Microsoft.Extensions.Http.Polly`, by using the NuGet explorer in Visual Studio, or by adding a `<PackageReference>` element to your project file as shown below

```
<PackageReference Include="Microsoft.Extensions.Http.Polly"
    Version="3.1.6" />
```

2. Configure a named or typed client as shown in listings 21.5 and 21.7.
3. Configure a transient error handling policy for your client as shown in listing 21.8.

Listing 21.8 Configuring a transient error handling policy for a typed client in Startup.cs

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddHttpClient<ExchangeRatesClient>()                    #A
        .AddTransientHttpErrorPolicy(policy =>                       #B
            policy.WaitAndRetryAsync(new[] {                         #C
                TimeSpan.FromMilliseconds(200),                      #D
                TimeSpan.FromMilliseconds(500),                      #D
                TimeSpan.FromSeconds(1)                              #D
            })
        );
}
```

#A You can add transient error handler to named or typed handlers
#B Use the extension methods provided by the NuGet package to add transient error handler
#C Configure the retry policy used by the handler. There are many types of policy to choose from
#D Configures a policy that waits and retries 3 times if an error occurs

In the listing above, we configure the error handler to catch transient errors and retry three times, waiting an increasing amount of time between requests. If the request fails on the third try, the handler will ignore the error, and pass it back to the client, just as if there was no error handler at all. By default, the handler will retry any request that either

- Throws an `HttpRequestException`, indicating an error at the protocol level, such as a closed connection, or
- Returns an HTTP 5xx status code, indicating a server error at the API, or
- Returns an HTTP 408 status code, indicating a timeout.

> **TIP** **If you want to handle more cases automatically, or to restrict the responses that will be automatically retried, you can customize the selection logic as described in the documentation: https://github.com/App-vNext/Polly/wiki/Polly-and-HttpClientFactory.**

Using standard handlers like the transient error handler allows you to apply the same logic across all requests made by a given `HttpClient`. The exact strategy you choose will depend on the characteristics of both the service and the request, but a good retry strategy is a must whenever you interact with potentially unreliable HTTP APIs.

The Polly error handler is an example of an optional HttpMessageHandler that you can plug in to your HttpClient, but you can also create your own custom handler. In the next section you'll see how to create a handler that adds a header to all outgoing requests.

21.4 Creating a custom HttpMessageHandler

In this section you'll learn how to create an HttpMessageHandler that adds a custom HTTP header to all outgoing requests. You could use this handler to attach an API key to all outgoing requests to a given third-party API, for example. You'll see how to create the handler and how to register it with a typed client.

Most third-party APIs will require some form of authentication when you're calling them. For example, many services require you attach an API key to an outgoing request, so that the request can be tied to your account. Instead of having to remember to manually add this header for every request to the API, you could configure a custom HttpMessageHandler to automatically attach the header for you.

NOTE More complex APIs may use Json Web Tokens (JWT) obtained from an identity provider. If that's the case, consider using the open source IdentityModel library (https://identitymodel.readthedocs.io) which provides integration points for ASP.NET Core Identity and HttpClientFactory.

You can configure a named or typed client using IHttpClientFactory to use your API-key handler as part of the HttpClient's handler pipeline, as shown in figure 21.6. When you use the HttpClient to send a message, the HttpRequestMesssage is passed through each handler in turn. The API-key handler adds the extra header and passes the request to the next handler in the pipeline. Eventually, the HttpClientHandler makes the network request to send the HTTP request. After the response is received, each handler gets a chance to inspect (and potentially modify) the response.

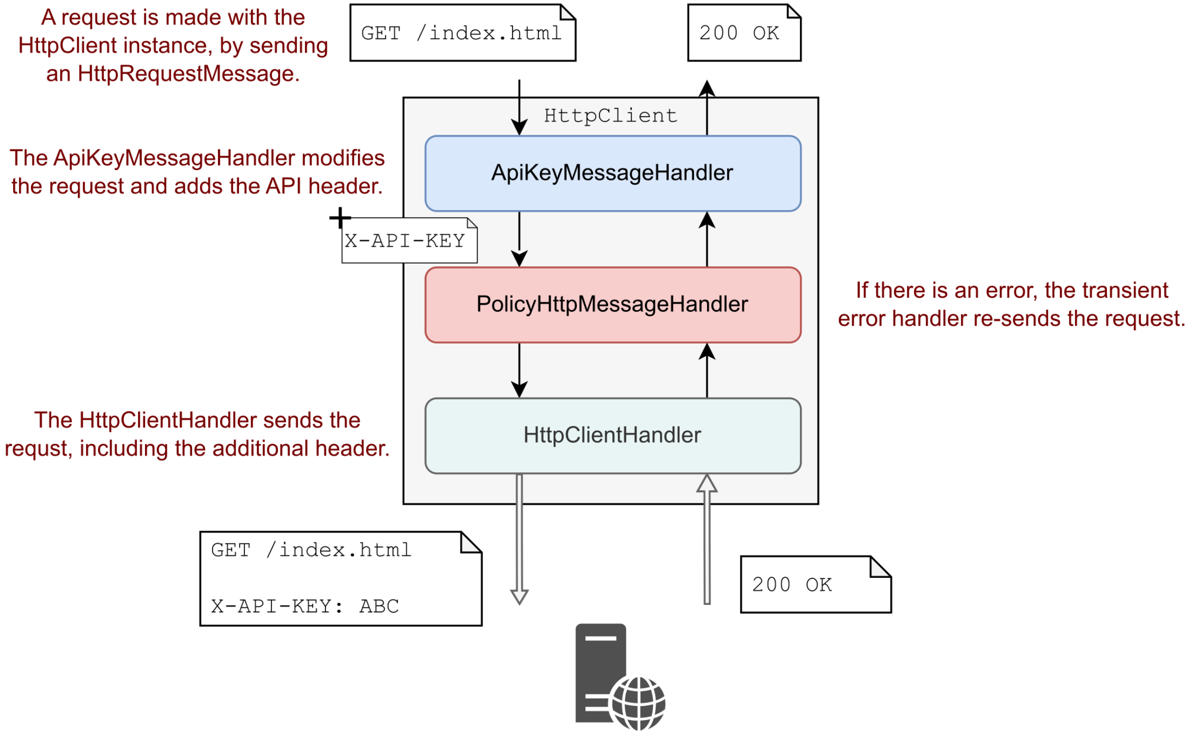

A request is made with the HttpClient instance, by sending an HttpRequestMessage.
GET /index.html
200 OK
HttpClient
The ApiKeyMessageHandler modifies the request and adds the API header.
ApiKeyMessageHandler
+
X-API-KEY
PolicyHttpMessageHandler
If there is an error, the transient error handler re-sends the request.
The HttpClientHandler sends the requst, including the additional header.
HttpClientHandler
GET /index.html
X-API-KEY: ABC
200 OK

Figure 21.6 You can use a custom `HttpMessageHandler` to modify requests before they're sent to third-party APIs. Every request passes through the handler, before the final handler, the `HttpClientHandler` sends the request to the HTTP API. After the response is received, each handler gets a chance to inspect and modify the response.

To create a custom `HttpMessageHandler` and add it to a typed or named client's pipeline, you must:

1. Create a custom handler by deriving from the `DelegatingHandler` base class.
2. Override the `SendAsync()` method to provide your custom behavior. Call `base.SendAsync()` to execute the remainder of the handler pipeline.
3. Register your handler with the DI container. If your handler does not require state, you can register it as a singleton service, otherwise you should register it as a transient service.
4. Add the handler to one or more of your named or typed clients by calling `AddHttpMessageHandler<T>()`, on an `IHttpClientBuilder`, where `T` is your handler type. The order you register handlers dictates the order they will be added to the `HttpClient` handler pipeline. You can add the same handler type more than once in a pipeline if you wish, and to multiple typed or named clients.

The following listing shows an example of a custom `HttpMessageHandler` that adds a header to every outgoing request. We use the custom `"X-API-KEY"` header in this example, but the header you need will vary depending on the third-party API you're calling. This example uses strongly typed configuration to inject the secret API key, as you saw in chapter 10.

Listing 21.9 Creating a custom `HttpMessageHandler`

```
public class ApiKeyMessageHandler : DelegatingHandler      #A
{
    private readonly ExchangeRateApiSettings _settings;    #B
    public ApiKeyMessageHandler(        #B
        IOptions<ExchangeRateApiSettings> settings)        #B
    {           #B
        _settings = settings.Value;      #B
    }           #B

    protected override async Task<HttpResponseMessage> SendAsync(    #C
        HttpRequestMessage request,             #C
        CancellationToken cancellationToken)     #C
    {
        request.Headers.Add("X-API-KEY", _settings.ApiKey);       #D

        HttpResponseMessage response =             #E
            await base.SendAsync(request, cancellationToken);      #E

        return response;           #F
    }
}
```

#A Custom HttpMessageHandlers should derive from DelegatingHandler
#B Inject the strongly typed configuration values using dependency injection
#C Override the SendAsync method to implement the custom behavior
#D Add the extra header to all outgoing requests
#E Call the remainder of the pipeline and receive the response
#F You could inspect or modify the response before returning it

To use the handler, you must register it with the DI container, and add it to a named or typed client. In the following listing, we add it to the `ExchangeRatesClient`, along with the transient error handler we registered in listing 21.8. This creates a pipeline similar to that shown in figure 21.6.

Listing 21.10 Registering a custom handler in Startup.ConfigureServices

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddTransient<ApiKeyMessageHandler>();     #A

    services.AddHttpClient<ExchangeRatesClient>()
        .AddHttpMessageHandler<ApiKeyMessageHandler>()    #B
        .AddTransientHttpErrorPolicy(policy =>      #C
            policy.WaitAndRetryAsync(new[] {
                TimeSpan.FromMilliseconds(200),
                TimeSpan.FromMilliseconds(500),
                TimeSpan.FromSeconds(1)
            })
        );
}
```

#A Register the custom handler with the DI container
#B Configure the typed client to use the custom handler
#C Add the transient error handler. The order they are registered, dictates their order in the pipeline

Whenever you make a request using the typed client `ExchangeRatesClient`, you can be sure the API key will be added, and that transient errors will be handled automatically for you.

That brings us to the end of this chapter on `IHttpClientFactory`. Given the difficulties in using `HttpClient` correctly I showed in section 21.1, you should always favor `IHttpClientFactory` where possible. As a bonus, `IHttpClientFactory` allows you to easily centralize your API configuration using named clients and to encapsulate your API interactions using typed clients.

21.5 Summary

- Use the `HttpClient` class for calling HTTP APIs. You can use it to make HTTP calls to APIs, providing all the headers and body to send in a request, and reading the response headers and data you get back.
- `HttpClient` uses a pipeline of handlers, consisting of multiple `HttpMessageHandlers`, connected in a similar way to the middleware pipeline used in ASP.NET Core. The final handler is the `HttpClientHandler` which is responsible for making the network connection and sending the request.
- `HttpClient` implements `IDisposable`, but you shouldn't typically dispose it. When the `HttpClientHandler` which makes the TCP/IP connection is disposed, it keeps a connection open for the TIME_WAIT period. Disposing many `HttpClient`s in a short period of time can lead to socket exhaustion, preventing a machine from handling any more requests.
- Prior to .NET Core 2.1, the advice was to use a single `HttpClient` for the lifetime of your application. Unfortunately, a singleton `HttpClient` will not respect DNS changes, which are commonly used for traffic management in cloud environments.
- `IHttpClientFactory` solves both these problems by managing the lifetime of the `HttpMessageHandler` pipeline. You can create a new `HttpClient` by calling `CreateClient()`, and `IHttpClientFactory` takes care of disposing the handler pipeline when it is no longer in use.
- You can centralize the configuration of an `HttpClient` in `ConfigureServices()` using *named* clients by calling `AddHttpClient("test", c => {})`. You can then retrieve a configured instance of the client in your services by calling `IHttpClientFactory.CreateClient("test")`.
- You can create a *typed* client by injecting an `HttpClient` into a service, `T`, and configuring the client using `AddHttpClient<T>(c => {})`. Typed clients are great for abstracting the HTTP mechanics away from consumers of your client.
- You can use the Microsoft.Extensions.Http.Polly library to add transient HTTP error

handling to your HttpClients. Call AddTransientHttpErrorPolicy() when configuring your IHttpClientFactory in ConfigureServices, and provide a Polly policy to control when errors should be automatically handled and retried.

- It's common to use a simple "retry" policy to try making a request multiple times before giving up and returning an error. When designing a policy be sure to consider the impact of your policy; in some circumstances it may be better to fail quickly instead of retrying a request which is never going to succeed. Polly includes additional policies such as circuit-breakers to create more advanced approaches.
- By default, the transient error handling middleware will handle connection errors, server errors that return a 5xx error code, and 408 (timeout) errors. You can customize this if you want to handle additional error types but ensure that you only retry requests which are safe to do so.
- You can create a custom HttpMessageHandler to modify each request made through a named or typed client. Custom handlers are good for implementing cross-cutting concerns such as logging, metrics, and authentication.
- To create a custom HttpMessageHandler, derive from DelegatingHandler and override the SendAsync() method. Call base.SendAsync() to send the request to the next handler in the pipeline and finally to the HttpClientHandler which makes the HTTP request.
- Register your custom handler in the DI container as either a transient or a singleton. Add it to a named or typed client using AddHttpMessageHandler<T>(). The order you register the handler in the IHttpClientBuilder is the order the handler will appear in the HttpClient handler pipeline.

22

Building background tasks and services

This chapter covers

- **Creating tasks that run in the background for your application**
- **Using the generic `IHost` to create Windows Services and Linux daemons**
- **Using Quartz.NET to run tasks on a schedule, in a clustered environment**

We've covered a lot of ground in the book so far. You've learned how to create page-based applications using Razor Pages and how to create APIs for mobile clients and services. You've seen how to add authentication and authorization to your application, how to use EF Core for storing state in the database, and how to create custom components to meet your requirements.

As well as these "UI" focused apps, you may find you need to build "background" or "batch-task" services. These services aren't meant to interact with users directly. Rather they stay running in the background, processing items from a queue or periodically executing a long-running process.

For example, you might want to have a background service that sends email confirmations for eCommerce orders, or a batch job that calculates sales and losses for retail stores after the shops close. ASP.NET Core includes support for these "background tasks" by providing abstractions for running a task in the background when your application starts.

In section 22.1 you'll learn about the background task support provided in ASP.NET Core by the `IHostedService` interface. You'll learn how to use the `BackgroundService` helper class to create tasks that run on a timer, and how to manage your DI lifetimes correctly in a long-running task.

In section 22.2 we take the background service concept one step further to create "headless" worker services, using the generic `IHost`. Worker services don't use Razor Pages or API controllers; instead they consist only of `IHostedService`s running tasks in the background. You'll also see how to configure and install a worker service app as a Windows Service, or as a Linux daemon.

In section 22.3 I introduce the open source library Quartz.NET, which provides extensive scheduling capabilities for creating background services. You'll learn how to install Quartz.NET in your applications, how to create complex schedules for your tasks, and how to add redundancy to your worker services by using clustering.

Before we get to more complex scenarios, we'll start by looking at the built-in support for running background tasks in your apps.

22.1 Running background tasks with IHostedService

In this section you'll learn how to create background tasks that run for the lifetime of the application using `IHostedService`. You'll create a task that caches the values from a remote service every 5 minutes, so that the rest of the application can retrieve the values from the cache. You'll then learn how to use services with a scoped lifetime in your singleton background services by managing container scopes yourself.

In most applications, it's common to want to create tasks that happen in the background, rather than in response to a request. This could be a task to process a queue of emails; handling events published to some sort of a message bus; or running a batch process to calculate daily profits. By moving this work to a background task, your user interface can stay responsive. Instead of trying to send an email immediately for example, you could add the request to a queue and return a response to the user immediately. The background task can consume that queue in the background at its leisure.

In ASP.NET Core, you can use the `IHostedService` interface to run tasks in the background. Classes which implement this interface are started when your application starts, shortly after your application starts handling requests, and are stopped shortly before your application is stopped. This provides the hooks you need to perform most tasks

> **NOTE** Even the ASP.NET Core server, Kestrel, runs as an `IHostedService`. In one sense, almost everything in an ASP.NET Core app is a "background" task!

In this section you'll see how to use the `IHostedService` to create a background task that runs continuously throughout the lifetime of your app. This could be used for many different things, but in the next section you'll see how to use it to populate a simple cache.

22.1.1 Running background tasks on a timer

In this section you'll learn how to create a background task that runs periodically on a timer, throughout the lifetime of your app. Running background tasks can be useful for many reasons, such as scheduling work to be performed later or for performing work in-advance.

For example, in chapter 21, we used IHttpClientFactory and a typed client to call a third-party service to retrieve the current exchange rate between various currencies, and returned them in an API controller, as shown in the following listing. A simple optimization for this code might be to cache the exchange rate values for a period.

Listing 22.1 Using a typed client to return exchange rates from a third-party service

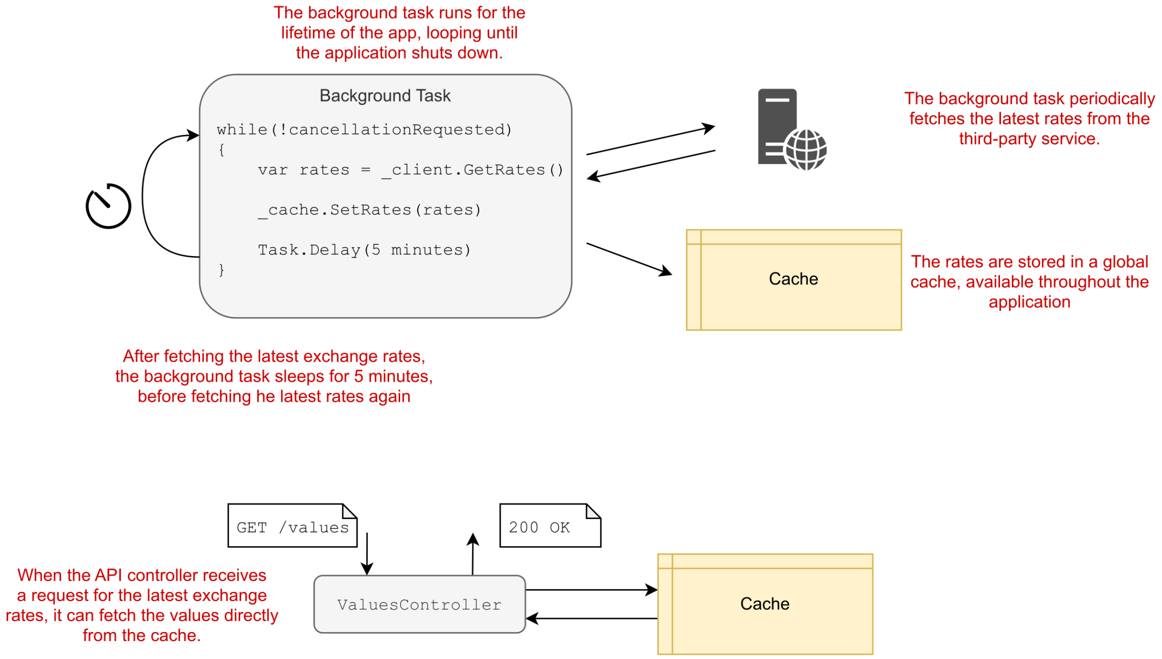
```
[ApiController]
public class ValuesController : ControllerBase
{
    private readonly ExchangeRatesClient _typedClient;          #A
    public ValuesController(ExchangeRatesClient typedClient)    #A
    {
        _typedClient = typedClient;
    }

    [HttpGet("values")]
    public async Task<string> GetRates()
    {
        return await _typedClient.GetLatestRatesAsync()    #B
    }
}
```

#A A typed client created using IHttpClientFactory is injected in the constructor
#B The typed client is used to retrieve exchange rates from the remote API and returns them

There are multiple ways you could implement that, but in this section, we'll use a simple cache that pre-emptively fetches the exchange rates in the background, as shown in figure 22.1. The API controller simply reads from the cache; it never has to make HTTP calls itself, so it remains fast.

> **NOTE** **An alternative approach might add caching to your strongly typed client,** ExchangeRateClient**. The downside is that when you need to update the rates, you will have to do the request immediately, making the overall response slower. Using a background service keeps your API controller consistently fast.**


The background task runs for the lifetime of the app, looping until the application shuts down.
Background Task
The background task periodically fetches the latest rates from the third-party service.
Cache
The rates are stored in a global cache, available throughout the application
After fetching the latest exchange rates, the background task sleeps for 5 minutes, before fetching he latest rates again
GET /values
200 OK
When the API controller receives a request for the latest exchange rates, it can fetch the values directly from the cache.
ValuesController
Cache

```
while(!cancellationRequested)
{
    var rates = _client.GetRates()

    _cache.SetRates(rates)

    Task.Delay(5 minutes)
}
```

Figure 22.1 You can use a background task to cache the results from a third-party API on a schedule. The API controller can then read directly from the cache, instead of calling the third-party API itself. This reduces the latency of requests to your API controller, while ensuring the data remains fresh.

You can implement a background task using the interface `IHostedService`. This consists of two methods:

```
public interface IHostedService
{
    Task StartAsync(CancellationToken cancellationToken);
    Task StopAsync(CancellationToken cancellationToken);
}
```

but there are subtleties to implementing the interface correctly. In particular, the `StartAsync()` method, although asynchronous, runs “inline” as part of your application startup. Background tasks that are expected to run for the lifetime of your application must return a `Task` immediately, and schedule background work on a different thread.

> **WARNING** **Calling await in `IHostedService.StartAsync()` method will block your application starting until the method completes. This can be useful in some cases but is often not the desired behavior for background tasks.**

To make it easier to create background services using best practice patterns, ASP.NET Core provides the abstract base class `BackgroundService` which implements `IHostedService` and is designed to be used for long running tasks. To create a background task you must override a single method of this class, `ExecuteAsync()`. You're free to use `async-await` inside this method and you can keep running the method for the lifetime of your app.

For example, the following listing shows a background service that fetches the latest interest rates using a typed client and saves them in a cache, as you saw in figure 22.1. The `ExecuteAsync()` method keeps looping and updating the cache until the `CancellationToken` passed as an argument indicates that the application is shutting down.

Listing 22.2 Implementing a `BackgroundService` that calls a remote HTTP API

```
public class ExchangeRatesHostedService : BackgroundService              #A
{
    private readonly IServiceProvider _provider;                         #B
    private readonly ExchangeRatesCache _cache;                          #C
    public ExchangeRatesHostedService(
        IServiceProvider provider, ExchangeRatesCache cache)
    {
        _provider = provider;
        _cache = cache;
    }

    protected override async Task ExecuteAsync(                          #D
        CancellationToken stoppingToken)                                 #E
    {
        while (!stoppingToken.IsCancellationRequested)                   #F
        {
            var client = _provider                                       #G
                .GetRequiredService<ExchangeRatesClient>();              #G

            string rates= await client.GetLatestRatesAsync();            #H
            _cache.SetRates(latest);                                     #I

            await Task.Delay(TimeSpan.FromMinutes(5), stoppingToken);    #J
        }
    }
}
```

#A Derive from BackgroundService to create a task that runs for the lifetime of your app
#B Inject an IServiceProvider so you can create instances of the typed client
#C A simple cache for exchange rates
#D You must override ExecuteAsync to set the service's behavior
#E The CancellationToken passed as an argument is triggered when the application shuts down
#F Keep looping until the application shuts down
#G Create a new instance of the typed client, so that the HttpClient is short-lived
#H Fetch the latest rates from the remote API
#I Store the rates in the cache
#J Wait for 5 minutes (or for the application to shut down) before updating the cache,

The `ExchangeRateCache` in listing 22.2 is a simple singleton that stores the latest rates. It must be thread-safe, as it will be accessed concurrently by your API controllers. You can see a simple implementation in the source code for this chapter.

To register your background service with the DI container, use the `AddHostedService()` extension method in the `ConfigureServices()` method of Startup.cs, as shown in the following listing.

Listing 22.3 Registering an `IHostedService` with the DI container

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddHttpClient<ExchangeRatesClient>()               #A
    services.AddSingleton<ExchangeRatesCache>();                #B
    services.AddHostedService<ExchangeRatesHostedService>();    #C
}
```

#A Register the typed client as before
#B Add the cache object as a singleton, as you must share the same instance throughout your app
#C Register the ExchangeRatesHostedService as an IHostedService

By using a background service to fetch the exchange rates, your API controller becomes very simple. Instead of fetching the latest rates itself, it returns the value from the cache, which is kept up to date by the background service:

```
[ApiController]
public class ValuesController : ControllerBase
{
    private readonly ExchangeRatesCache _cache;
    public ValuesController(ExchangeRatesCache cache)
    {
        _cache = cache;
    }

    [HttpGet("values"]
    public string GetValues()
    {
        return _cache.GetLatestRates();
    }
}
```

One slightly messy aspect of listing 22.2 is that I've used the service-locator pattern to retrieve the typed client. This isn't ideal, but you shouldn't inject typed clients into background services directly. Typed clients are designed to be short lived, to ensure you take advantage of the `HttpClient` handler rotation as described in chapter 21. In contrast, background services are singletons that live for the lifetime of your application.

> **TIP** If you wish, you can avoid the service-locator pattern used in listing 22.2 by using the factory pattern described in this post: https://www.stevejgordon.co.uk/ihttpclientfactory-patterns-using-typed-clients-from-singleton-services.

The need to have short-lived services leads to another common question—how can you use "scoped" services in a background service?

22.1.2 Using scoped services in background tasks

Background services that implement `IHostedService` are created once when your application starts. That means they are, by necessity, singletons, as there will only ever be a single instance of the class.

That leads to a problem if you need to use services registered with a *scoped* lifetime. Any services you inject into the constructor of your singleton `IHostedService` must themselves be registered as singletons. Does that mean there's no way to use scoped dependencies in a background service?

> **REMINDER** As I discussed in chapter 10, a service should only use dependencies with a lifetime longer than or equal to the lifetime of the service, to avoid captured dependencies.

For example, lets imagine a slight variation of the caching example from section 22.1.1. Instead of storing the exchange rates in a singleton cache object, you want to save the exchange rates to a database, so you can look up the historic rates.

Most database providers, including EF Core's `DbContext`, register their services with scoped lifetimes. That means you need to access the *scoped* `DbContext`, from inside the *singleton* `ExchangeRatesHostedService`, which precludes injecting the `DbContext` with constructor injection. The solution is to create a new container scope every time you update the exchange rates.

In typical ASP.NET Core applications, the framework creates a new container scope every time a new request is received, just before the middleware pipeline executes. All the services that are used in that request are fetched from the scoped container. In a background service, there *are* no requests, so no container scopes are created. The solution is to create your own!

You can create a new container scope anywhere you have access to an `IServiceProvider` by calling `IServiceProvider.CreateScope()`. This creates a scoped container, which you can use to retrieve scoped services.

> **WARNING** Always make sure to dispose the `IServiceScope` returned by `CreateScope()` when you're finished with it, typically with a `using` statement. This disposes any services that were created by the scoped container, and prevents memory leaks.

The following listing shows a version of the `ExchangeRatesHostedService` that stores the latest exchange rates as an EF Core entity in the database. It creates a new scope for each iteration of the `while` loop and retrieves the scoped `AppDbContext` from the scoped container.

Listing 22.4 Consuming scoped services from an IHostedService

```
public class ExchangeRatesHostedService : BackgroundService              #A
{
    private readonly IServiceProvider _provider;                         #B
    public ExchangeRatesHostedService(IServiceProvider provider)         #B
    {
        _provider = provider;
    }

    protected override async Task ExecuteAsync(
        CancellationToken stoppingToken)
    {
        while (!stoppingToken.IsCancellationRequested)
        {
            using(IServiceScope scope = _provider.CreateScope())         #C
            {
                var scopedProvider = scope.ServiceProvider;              #D

                   var client = scope.ServiceProvider                       #E
                    .GetRequiredService<ExchangeRatesClient>();          #E

                var context = scope.ServiceProvider                      #E
                    .GetRequiredService<AppDbContext>();                 #E

                var rates= await client.GetLatestRatesAsync();           #F

                context.Add(rates);                                      #F
                await context.SaveChanges(rates);                        #F
             }                                                           #G

            await Task.Delay(TimeSpan.FromMinutes(5), stoppingToken);    #H
        }
    }
}
```

#A BackgroundService is registered as a singleton
#B The injected IServiceProvider can be used to retrieve singleton services, or to create scopes
#C Create a new scope using the root IServiceProvider
#D The scope exposes an IServiceProvider that can be used to retrieve scoped components
#E Retrieve the scoped services from the container
#F Fetch the latest rates, and save using EF Core
#G Dispose the scope with the using statement.
#H Wait for the next iteration. A new scope is created on the next iteration.

Creating scopes like this is a general solution whenever you find you need to access scoped services and you’re not running in the context of a request. A prime example is when you’re implementing `IConfigureOptions`, as you saw in chapter 19. You can take the exact same approach—creating a new scope—as shown here http://mng.bz/6m17.

> **TIP Using service location in this way always feels a bit convoluted. I typically try and extract the body of the task to a separate class and use service location to retrieve that class only. You can see an example of this approach in the documentation: https://docs.microsoft.com/aspnet/core/fundamentals/host/hosted-services#consuming-a-scoped-service-in-a-background-task.**

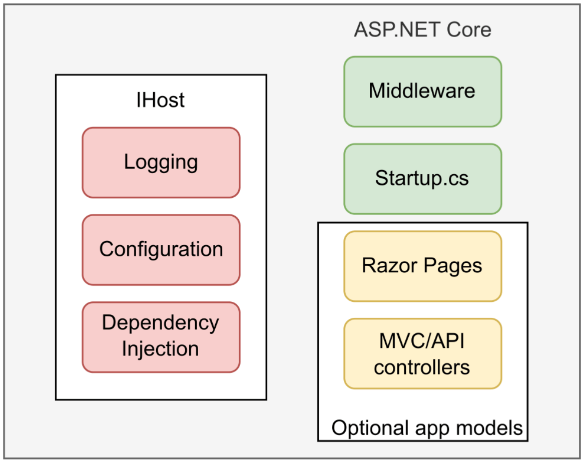
`IHostedService` is available in ASP.NET Core, so you can run background tasks in your Razor Pages or API controller applications. However, sometimes all you *want* is the background task and you don’t need any UI. For those cases, you can use the raw `IHost` abstraction, without having to bother with HTTP handling at all.

22.2 Creating headless worker services using IHost

In this section you'll learn about worker services, which are ASP.NET Core applications that do not handle HTTP traffic. You'll learn how to create a new worker service from a template and compare the generated code to a traditional ASP.NET Core application. You'll also learn how to install the worker service as a Windows Service or as a systemd daemon on Linux.

In section 22.1 we cached exchange rates based on the assumption that they're being consumed directly by the UI part of your application, by Razor Pages or API controllers for example. However, in the section 22.1.2 example we saved the rates to the database instead of storing them in-process. That raises the possibility of *other* applications with access to the database using the rates too. Taking that one step further, could we create an application which is *only* responsible for caching these rates, and has no UI at all?

Since .NET Core 3.0, ASP.NET Core has been built on top of a "generic" (as opposed to "web") `IHost` implementation. It is the `IHost` implementation that provides features such as configuration, logging, and dependency injection. ASP.NET Core adds the middleware pipeline for handling HTTP requests, as well as paradigms such as Razor Pages or MVC on top of that, as shown in figure 22.2.



The .NET Core generic IHost abstraction provides logging, configuration, and dependency injection abstractions.

ASP.NET Core adds HTTP handling using middleware, and Startup.cs to separate DI and middleware configuration from host configuration

On top of the middleware basics you can optionally add programming models like Razor Pages and API controllers

Figure 22.2 ASP.NET Core builds on the generic `IHost` implementation. The `IHost` provides features such as configuration, dependency injection, and configuration. ASP.NET Core adds HTTP handling on top of that by way of the middleware pipeline, Razor Pages and API controllers. If you don't need HTTP handling, you can use the `IHost` without the additional ASP.NET Core libraries to create a smaller application.

If your application doesn't *need* to handle HTTP requests, then there's no real reason to use ASP.NET Core. You can use the `IHost` implementation alone to create an application that will have a lower memory footprint, faster startup, and less surface area to worry about from a security side than a full ASP.NET Core application. .NET Core applications that use this approach are commonly called *worker services* or *workers*.

> **DEFINITION** **A *worker* is a .NET Core application that uses the generic `IHost` but doesn't include the ASP.NET Core libraries for handling HTTP requests. They are sometimes called "headless" services, as they don't expose a UI for you to interact with.**

Workers are commonly used for running background tasks (`IHostedService` implementations) which don't require a UI. These tasks could be for running batch jobs, for running tasks repeatedly on a schedule, or for handling events using some sort of message bus. In the next section we'll create a worker for retrieving the latest exchange rates from a remote API, instead of adding the background task to an ASP.NET Core application.

22.2.1 Creating a worker service from a template

In this section you'll see how to create a basic worker service from a template. Visual Studio includes a template for creating worker services by choosing File > New > Project > Worker Service. You can create a similar template using the .NET CLI by running `dotnet new worker`. The resulting template consists of two C# files:

- Worker.cs—This is a simple `BackgroundService` implementation that writes to the log every second. You can replace this class with your own `BackgroundService` implementation, such as the example from listing 22.4.
- Program.cs—As with a typical ASP.NET Core application, this contains the entry point for your application, and is where the `IHost` is built and run. In contrast to a typical ASP.NET Core app, it's *also* where you will configure the dependency injection container for your application.

The most notable difference between the worker service template and an ASP.NET Core template is that there is no Startup.cs file. In ASP.NET Core applications, Startup.cs is where you usually configure your DI container and your middleware pipeline. The worker service doesn't have a middleware pipeline (as it doesn't handle HTTP requests), but it *does* use DI, so where is that configured?

In worker service templates, you configure DI in Program.cs using the `ConfigureServices()` method as shown in the following listing. This method is functionally identical to the `ConfigureServices()` method in Startup.cs, so you can use exactly the same syntax. The following listing shows how to configure EF Core, the exchange rates typed client from chapter 21, and the background service that saves exchange rates to the database, as you saw in section 22.1.2.

Listing 22.5 Program.cs for a worker service that saves exchange rates using EF Core

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();                          #A
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>      #B
        Host.CreateDefaultBuilder(args)                                 #B
            .ConfigureServices((hostContext, services) =>
            {
                services.AddHttpClient<ExchangeRatesClient>();          #C
                services                                                #C
                  .AddHostedService<ExchangeRatesHostedService>();      #C

                services.AddDbContext<AppDbContext>(options =>          #C
                  options.UseSqlite(                                    #C
                      hostContext.Configuration                         #D
                          .GetConnectionString("SqlLiteConnection"))    #D
                );
            });
}
```

#A A worker creates an IHostBuilder, builds an IHost, and runs it, the same as an ASP.NET Core app
#B The same HostBuilder code is used, but there is no call to ConfigureWebHostDefaults
#C Add services in ConfigureServices, the same as you typically would in Startup.cs
#D IConfiguration can be accessed from the HostBuilderContext parameter

> **TIP** You can use the `IHostBuilder.ConfigureServices()` methods in ASP.NET Core apps too, but the general convention is to use Startup.cs instead. The `IHostBuilder` methods are useful in some circumstances when you need to control exactly when your background tasks start, as I describe in this post https://andrewlock.net/controlling-ihostedservice-execution-order-in-aspnetcore-3/.

The changes in Program.cs, and the lack of a Startup.cs file, are the most obvious differences between a worker service and an ASP.NET Core app, but there are some important differences in the .csproj project file too. The following listing shows the project file for a worker service that uses `IHttpClientFactory` and EF Core, and highlights some of the differences compared to a similar ASP.NET Core application.

Listing 22.6 Project file for a worker service

```
<Project Sdk="Microsoft.NET.Sdk.Worker">                              #A

  <PropertyGroup>
    <TargetFramework>netcoreapp3.1</TargetFramework>                  #B
    <UserSecretsId>5088-4277-B226-DC0A790AB790</UserSecretsId>        #C
  </PropertyGroup>

  <ItemGroup>
    <PackageReference Include="Microsoft.Extensions.Hosting"            #D
        Version="3.1.6" />                                              #D
    <PackageReference Include="Microsoft.Extensions.Http"               #E
        Version="3.1.6" />                                              #E
    <PackageReference Include="Microsoft.EntityFrameworkCore.Design"    #F
         Version="3.1.6" PrivateAssets="All" />                         #F
    <PackageReference Include="Microsoft.EntityFrameworkCore.Sqlite"    #F
         Version="3.1.6" />                                             #F
  </ItemGroup>
</Project>
```

#A Worker services use a different project SDK type to ASP.NET Core apps
#B The target framework is the same as for ASP.NET Core apps
#C Worker services use configuration, so can use UserSecrets, the same as ASP.NET Core apps
#D All worker services must explicitly add this package. ASP.NET Core apps add it implicitly
#E If you're using IHttpClientFactory, you'll need to add this package in worker services
#F EF Core packages must be explicitly added, the same as for ASP.NET Core apps

Some parts of the project file are the same for both worker services and ASP.NET Core apps:

- Both types of app must specify a `<TargetFramework>`, such as `netcoreapp3.1` for .NET Core 3.1, or `net5.0` for .NET 5.
- Both types of apps use the configuration system, so you can use `<UserSecretsId>` to manage secrets in development, as discussed in chapter 11.
- Both types of app must explicitly add references to the EF Core NuGet packages to use EF Core in the app.

There are also several differences in the project template:

- The `<Project>` element's `Sdk` for a worker service should be `Microsoft.NET.Sdk.Worker`, while for an ASP.NET Core app it is `Microsoft.NET.Sdk.Web`. The Web SDK includes implicit references to additional packages that are not generally required in worker services.
- The worker service *must* include an explicit `PackageReference` for the Microsoft.Extensions.Hosting NuGet package. This package includes the generic `IHost` implementation used by worker services.
- You may need to include additional packages to reference the same functionality, when compared to an ASP.NET Core app. An example of this is the Microsoft.Extensions.Http package (which provides `IHttpClientFactory`). This package is referenced implicitly in ASP.NET Core apps but must be explicitly referenced in worker services.

Running a worker service is the same as running an ASP.NET Core application: use `dotnet run` from the command line or hit F5 from Visual Studio. A worker service is essentially just a console application (as are ASP.NET Core applications), so they both run the same way.

You can run worker services in most of the same places you would run an ASP.NET Core application, though as a worker service doesn't handle HTTP traffic, some options make more sense than others. In the next section, we'll look at two supported ways of running your application: as a Windows Service or as a Linux systemd daemon.

22.2.2 Running worker services in production

In this section you'll learn how to run worker services in production. You'll learn how to install a worker service as a Windows service so that the operating system monitors and starts your worker service automatically. You'll also see how to prepare your application for installation as a systemd daemon on Linux.

Worker services, like ASP.NET Core applications, are fundamentally just .NET Core console applications. The difference is that they are typically intended to be long-running applications. The common approach for running these types of applications on Windows is to use a Windows Service or to use a systemd daemon on Linux.

> **NOTE** It's also very common to run applications in the Cloud using Docker containers or dedicated platform services like Azure App Service. The process for deploying a worker service to these managed services is typically identical to deploying an ASP.NET Core application.

Adding support for Windows services or systemd is easy, thanks to two optional NuGet packages:

- *Microsoft.Extensions.Hosting.Systemd*. Adds support for running the application as a systemd application. To enable systemd integration, call `UseSystemd()` on your `IHostBuilder` in Program.cs.
- *Microsoft.Extensions.Hosting.WindowsServices*. Adds support for running the application as a Windows Service. To enable the integration, call `UseWindowsService()` on your `IHostBuilder` in Program.cs.
- These packages each add a single extension method to `IHostBuilder` that enables the appropriate integration when running as a systemd daemon, or as a Windows Service. For example, the following listing shows how to enable Windows Service support.

Listing 22.7 Adding Windows Service support to a worker service

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateHostBuilder(args).Build().Run();
    }

    public static IHostBuilder CreateHostBuilder(string[] args) =>     #A
        Host.CreateDefaultBuilder(args)                                #A
            .ConfigureServices((hostContext, services) =>              #A
            {                                                          #A
                services.AddHostedService<Worker>();                   #A
            })                                                         #A
            .UseWindowsService();                                      #B
}
```

#A Configure your worker service as you would normally
#B Add support for running as a Windows Service

During development, or if you run your application as a console app, the `AddWindowsService()` does nothing; your application runs exactly the same as it would without the method call. However, your application can now be installed as a Windows Service, as your app now has the required integration hooks to work with the Windows Service system.

The following describes the basic steps to install a worker service app as a Windows Service:

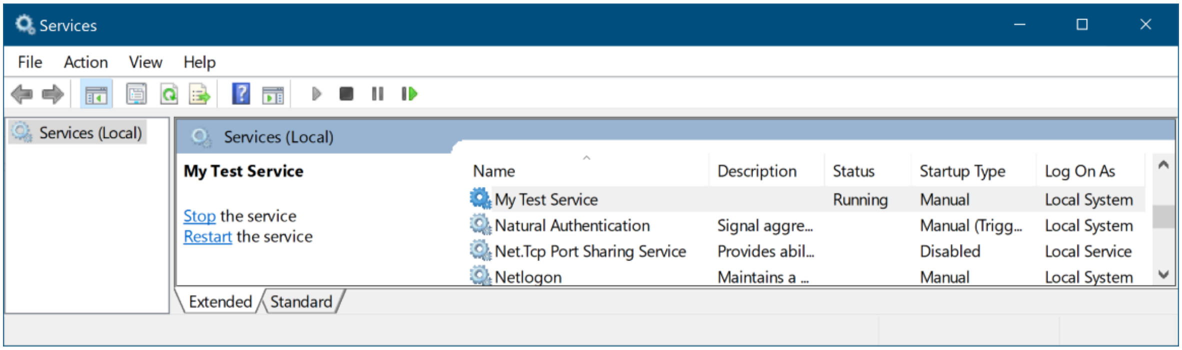
1. Add the Microsoft.Extensions.Hosting.WindowsServices NuGet package to your application using Visual Studio, by running `dotnet add package Microsoft.Extensions.Hosting.WindowsServices` in the project folder, or by adding a `<PackageReference>` to your .csproj file:

```
<PackageReference Include="Microsoft.Extensions.Hosting.WindowsServices"
Version="3.1.6" />
```

2. Add a call to `UseWindowsService()` on your `IHostBuilder`, as shown in listing 22.7.
3. Publish your application, as described in chapter 16. From the command line, you could run `dotnet publish -c Release` from the project folder.
4. Open a command prompt as Administrator, and install the application using the Windows `sc` utility. You need to provide the path to your published project’s .exe file and a name to use for the service, for example `My Test Service`:

```
sc create "My Test Service" BinPath="C:\path\to\MyService.exe"
```

5. You can manage the service from the Services control panel in Windows, as shown in figure 22.3. Alternatively, to start the service from the command line run `sc start "My Test Service"`, or to delete the service run `sc delete "My Test Service"`.



Name	Description	Status	Startup Type	Log On As
My Test Service		Running	Manual	Local System
Natural Authentication	Signal aggre...		Manual (Trigg...	Local System
Net.Tcp Port Sharing Service	Provides abil...		Disabled	Local Service
Netlogon	Maintains a ...		Manual	Local System

Figure 22.3 The Services control panel in Windows. After installing a worker service as a Windows Service using the `sc` utility, you can manage your worker service from here. This allows you to control when the Windows service starts and stops, the user account the application runs under, and how to handle errors.

> **WARNING** These steps are the bare minimum to install a Windows Service. When running in production you must consider many security aspects not covered here. For more details, see https://docs.microsoft.com/aspnet/core/host-and-deploy/windows-service.

After following the process above, your worker service will be running as a Windows service.

An interesting point of note is that installing as a Windows Service or systemd daemon isn't limited to worker services only—you can install an ASP.NET Core application in the same way. Simply follow the instructions above, add the call to `UseWindowsService()`, and install your ASP.NET Core app. This is thanks to the fact that the ASP.NET Core functionality is built directly on top of the generic `Host` functionality.

You can follow a similar process to install a worker service as a systemd daemon by installing the Microsoft.Extensions.Hosting.Systemd package, and calling `UseSystemd()` on your `IHostBuilder`. For more details on configuring systemd, see https://docs.microsoft.com/aspnet/core/host-and-deploy/linux-nginx#monitor-the-app.

So far in this chapter we've used `IHostedService` and the `BackgroundService` to run tasks that repeat on an interval, and you've seen how to install worker services as long running applications, by installing as a Windows Service.

In the final section of this chapter, we look at how you can create more advanced schedules for your background tasks, as well as how to add resiliency to your application by running multiple instances of your workers. To achieve that, we'll use a mature third-party library, Quartz.NET.

22.3 Coordinating background tasks using Quartz.NET

In this section you'll learn how to use the open source scheduler library Quartz.NET. You'll learn how to install and configure the library, and how to add a background job to run on a schedule. You'll also learn how to enable clustering for your applications, so that you can run multiple instances of your worker service, and share jobs between them.

All the background tasks you've seen so far in this chapter repeat a task on an interval indefinitely, from the moment the application starts. However, sometimes you want more control of this timing. Maybe you always want to run the application at 15 minutes past each hour. Or maybe you only want to run a task on the second Tuesday of the month at 3am. Additionally, maybe you want to run multiple instances of your application for redundancy, but ensure that only one of the services runs a task at any one time.

It would certainly be possible to build all this extra functionality into an application yourself, but there are excellent libraries available which already provide all this functionality for you. Two of the most well known in the .NET space are Hangfire (www.hangfire.io) and Quartz.NET(www.quartz-scheduler.net).

Hangfire is an open source library which also has a "Pro" subscription option. One of its most popular features is a dashboard user interface, that shows the state of all your running jobs, each task's history, and any errors that occurred.

Quartz.NET is completely open source and essentially offers a "beefed-up" version of the `BackgroundService` functionality. It has extensive scheduling functionality, as well as support for running in a "clustered" environment, where multiple instances of your application coordinate to distribute the jobs amongst themselves.

NOTE Quartz.NET is based on a similar Java library called Quartz Scheduler. When looking for information on Quartz.NET be sure you're looking at the correct Quartz!

Quartz.NET is based around four main concepts:

- *Jobs*. These are the background tasks that implement your logic.
- *Triggers*. These control *when* a job will run based on a schedule, such as "every 5 minutes", or "every second Tuesday". A job can have multiple triggers.
- *Job Factory*. The job factory is responsible for creating instances of your jobs. Quartz.NET integrates with ASP.NET Core's DI container, so you can use DI in your job classes.
- *Scheduler*. The Quartz.NET scheduler keeps track of the triggers in your application, creates job using the Job Factory, and runs your jobs. The scheduler typically runs as an `IHostedService` for the lifetime of your app.

Background services versus Cron Jobs

It's common to use cron jobs to run tasks on a schedule on linux and Windows has similar functionality called Scheduled Tasks. These are used to periodically run an application or script file, which is typically a short-lived task.

In contrast, .NET Core apps using background services are designed to be long-lived, even if they are only used to run tasks on a schedule. This allows your application to do things like adjust its schedule as required or perform optimizations. In addition, being long-lived means your app doesn't have to just run tasks on a schedule. It can respond to ad-hoc events, such as events in a message queue for example.

Of course, if you don't need those capabilities, and would rather not have a long-running application, you can use .NET Core in combination with cron jobs. You could create a simple .NET console app which runs your task and then shuts down, and could schedule it to execute periodically as a cron job. The choice is yours!

In this section I'll show how to install Quartz.NET and configure a background service to run on a schedule. I'll then show how to enable clustering, so that you can run multiple instances of your application and distribute the jobs between them.

22.3.1 Installing Quartz.NET in an ASP.NET Core application

In this section I show how to install the Quartz.NET scheduler into an ASP.NET Core application. Quartz.NET can be installed in any .NET Core application, so you can add it to an ASP.NET Core application or a worker service, depending on your requirements. Quartz.NET will run in the background in the same way as the `IHostedService` implementations do. In fact, Quartz.NET uses the `IHostedService` abstractions to schedule and run jobs.

DEFINITION A *job* in Quartz.NET is a task to be executed which implements the `IJob` interface. It is where you define the logic of your tasks to execute.

In this section you'll see how to install Quartz.NET into a worker service. You'll install the necessary dependencies and configure the Quartz.NET scheduler to run as a background service in a worker service app. In section 22.3.2 we'll convert the exchange-rate downloader task from section 22.1 to a Quartz.NET `IJob` and configure triggers to run on a schedule.

> **NOTE** The instructions in this section can be used to install Quartz.NET into either a worker service or a full ASP.NET Core application. The only difference is whether you use the ConfigueServices() method in Program.cs or Startup.cs, respectively.

To install Quartz.NET:

1. Install the Quartz.AspNetCore NuGet package in your project by running `dotnet add package Quartz.AspNetCore`, by using the NuGet explorer in Visual Studio, or by adding a `<PackageReference>` element to your project file as shown below

```
<PackageReference Include="Quartz.AspNetCore" Version="3.1.0" />
```

2. Add the Quartz.NET `IHostedService` scheduler by calling `AddQuartzServer()` on the `IServiceCollection` in `ConfigureServices`, as shown below. Set `WaitForJobsToComplete=true` so that your app will wait for any jobs in progress to finish when shutting down

```
services.AddQuartzServer(q => q.WaitForJobsToComplete = true);
```

3. Configure the required Quartz.NET services in `ConfigureServices`. The example in the following listing configures the Quartz.NET job factory to retrieve job implementations from a scoped DI container, and adds a required service.

Listing 22.8 Configuring Quartz.NET in a ConfigureServices

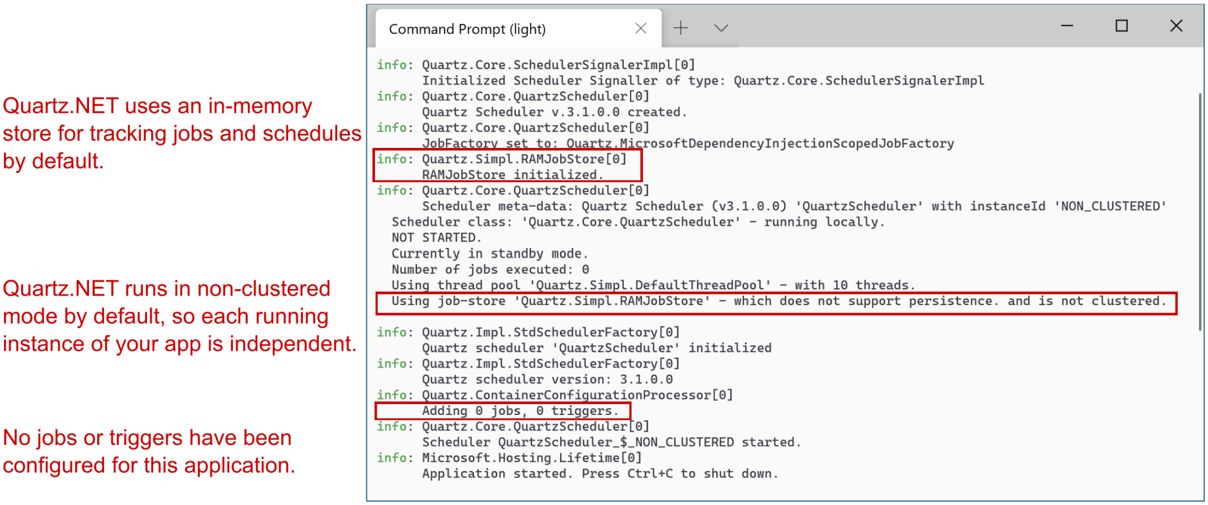
```
public void ConfigureServices(IService collection)                  #A
{
    services.AddQuartz(q =>                                         #B
    {
        q.UseMicrosoftDependencyInjectionScopedJobFactory();        #C
        q.UseSimpleTypeLoader();                                    #D
    });

    services.AddQuartzServer(q => q.WaitForJobsToComplete = true);  #E
}
```

#A Add Quartz.NET in Startup.cs for ASP.NET Core apps or in Program.cs for worker services
#B Register Quartz.NET services with the DI container
#C Configure Quartz.NET to load jobs from a scoped DI container
#D Required configuration for Quartz.NET internals
#E Add the Quartz.NET IHostedService that runs the Quartz.NET scheduler

This configuration registers all Quartz.NET's required components, so you can now run your application, using `dotnet run` or by pressing F5 in Visual Studio. When your app starts, the

Quartz.NET `IHostedService` starts its scheduler, as shown in figure 22.4. We haven't configured any jobs to run yet, so the scheduler doesn't have anything to schedule yet.



```
info: Quartz.Core.SchedulerSignalerImpl[0]
      Initialized Scheduler Signaller of type: Quartz.Core.SchedulerSignalerImpl
info: Quartz.Core.QuartzScheduler[0]
      Quartz Scheduler v.3.1.0.0 created.
info: Quartz.Core.QuartzScheduler[0]
      JobFactory set to: Quartz.MicrosoftDependencyInjectionScopedJobFactory
info: Quartz.Simpl.RAMJobStore[0]
      RAMJobStore initialized.
info: Quartz.Core.QuartzScheduler[0]
      Scheduler meta-data: Quartz Scheduler (v3.1.0.0) 'QuartzScheduler' with instanceId 'NON_CLUSTERED'
  Scheduler class: 'Quartz.Core.QuartzScheduler' - running locally.
  NOT STARTED.
  Currently in standby mode.
  Number of jobs executed: 0
  Using thread pool 'Quartz.Simpl.DefaultThreadPool' - with 10 threads.
  Using job-store 'Quartz.Simpl.RAMJobStore' - which does not support persistence. and is not clustered.

info: Quartz.Impl.StdSchedulerFactory[0]
      Quartz scheduler 'QuartzScheduler' initialized
info: Quartz.Impl.StdSchedulerFactory[0]
      Quartz scheduler version: 3.1.0.0
info: Quartz.ContainerConfigurationProcessor[0]
      Adding 0 jobs, 0 triggers.
info: Quartz.Core.QuartzScheduler[0]
      Scheduler QuartzScheduler_$_NON_CLUSTERED started.
info: Microsoft.Hosting.Lifetime[0]
      Application started. Press Ctrl+C to shut down.
```

Quartz.NET uses an in-memory store for tracking jobs and schedules by default.

Quartz.NET runs in non-clustered mode by default, so each running instance of your app is independent.

No jobs or triggers have been configured for this application.

Figure 22.4 The Quartz.NET scheduler starts on app startup and logs its configuration. The default configuration stores the list of jobs and their schedules in memory and runs in a non-clustered state. In this example you can see that no jobs or triggers have been registered, so the scheduler has nothing to schedule yet.

> **TIP** **Running your application *before* you've added any jobs is a good practice to check that you have installed and configure Quartz.NET correctly before you get to more advanced configuration.**

A job scheduler without any jobs to schedule isn't a lot of use, so in the next section we'll create a job and add a trigger for it to run on a timer.

22.3.2 Configuring a job to run on a schedule with Quartz.NET

In section 22.1 we created an `IHostedService` that downloads exchange rates from a remote service and saves the results to a database using EF Core. In this section you'll see how you can create a similar Quartz.NET `IJob` and configure it to run on a schedule.

The following listing shows an implementation of `IJob` which downloads the latest exchange rates from a remote API using a typed client, `ExchangeRatesClient`. The results are then saved using an EF Core `DbContext`, `AppDbContext`.

Listing 22.9 A Quartz.NET IJob for downloading and saving exchange rates

```
public class UpdateExchangeRatesJob : IJob                          #A
{
    private readonly ILogger<UpdateExchangeRatesJob> _logger;       #B
    private readonly ExchangeRatesClient _typedClient;              #B
    private readonly AppDbContext _dbContext;                           #B
    public UpdateExchangeRatesJob(                                      #B
        ILogger<UpdateExchangeRatesJob> logger,                         #B
        ExchangeRatesClient typedClient,                                #B
        AppDbContext dbContext)                                         #B
    {                                                                   #B
        _logger = logger;                                               #B
        _typedClient = typedClient;                                     #B
        _dbContext = dbContext;                                         #B
    }                                                                   #B

    public async Task Execute(IJobExecutionContext context)             #C
    {
        _logger.LogInformation("Fetching latest rates");

        var latestRates = await _typedClient.GetLatestRatesAsync();     #D

        _dbContext.Add(latestRates);                                    #E
        await _dbContext.SaveChangesAsync();                            #E

        _logger.LogInformation("Latest rates updated");
    }
}
```

#A Quartz.NET jobs must implement the IJob interface
#B You can use standard dependency injection to inject any dependencies
#C IJob requires you implement a single asynchronous method, Execute
#D Download the rates from the remote API
#E Save the rates to the database

Functionally, the `IJob` in the previous listing is doing a similar task to the `BackgroundService` implementation I provided in listing 22.4, with a few notable exceptions:

- *The* `IJob` *only defines the task to execute, it doesn't define timing information*. In the `BackgroundService` implementation, we also had to control how often the task was executed.
- *A new* `IJob` *instance is created every time the job is executed*. In contrast, the `BackgroundService` implementation is only created once and its `Execute` method is only invoked once.
- *We can inject scoped dependencies directly into the* `IJob` *implementation*. To use scoped dependencies in the `IHostedService` implementation, we had to manually create our own scope, and use service location to load dependencies. Quartz.NET takes care of that for us, allowing us to use pure constructor injection. Every time the job is executed, a new scope is created and is used to create a new instance of your `IJob`.

The `IJob` defines *what* to execute, but it doesn't define *when* to execute it. For that, Quartz.NET uses *triggers*. Triggers can be used to define arbitrarily complex blocks of time during which a job should be executed. For example, you can specify start and end times, how many times to repeat, and blocks of time when a job should or shouldn't run (such as only 9am-5pm, Monday-Friday).

In the following listing, we register the `UpdateExchangeRatesJob` with the DI container using the `AddJob<T>()` method and provide a unique name to identify the job. We also configure a trigger which fires immediately, and then every 5 minutes, until the application shuts down.

Listing 22.10 Configuring a Quartz.NET IJob and trigger

```
public void ConfigureServices(IService collection)
{
    services.AddQuartz(q =>
    {
        q.UseMicrosoftDependencyInjectionScopedJobFactory();
        q.UseSimpleTypeLoader();

        var jobKey = new JobKey("Update exchange rates");           #A
        q.AddJob<UpdateExchangeRatesJob>(opts =>                    #B
            opts.WithIdentity(jobKey));                             #B

        q.AddTrigger(opts => opts                                   #C
            .ForJob(jobKey)                                         #C
            .WithIdentity(jobKey.Name + " trigger")                 #D
            .StartNow()                                             #E
            .WithSimpleSchedule(x => x                              #F
                .WithInterval(TimeSpan.FromMinutes(5))              #F
                .RepeatForever())                                   #F
        );
    });

    services.AddQuartzServer(q => q.WaitForJobsToComplete = true);
}
```

#A Create a unique key for the job, used to associate it with a trigger
#B Add the IJob to the DI container, and associate with the job key
#C Register a trigger for the IJob via the job key
#D Provide a unique name for the trigger for use in logging and in clustered scenarios
#E Fire the trigger as soon as the Quartz.NET scheduler runs on app startup
#F Fire the trigger every five minutes, until the app shuts down.

Simple triggers like the schedule defined above are common, but you can also achieve more complex configurations using other schedules. For example, the following configuration would configure a trigger to fire every week, on a Friday, at 5:30pm:

```
q.AddTrigger(opts => opts
    .ForJob(jobKey)
    .WithIdentity("Update exchange rates trigger")
    .WithSchedule(CronScheduleBuilder
        .WeeklyOnDayAndHourAndMinute(DayOfWeek.Friday, 17, 30))
```

You can configure a wide array of time and calendar-based triggers with Quartz.NET. You can also control how Quartz.NET handles "missed triggers"—that is, triggers that should have fired, but your app wasn't running at the time. For a detailed description of the trigger configuration options and more examples, see the Quartz.NET documentation at [www.quartz-scheduler.net/documentation/.](www.quartz-scheduler.net/documentation/)

> **TIP** A common problem people run into with long running jobs is that Quartz.NET will keep starting new instances of the job when a trigger fires, even though it's already running! To avoid that, tell Quartz.NET to not start another instance by decorating your `IJob` implementation with the `[DisallowConcurrentExecution]` attribute.

The ability to configure advanced schedules, simple use of dependency injection in background tasks, and the separation of jobs from triggers, is reason enough for me to recommend Quartz.NET as soon as you have anything more than the most basic background service needs. However, the real tipping point is when you need to scale your application for redundancy or performance reasons—that's when Quartz.NET's clustering capabilities make it shine.

22.3.3 Using clustering to add redundancy and to your background tasks

In this section you'll learn how to configure Quartz.NET to persist its configuration to a database. This is a necessary step that enables clustering, so that multiple instances of your application can coordinate to run your Quartz.NET jobs.

As your applications become more popular, you may find you need to run more instances of your app to handle the traffic they receive. If you keep your ASP.NET Core applications stateless, then the process of scaling is relatively simple: the more applications you have, the more traffic you can handle, everything else being equal.

However, scaling applications that use `IHostedService` to run background tasks might *not* be as simple. For example, imagine your application includes the `BackgroundService` that we created in section 22.1.2, which saves exchange rates to the database every 5 minutes. When you're running a single instance of your app, the task runs every 5 minutes as expected.

But what happens if you scale your application, and run 10 instances of it? Every one of those applications will be running the `BackgroundService`, and they'll *all* be updating every 5 minutes from the time each instance started!

One option would be to move the `BackgroundService` to a separate worker service app. You could then continue to scale your ASP.NET Core application to handle the traffic as required but deploy a single instance of the worker service. As only a single instance of the `BackgroundService` would be running, the exchange rates would be updated on the correct schedule again.

> **TIP** Differing scaling requirements, as in this example, are one of the best reasons for splitting up bigger apps into smaller "microservices". Breaking up an app like this has a maintenance overhead, however, so think about the tradeoffs if you take this route. For more on this tradeoff, I recommend *Microservices in .NET Core* by Christian Horsdal Gammelgaard (Manning, 2020)

However, if you take this route, you add a hard limitation that you can only *ever* have a single instance of your worker service. If your need to run more instances of your worker service to handle additional load, you'll be stuck.

An alternative option to enforcing a single service is to use *clustering*. Clustering allows you to run multiple instances of your application, and tasks are distributed between all the instances of your application. Quartz.NET achieves clustering by using a database as a backing store. When a trigger indicates a job needs to execute, the Quartz.NET schedulers in each app attempt to obtain a lock to execute the job, as shown in figure 22.5. Only a single app can be successful, ensuring that a single app handles the trigger for the `IJob`.

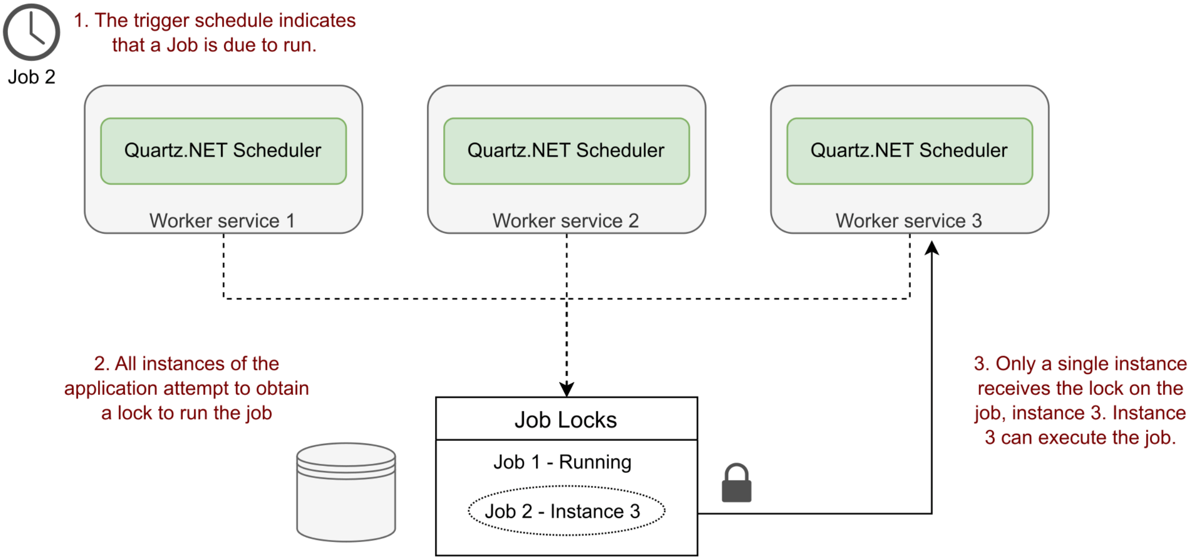

1. The trigger schedule indicates that a Job is due to run.
Job 2
Quartz.NET Scheduler
Worker service 1
Quartz.NET Scheduler
Worker service 2
Quartz.NET Scheduler
Worker service 3
2. All instances of the application attempt to obtain a lock to run the job
Job Locks
Job 1 - Running
Job 2 - Instance 3
3. Only a single instance receives the lock on the job, instance 3. Instance 3 can execute the job.

Figure 22.5 Using clustering with Quartz.NET allows horizontal scaling. Quartz.NET uses a database as a backing store, ensuring that only a single instance of the application handles a trigger at a time. This makes it possible to run multiple instances of your application to meet scalability requirements.

Quartz.NET relies on a persistent database for its clustering functionality. Quartz.NET stores descriptions of the jobs and triggers in the database, including when the trigger last fired for example. It’s the “locking” features of the database that ensure only a single application can execute a task at a time.

> **TIP** You can enable persistence without enabling clustering. This allows the Quartz.NET scheduler to “catch up” with missed triggers.

The following listing shows how to enable persistence for Quartz.NET, and, additionally, how to enable clustering. The example below stores data in an MS SQLServer (or LocalDB) server, but Quartz.NET supports many other databases. The example below uses the recommended values for enabling clustering and persistence as outlined in the documentation.[104]

Listing 22.11 Enabling persistence and clustering for Quartz.NET

```
public void ConfigureServices(IService collection)                  #A
{
    var connectionString = Configuration                            #B
        .GetConnectionString("DefaultConnection");                  #B

    services.AddQuartz(q =>
    {
        q.SchedulerId = "AUTO";                                     #C

        q.UseMicrosoftDependencyInjectionScopedJobFactory();
        q.UseSimpleTypeLoader();

        q.UsePersistentStore(s =>                                   #D
        {
           s.UseSqlServer(connectionString);                        #E
           s.UseClustering();                                       #F
           s.UseProperties = true;                                  #G
           s.UseJsonSerializer();                                   #G
        });

        var jobKey = new JobKey("Update exchange rates");
        q.AddJob<UpdateExchangeRatesJob>(opts =>
            opts.WithIdentity(jobKey));

        q.AddTrigger(opts => opts
            .ForJob(jobKey)
            .WithIdentity(jobKey.Name + " trigger")
            .StartNow()
            .WithSimpleSchedule(x => x
                .WithInterval(TimeSpan.FromMinutes(5))
                .RepeatForever())
        );
    });

    services.AddQuartzServer(q => q.WaitForJobsToComplete = true);
}
```

#A Configuration is identical for both ASP.NET Core apps and worker services
#B Obtain the connection string for your database from configuration
#C Each instance of your app must have a unique SchedulerId. AUTO takes care of this for you
#D Enable database persistence for the Quartz.NET scheduler data
#E Store the scheduler data in a SQLServer (or LocalDb) database
#F Enables clustering between multiple instances of your app

[104] The Quartz.NET documentation discusses many configuration setting controls for persistence (https://www.quartz-scheduler.net/documentation/quartz-3.x/tutorial/job-stores.html).

#G Adds the recommended configuration for job persistence

With this configuration, Quartz.NET stores a list of jobs and triggers in the database and uses database locking to ensure only a single instance of your app "handles" a trigger and runs the associated job.

> **NOTE** SQLite doesn't support the database locking primitives required for clustering. You can use SQLite as a persistence store, but you won't be able to use clustering.

Quartz.NET stores data in your database, but it doesn't attempt to create the tables it uses itself. Instead, you must manually add the required tables. Quartz.NET provides SQL scripts for all of the supported database server types on GitHub, including MS SQL Server, SQLite, PostgreSQL, MySQL, and many more: https://github.com/quartznet/quartznet/tree/master/database/tables

> **TIP** If you're using EF Core migrations to manage your database, I suggest using them even for "ad hoc" scripts like these. In the code sample associated with this chapter, you can see a migration that creates the required tables using the Quartz.NET scripts.

Clustering is one of those advanced features that is only necessary as you start to scale your application, but it's an important tool to have in your belt. It gives you the ability to safely scale your services as you add more jobs. There are some important things to bear in mind however, so I suggest reading through the warnings in the Quartz.NET documentation https://www.quartz-scheduler.net/documentation/quartz-3.x/tutorial/advanced-enterprise-features.html.

That brings us to the end of this chapter on background services. In the final chapter of this book, I'll describe an important aspect of web development which, sometimes despite the best of intentions, is often left until last: testing. You'll learn how to write simple unit tests for your classes, how to design for testability, and how to build integration tests that test your whole app.

22.4 Summary

- You can use the `IHostedService` interface to run tasks in the background of your ASP.NET Core apps. Call `AddHostedSerice<T>()` to add an implementation `T` to the DI container. `IHostedService` is useful for implementing long-running tasks.
- Typically, you should derive from `BackgroundService` to create an `IHostedService`, as this implements best-practices required for long-running tasks. You must override a single method, `ExecuteAsync`, which is called when your app starts. You should run your tasks within this method until the provided `CancellationToken` indicates the app is shutting down.
- You can manually create DI scopes using `IServiceProvider.CreateScope()`. This is useful for accessing *scoped* lifetime services from within a *singleton* lifetime

component, for example from an IHostedService implementation.

- A *worker service* is a .NET Core application that uses the generic IHost but doesn't include the ASP.NET Core libraries for handling HTTP requests. They generally have a smaller memory and disk footprint than the ASP.NET Core equivalent.
- Worker services use the same logging, configuration, and dependency injection systems as ASP.NET Core apps. However, they don't use the Startup.cs file, so you must configure your DI services in IHostBuilder.ConfigureServices().
- To run a worker service or ASP.NET Core app as a Windows Service, add the Microsoft.Extensions.Hosting.WindowsServices NuGet package, and call AddWindowsService() on IHostBuilder. You can install and manage your app with the Windows sc utility.
- To install a Linux systemd daemon, add the Microsoft.Extensions.Hosting.Systemd NuGet package, and call AddSystemd() on IHostBuilder. Both the Systemd and Windows Service integration packages do nothing when running the application as a console app, which is great for testing your app.
- Quartz.NET runs jobs based on triggers using advanced schedules. It builds on the IHostedService implementation to add extra features and scalability. You can install Quartz by adding the Quartz.AspNetCore NuGet package, and calling AddQuartz() and AddQuartzServer() in ConfigureServices().
- You can create a Quartz.NET job by implementing the IJob interface. This requires implementing a single method, Execute. You can enable DI for the job by calling UseMicrosoftDependencyInjectionScopedJobFactory in AddQuartz(). This allows you to directly inject scoped (or transient) services into your job, without having to create your own scopes.
- You must register your job, T, with DI by calling AddJob<T>() and providing a JobKey name for the job. You can add an associated trigger by calling AddTrigger() and providing the JobKey. Triggers have a wide variety of schedules available for controlling when a job should be executed.
- By default, triggers will continue to spawn new instances of a job as often as necessary. For long running jobs scheduled with a short interval that will result in many instances of your app running concurrently. If you only want a trigger to execute a job when an instance is not already running, decorate your job with the [DisallowConcurrentExecution] attribute.
- Quartz.NET supports database persistence for storing when triggers have executed. To enable persistence, call UsePersistentStore() in your AddQuartz() configuration method, and configure a database, using UseSqlServer() for example. With persistence, Quartz.NET can persist details about jobs and triggers between application restarts.
- Enabling persistence also allows you to use clustering. Clustering enables multiple apps using Quartz.NET to coordinate, so that jobs are spread across multiple schedulers. To enable clustering, first enable database persistence, and then call UseClustering().

23

Testing your application

This chapter covers

- **Creating unit test projects with xUnit**
- **Writing unit tests for custom middleware and API controllers**
- **Using the Test Host package to write integration tests**
- **Testing your real application's behavior with** `WebApplicationFactory`
- **Testing code dependent on EF Core with the in-memory database provider**

When I first started programming, I didn't understand the benefits of automated testing. It involved writing so much more code—wouldn't it be more productive to be working on new features instead? It was only when my projects started getting bigger that I appreciated the advantages. Instead of having to manually run my app and test each scenario, I could press Play on a suite of tests and have my code tested for me automatically.

Testing is universally accepted as good practice, but how it fits into your development process can often turn into a religious debate. How many tests do you need? Is anything less than 100% coverage of your code base adequate? Should you write tests before, during, or after the main code?

This chapter won't address any of those questions. Instead, I focus on the *mechanics* of testing an ASP.NET Core application. I show you how to use isolated *unit tests* to verify the behavior of your services in isolation, how to test your API controllers and custom middleware, and how to create *integration tests* that exercise multiple components of your application at once. Finally, I touch on the EF Core in-memory provider, a feature that lets you test components that depend on a `DbContext` without having to connect to a database.

TIP For a broader discussion around testing, or if you're brand new to unit testing, see *The Art of Unit Testing, Third Edition* by Roy Osherove (Manning, 2021). Alternatively, for an in-depth look at testing with xUnit in .NET Core, see *.NET Core in Action* by Dustin Metzgar (Manning, 2018).

In section 23.1, I introduce the .NET SDK testing framework, and how you can use it to create unit testing apps. I describe the components involved, including the testing SDK and the testing frameworks themselves, like xUnit and MSTest. Finally, I cover some of the terminology I use throughout the chapter.

In section 23.2, you'll create your first test project. You'll be testing a simple class at this stage, but it'll allow you to come to grips with the various testing concepts involved. You'll create several tests using the xUnit test framework, make assertions about the behavior of your services, and execute the test project both from Visual Studio and the command line.

In sections 23.3 and 23.4, we'll look at how to test common features of your ASP.NET Core apps: API controllers and custom middleware. I show you how to write isolated unit tests for both, much like you would any other service, as well as the tripping points to look out for.

To ensure components work correctly, it's important to test them in isolation. But you also need to test they work correctly in a middleware pipeline. ASP.NET Core provides a handy Test Host package that lets you easily write these *integration tests* for your components. You can even go one step further with the `WebApplicationFactory` helper class, and test that your *app* is working correctly. In section 23.5, you'll see how to use `WebApplicationFactory` to simulate requests to your application, and to verify it generates the correct response.

In the final section of this chapter, I demonstrate how to use the SQLite database provider for EF Core with an in-memory database. You can use this provider to test services that depend on an EF Core `DbContext`, without having to use a real database. That avoids the pain of having a known database infrastructure, of resetting the database between tests, and of different people having slightly different database configurations.

Let's start by looking at the overall testing landscape for ASP.NET Core, the options available to you, and the components involved.

23.1 An introduction to testing in ASP.NET Core

In this section you'll learn about the basics of testing in ASP.NET Core. You'll learn about the different types of tests you can write, such as unit tests and integration tests, and why you should write both types. Finally, you'll see how testing fits into ASP.NET Core.

If you have experience building apps with the full .NET Framework or mobile apps with Xamarin, then you might have some experience with unit testing frameworks. If you were building apps in Visual Studio, exactly how to create a test project would vary between testing frameworks (xUnit, NUnit, MSTest), and running the tests in Visual Studio often required installing a plugin. Similarly, running tests from the command line varied between frameworks.

With the .NET Core SDK, testing in ASP.NET Core and .NET Core is now a first-class citizen, on a par with building, restoring packages, and running your application. Just as you can run `dotnet build` to build a project, or `dotnet run` to execute it, you can use `dotnet test` to execute the tests in a test project, regardless of the testing framework used.

The `dotnet test` command uses the underlying .NET Core SDK to execute the tests for a given project. This is exactly the same as when you run your tests using the Visual Studio test runner, so whichever approach you prefer, the results are the same.

Test projects are console apps that contain a number of *tests*. A test is typically a method that evaluates whether a given class in your app behaves as expected. The test project will typically have dependencies on at least three components:

- The .NET Test SDK
- A unit testing framework, for example xUnit, NUnit, Fixie, or MSTest
- A test-runner adapter for your chosen testing framework, so that you can execute your tests by calling `dotnet test`

These dependencies are normal NuGet packages that you can add to a project, but they allow you to hook in to the `dotnet test` command and the Visual Studio test runner. You'll see an example csproj from a test app in the next section.

Typically, a test consists of a method that runs a small piece of your app in isolation and checks that it has the desired behavior. If you were testing a `Calculator` class, you might have a test that checks that passing the values `1` and `2` to the `Add()` method returns the expected result, `3`.

You can write lots of small, isolated tests like this for your app's classes to verify that each component is working correctly, independent of any other components. Small isolated tests like these are called *unit tests*.

Using the ASP.NET Core framework, you can build apps that you can easily unit test; you can test some aspects of your controllers in isolation from your action filters and model binding. This is because the framework:

- Avoids static types.
- Uses interfaces instead of concrete implementations.
- Has a highly modular architecture; you can test your controllers in isolation from your action filters and model binding, for example.

But just because all your components work correctly independently, doesn't mean they'll work when you put them together. For that, you need *integration tests*, which test the interaction between multiple components.

The definition of an integration test is another somewhat contentious issue, but I think of integration tests as any time you're testing multiple components together, or you're testing large vertical slices of your app. Testing a user manager class that can save values to a database, or testing that a request made to a health-check endpoint returns the expected response, for example. Integration tests don't necessarily include the *entire* app, but they definitely use more components than unit tests.

NOTE I don't cover UI tests which, for example, interact with a browser to provide true end-to-end automated testing. Selenium (www.seleniumhq.org) and Cypress (www.cypress.io) are two of the best known tools for UI testing.

ASP.NET Core has a couple of tricks up its sleeve when it comes to integration testing. You can use the Test Host package to run an in-process ASP.NET Core server, which you can send requests to and inspect the responses. This saves you from the orchestration headache of trying to spin up a web server on a different process, making sure ports are available and so on, but still allowing you to exercise your whole app.

At the other end of the scale, the EF Core SQLite in-memory database provider lets you isolate your tests from the database. Interacting and configuring a database is often one of the hardest aspects of automating tests, so this provider lets you sidestep the issue entirely. You'll see how to use it in section 23.6.

The easiest way to get to grips with testing is to give it a try, so in the next section, you'll create your first test project and use it to write unit tests for a simple custom service.

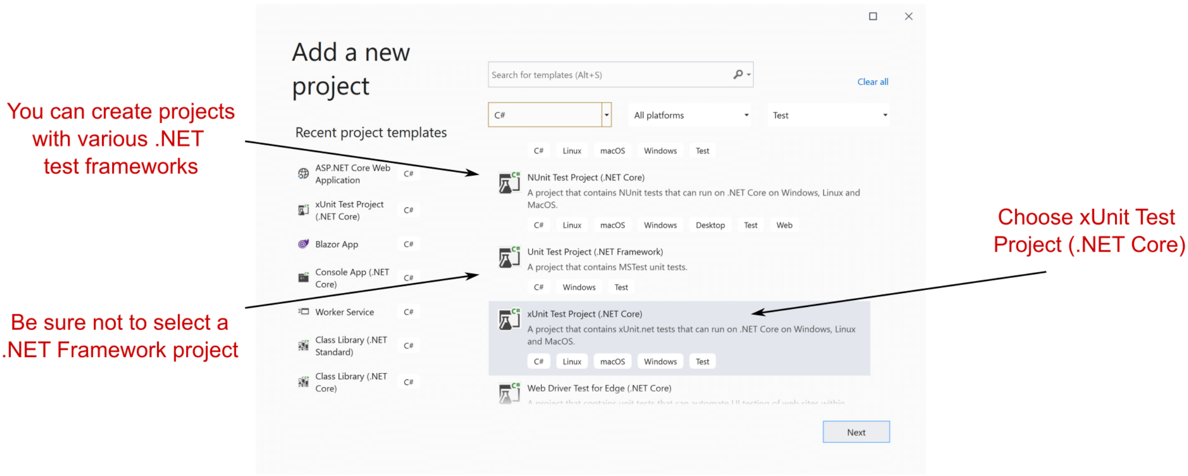
23.2 Unit testing with xUnit

In this section, you'll learn how to create unit test projects, how to reference classes in other projects, and how to run tests with Visual Studio or the .NET CLI. You'll create a test project and use it to test the behavior of a basic currency converter service. You'll write some simple unit tests that check that the service returns the expected results, and that it throws exceptions when you expect it to.

As I described in section 23.1, to create a test project you need to use a testing framework. You have many options, such as NUnit or MSTest, but the most commonly used test framework with .NET Core is xUnit (https://xunit.github.io/). The ASP.NET Core framework project itself uses xUnit as its testing framework, so it's become somewhat of a convention. If you're familiar with a different testing framework, then feel free to use that instead.

23.2.1 Creating your first test project

Visual Studio includes a template to create a .NET Core xUnit test project, as shown in figure 23.1. Choose File > New Project and choose xUnit Test Project (.NET Core) from the New Project dialog. Alternatively, you could choose MSTest Test Project (.NET Core) or NUnit Test Project (.NET Core) if you're more comfortable with those frameworks.


Add a new project
Search for templates (Alt+S)
Clear all
C#
All platforms
Test
Recent project templates
ASP.NET Core Web Application C#
xUnit Test Project (.NET Core) C#
Blazor App C#
Console App (.NET Core) C#
Worker Service C#
Class Library (.NET Standard) C#
Class Library (.NET Core) C#
C# Linux macOS Windows Test
NUnit Test Project (.NET Core)
A project that contains NUnit tests that can run on .NET Core on Windows, Linux and MacOS.
C# Linux macOS Windows Desktop Test Web
Unit Test Project (.NET Framework)
A project that contains MSTest unit tests.
C# Windows Test
xUnit Test Project (.NET Core)
A project that contains xUnit.net tests that can run on .NET Core on Windows, Linux and MacOS.
C# Linux macOS Windows Test
Web Driver Test for Edge (.NET Core)
Next

You can create projects with various .NET test frameworks

Be sure not to select a .NET Framework project

Choose xUnit Test Project (.NET Core)

Figure 23.1 The New Project Dialog in Visual Studio. Choose xUnit Test Project to create an xUnit project or choose Unit Test Project to create an MSTest project.

Alternatively, if you’re not using Visual Studio, you can create a similar template using the .NET CLI with

```
dotnet new xunit
```

Whether you use Visual Studio or the .NET CLI, the template creates a console project and adds the required testing NuGet packages to your csproj file, as shown in the following listing. If you chose to create an MSTest (or other framework) test project, then the xUnit and xUnit runner packages would be replaced with packages appropriate to your testing framework of choice.

Listing 23.1 The csproj file for an xUnit test project

```
<Project Sdk="Microsoft.NET.Sdk">      #A
  <PropertyGroup>                      #A
    <TargetFramework>netcoreapp3.1</TargetFramework>    #A
    <IsPackable>false</IsPackable>
  </PropertyGroup>
  <ItemGroup>
    <PackageReference
        Include="Microsoft.NET.Test.Sdk" Version="16.5.0" />      #B
    <PackageReference Include="xunit" Version="2.4.0" />      #C
    <PackageReference
        Include="xunit.runner.visualstudio" Version="2.4.0" />      #D
    <PackageReference Include="coverlet.collector" Version="1.2.0" />     #E
  </ItemGroup>
</Project>
```

#A The test project is a standard .NET Core project targeting .NET Core 3.1.
#B The .NET Test SDK, required by all test projects

#C The xUnit test framework
#D The xUnit test adapter for the .NET Test SDK
#E An optional package that collects metrics about how much of your code base is covered by tests

In addition to the NuGet packages, the template includes a single example unit test. This doesn't *do* anything, but it's a valid xUnit test all the same, as shown in the following listing. In xUnit, a test is a method on a public class, decorated with a `[Fact]` attribute.

Listing 23.2 An example xUnit unit test, created by the default template

```
public class UnitTest1          #A
{
    [Fact]                     #B
    public void Test1()        #C
    {
    }
}
```

#A xUnit tests must be in public classes.
#B The [Fact] attribute indicates the method is a test method.
#C The Fact must be public and have no parameters.

Even though this test doesn't test anything, it highlights some characteristics of xUnit `[Fact]` tests:

- Tests are denoted by the `[Fact]` attribute.
- The method should be public, with no method arguments.
- The method is `void`. It could also be an `async` method and return `Task`.
- The method resides inside a public, non-static class.

> **NOTE** **The `[Fact]` attribute, and these restrictions, are specific to the xUnit testing framework. Other frameworks will use other ways to denote test classes and have different restrictions on the classes and methods themselves.**

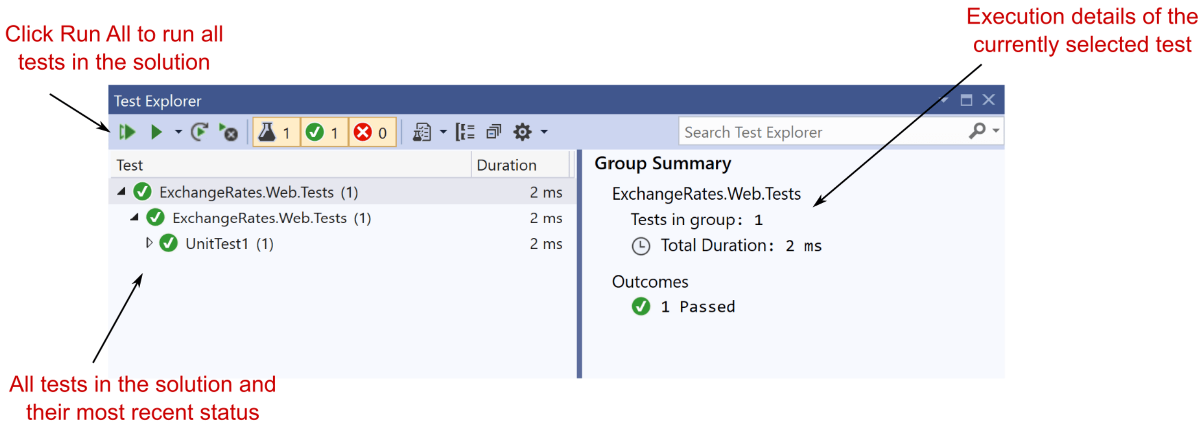
It's also worth noting that, although I said that test projects are console apps, there's no `Program` class or `static void main` method. Instead, the app looks more like a class library. This is because the test SDK automatically injects a `Program` class at build time. It's not something you have to worry about in general, but you may have issues if you try to add your own Program.cs file to your test project.[105]

Before we go any further and create some useful tests, we'll run the test project as it is, using both Visual Studio and the .NET SDK tooling, to see the expected output.

[105] This isn't a common thing to do, but I've seen it used occasionally. I describe this issue in detail, and how to fix it, at http://mng.bz/1NyQ.

23.2.2 Running tests with dotnet test

When you create a test app that uses the .NET Test SDK, you can run your tests either with Visual Studio or using the .NET CLI. In Visual Studio, you run tests by choosing Tests > Run > All Tests from the main menu, or by clicking Run All in the Test Explorer window, as shown in figure 23.2.


Click Run All to run all tests in the solution

Execution details of the currently selected test

All tests in the solution and their most recent status

Test	Duration
ExchangeRates.Web.Tests (1)	2 ms
ExchangeRates.Web.Tests (1)	2 ms
UnitTest1 (1)	2 ms

Group Summary

ExchangeRates.Web.Tests

Tests in group: 1

Total Duration: 2 ms

Outcomes

1 Passed

Figure 23.2 The Test Explorer window in Visual Studio lists all tests found in the solution, and their most recent pass/fail status. Click a test in the left-hand pane to see details about the most recent test run in the right-hand pane.

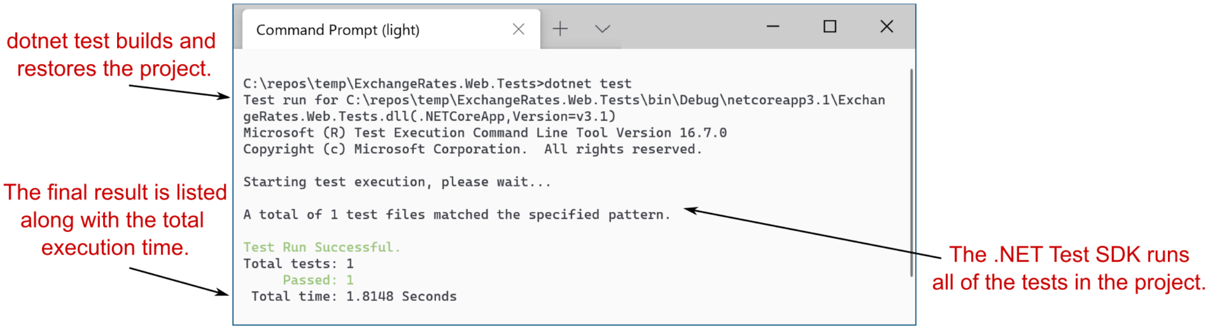
The Test Explorer window lists all the tests found in your solution and the results of each test. In xUnit, a test will pass if it doesn't throw an exception, so `Test1` passed successfully.

Alternatively, you can run your tests from the command line using the .NET CLI by running

```
dotnet test
```

from the unit test project's folder, as shown in figure 23.3.

> **NOTE** You can also run `dotnet test` from the *solution* folder. This will run all test projects referenced in the .sln solution file.



dotnet test builds and restores the project.

The final result is listed along with the total execution time.

The .NET Test SDK runs all of the tests in the project.

```
C:\repos\temp\ExchangeRates.Web.Tests>dotnet test
Test run for C:\repos\temp\ExchangeRates.Web.Tests\bin\Debug\netcoreapp3.1\Exchan
geRates.Web.Tests.dll(.NETCoreApp,Version=v3.1)
Microsoft (R) Test Execution Command Line Tool Version 16.7.0
Copyright (c) Microsoft Corporation.  All rights reserved.

Starting test execution, please wait...

A total of 1 test files matched the specified pattern.

Test Run Successful.
Total tests: 1
     Passed: 1
 Total time: 1.8148 Seconds
```

Figure 23.3 You can run tests from the command line using `dotnet test`**. This restores and builds the test project before executing all the tests in the project.**

Calling `dotnet test` runs a restore and build of your test project and then runs the tests, as you can see from the console output in figure 23.3. Under the hood, the .NET CLI calls into the same underlying infrastructure as Visual Studio does (the .NET Core SDK), so you can use whichever approach better suits your development style.

You've seen a successful test run, so it's time to replace that placeholder test with something useful. First things first, you need something to test.

23.2.3 Referencing your app from your test project

In test-driven development (TDD), you typically write your unit tests before you write the actual class you're testing, but I'm going to take a more traditional route here and create the class to test first. You'll write the tests for it afterwards.

Let's assume you've created an app called ExchangeRates.Web, which is used to convert between different currencies, and you want to add tests for it. You've added a test project to your solution as described in section 23.2.1, so your solution looks like figure 23.4.

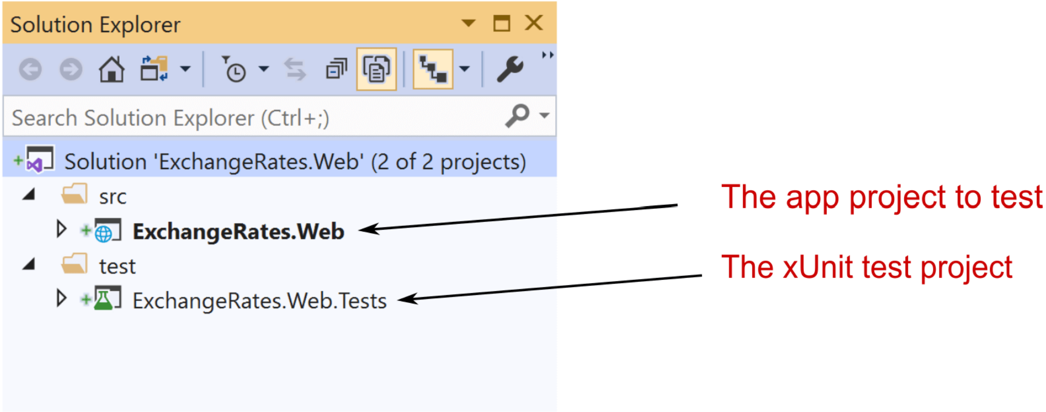
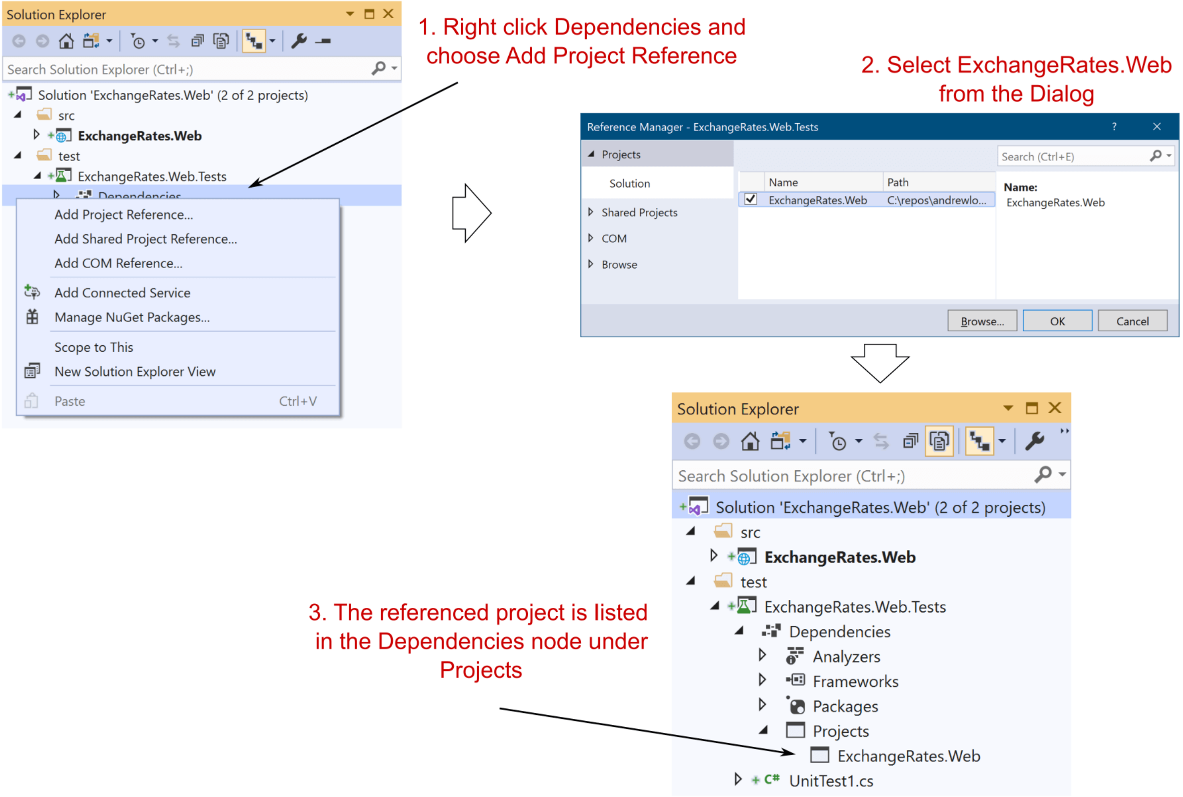


Figure 23.4 A basic solution, containing an ASP.NET Core app called ExchangeRates.Web and a test project called ExchangeRates.Web.Test.

In order for the ExchangeRates.Web.Test project to be able to test the classes in the ExchangeRates.Web project, you need to add a reference to the web project in your test project. In Visual Studio, you can do this by right-clicking the Dependencies node of your test project and choosing Add Reference, as shown in figure 23.5. You can then select the web project from the Add Reference Dialog. After adding it to your project, it shows up inside the Dependencies node, under Projects.



1. Right click Dependencies and choose Add Project Reference

2. Select ExchangeRates.Web from the Dialog

3. The referenced project is listed in the Dependencies node under Projects

Figure 23.5 To test your app project, you need to add a reference to it from the test project. Right-click the Dependencies node and choose Add Project Reference. The app project is shown referenced inside the Dependencies Node, under Projects.

Alternatively, you can edit the csproj file directly and add a `<ProjectReference>` element inside an `<ItemGroup>` element with the relative path to the referenced project's csproj file.

```
<ItemGroup>
  <ProjectReference
    Include="..\..\src\ExchangeRates.Web\ExchangeRates.Web.csproj" />
</ItemGroup>
```

Note that the path is the *relative* path. A `".."` in the path means the parent folder, so the relative path shown correctly traverses the directory structure for the solution, including both the src and test folders shown in Solution Explorer in figure 23.5.

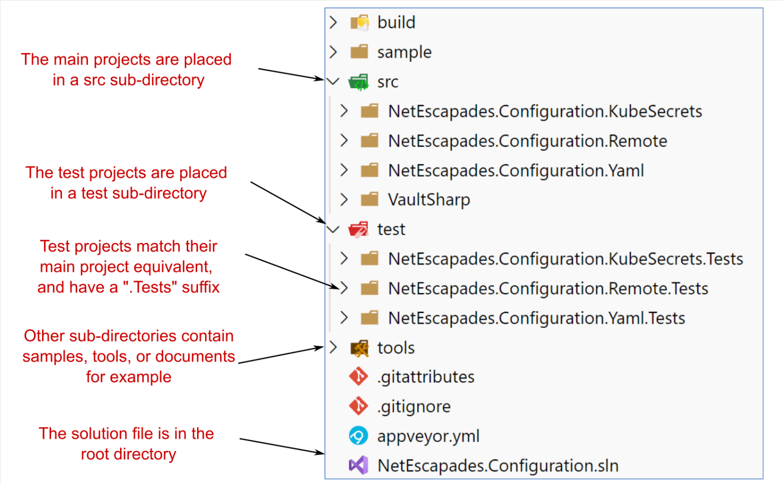
> **TIP** **Remember, you can edit the csproj file directly in Visual Studio by doubly-clicking the project in Solution Explorer.**

Common conventions for project layout

The layout and naming of projects within a solution is completely up to you, but ASP.NET Core projects have generally settled on a couple of conventions that differ slightly from the Visual Studio File New defaults. These conventions are used by the ASP.NET team on GitHub, as well as many other open source C# projects.

The following figure shows an example of these layout conventions. In summary, these are:

- The .sln solution file is in the root directory.
- The main projects are placed in a src sub-directory.
- The test projects are placed in a test or tests sub-directory.
- Each main project has a test project equivalent, named the same as the associated main project with a “.Test” or “.Tests” suffix.
- Other folders, such as samples, tools, or docs contain sample projects, tools for building the project, or documentation.



The main projects are placed in a src sub-directory
The test projects are placed in a test sub-directory
Test projects match their main project equivalent, and have a ".Tests" suffix
Other sub-directories contain samples, tools, or documents for example
The solution file is in the root directory
build
sample
src
NetEscapades.Configuration.KubeSecrets
NetEscapades.Configuration.Remote
NetEscapades.Configuration.Yaml
VaultSharp
test
NetEscapades.Configuration.KubeSecrets.Tests
NetEscapades.Configuration.Remote.Tests
NetEscapades.Configuration.Yaml.Tests
tools
.gitattributes
.gitignore
appveyor.yml
NetEscapades.Configuration.sln

Conventions around project structures have emerged in the ASP.NET Core framework libraries and open source projects on GitHub. You don’t have to follow them for your own project, but it’s worth being aware of them.

Whether or not you choose to follow these conventions is entirely up to you, but it’s good to be aware of them at least, so you can easily navigate other projects on GitHub.

Your test project is now referencing your web project, so you can write tests for classes in the web project. You’re going to be testing a simple class used for converting between currencies, as shown in the following listing.

Listing 23.3 Example `CurrencyConverter` class to convert currencies to GBP

```
public class CurrencyConverter
{
    public decimal ConvertToGbp(                                    #A
        decimal value, decimal exchangeRate, int decimalPlaces)     #A
    {
        if (exchangeRate <= 0)              #B
        {                                #B
```

```
            throw new ArgumentException(       #B
               "Exchange rate must be greater than zero",          #B
               nameof(exchangeRate));          #B
        }                         #B
        var valueInGbp = value / exchangeRate;      #C
        return decimal.Round(valueInGbp, decimalPlaces);           #D
    }
}
```

#A The ConvertToGbp method converts a value using the provided exchange rate and rounds it.
#B Guard clause, as only positive exchange rates are valid.
#C Converts the value
#D Rounds the result and returns it

This class only has a single method, `ConvertToGbp()`, which converts a `value` from one currency into GBP, given the provided `exchangeRate`. It then rounds the value to the required number of decimal places and returns it.

> **WARNING This class is only a basic implementation. In practice, you'd need to handle arithmetic overflow/underflow for large or negative values, as well as considering other edge cases. This is only for demonstration purposes!**

Imagine you want to convert 5.27 USD to GBP, and the exchange rate from GBP to USD is 1.31. If you want to round to 4 decimal places, you'd call

```
converter.ConvertToGbp(value: 5.27, exchangeRate: 1.31, decimalPlaces: 4);
```

You have your sample application, a class to test, and a test project, so it's about time you wrote some tests.

23.2.4 Adding Fact and Theory unit tests

When I write unit tests, I usually target one of three different paths through the method under test:

- *The happy path*—Where typical arguments with expected values are provided
- *The error path*—Where the arguments passed are invalid and tested for
- *Edge cases*—Where the provided arguments are right on the edge of expected values

I realize this is a broad classification, but it helps me think about the various scenarios I need to consider.[106] Let's start with the happy path, by writing a unit test that verifies that the `ConvertToGbp()` method is working as expected with typical input values.

[106] A whole other way to approach testing is property-based testing. This fascinating approach is common in functional programming communities, like F#. You can find a great introduction here https://fsharpforfunandprofit.com/posts/property-based-testing/. That post uses F#, but it is still highly accessible even if you're new to the language.

Listing 23.4 Unit test for `ConvertToGbp` using expected arguments

```
[Fact]                                                        #A
public void ConvertToGbp_ConvertsCorrectly()                  #B
{
    var converter = new CurrencyConverter();                  #C
    decimal value = 3;                                        #D
    decimal rate = 1.5m;                                      #D
    int dp = 4;                                               #D
    decimal expected = 2;                                     #E

    var actual = converter.ConvertToGbp(value, rate, dp);     #F

    Assert.Equal(expected, actual);                           #G
}
```

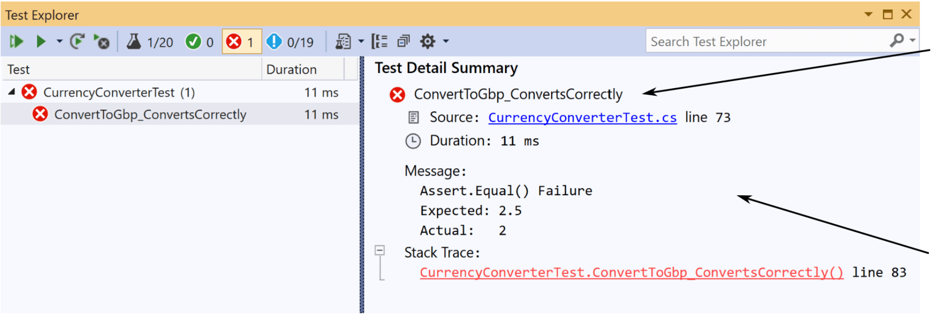
#A The [Fact] attribute marks the method as a test method.
#B You can call the test anything you like.
#C The class to test, commonly called the "system under test" (SUT)
#D The parameters of the test that will be passed to ConvertToGbp
#E The result you expect.
#F Executes the method and captures the result
#G Verifies the expected and actual values match. If they don't, this will throw an exception.

This is your first proper unit test, which has been configured using the Arrange, Act, Assert (AAA) style:

- *Arrange*—Define all the parameters and create an instance of the system (class) under test (SUT)
- *Act*—Execute the method being tested and capture the result
- *Assert*—Verify that the result of the Act stage had the expected value

Most of the code in this test is standard C#, but if you're new to testing, the `Assert` call will be unfamiliar. This is a helper class provided by xUnit for making assertions about your code. If the parameters provided to `Assert.Equal()` aren't equal, the `Equal()` call will throw an exception and fail the test. If you change the `expected` variable in listing 23.4 to be `2.5` instead of `2`, for example, and run the test, you can see that Test Explorer shows the failure in figure 23.6.

> **TIP** **Alternative assertion libraries such as FluentAssertions (https://fluentassertions.com/) and Shouldly (https://github.com/shouldly/shouldly) allow you to write your assertions in a more natural style, for example** `actual.Should().Be(expected)`**. These libraries are entirely optional, but I find they make tests more readable and error messages easier to understand.**



```
Test                                   Duration
◢ ☒ CurrencyConverterTest (1)           11 ms
    ☒ ConvertToGbp_ConvertsCorrectly    11 ms
```

```
Test Detail Summary
  ☒ ConvertToGbp_ConvertsCorrectly
    Source: CurrencyConverterTest.cs line 73
    Duration: 11 ms

  Message:
    Assert.Equal() Failure
    Expected: 2.5
    Actual:   2
  Stack Trace:
    CurrencyConverterTest.ConvertToGbp_ConvertsCorrectly() line 83
```

Failed tests are marked with a red cross

The details pane details why the test failed.

Figure 23.6 When a test fails, it's marked with a red cross in Test Explorer. Clicking the test in the left pane shows the reason for the failure in the right pane. In this case, the expected value was `2.5`, but the actual value was `2`.

> **NOTE** The names of your test class and method are used throughout the test framework to describe your test. You can customize how these are displayed in Visual Studio and in the CLI by configuring an xunit.runner.json file, as described here: https://xunit .github.io/docs/configuring-with-json.html.

In listing 23.4, you chose specific values for `value`, `exchangeRate`, and `decimalPlaces` to test the happy path. But this is only one set of values in an infinite number of possibilities, so you should probably at least test *a few* different combinations.

One way to achieve this would be to copy and paste the test multiple times, tweak the parameters, and change the test method name to make it unique. xUnit provides an alternative way to achieve the same thing without requiring so much duplication.

Instead of creating a `[Fact]` test method, you can create a `[Theory]` test method. A Theory provides a way of parameterizing your test methods, effectively taking your test method and running it multiple times with different arguments. Each set of arguments is considered a different test.

You could rewrite the `[Fact]` test in listing 23.4 to be a `[Theory]` test, as shown next. Instead of specifying the variables in the method body, pass them as parameters to the method, then decorate the method with three `[InlineData]` attributes. Each instance of the attribute provides the parameters for a single run of the test.

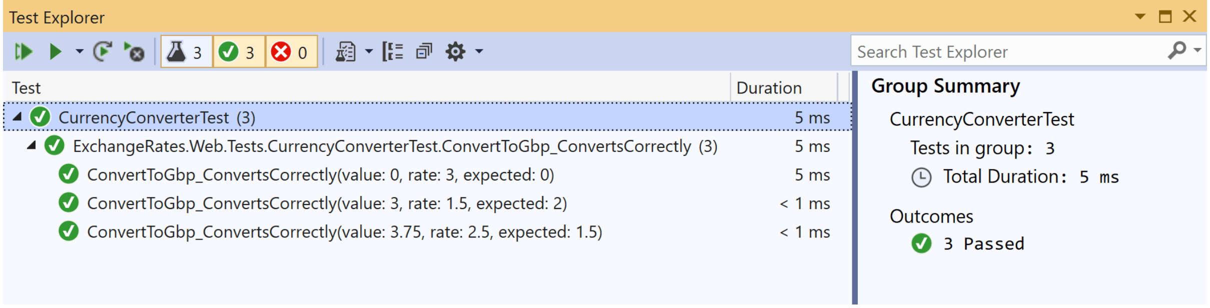
Listing 23.5 Theory test for `ConvertToGbp` testing multiple sets of values

```
[Theory]                                                    #A
[InlineData(0, 3, 0)]                                       #B
[InlineData(3, 1.5, 2)]                                     #B
[InlineData(3.75, 2.5, 1.5)]                                #B
public void ConvertToGbp_ConvertsCorrectly (                #C
    decimal value, decimal rate, decimal expected)          #C
{
    var converter = new CurrencyConverter();
    int dps = 4;
    var actual = converter.ConvertToGbp(value, rate, dps);   #D

    Assert.Equal(expected, actual);                          #E
}
```

#A Marks the method as a parameterized test
#B Each [InlineData] attribute provides all the parameters for a single run of the test method.
#C The method takes parameters, which are provided by the [InlineData] attributes.
#D Executes the system under test
#E Verifies the result

If you run this `[Theory]` test using `dotnet test` or Visual Studio, then it will show up as three separate tests, one for each set of `[InlineData]`, as shown in figure 23.7.



```
◢ ✓ CurrencyConverterTest (3)                                                          5 ms
  ◢ ✓ ExchangeRates.Web.Tests.CurrencyConverterTest.ConvertToGbp_ConvertsCorrectly (3)  5 ms
      ✓ ConvertToGbp_ConvertsCorrectly(value: 0, rate: 3, expected: 0)                 5 ms
      ✓ ConvertToGbp_ConvertsCorrectly(value: 3, rate: 1.5, expected: 2)             < 1 ms
      ✓ ConvertToGbp_ConvertsCorrectly(value: 3.75, rate: 2.5, expected: 1.5)        < 1 ms
```

```
Group Summary
  CurrencyConverterTest
    Tests in group: 3
    Total Duration: 5 ms

  Outcomes
    ✓ 3 Passed
```

Figure 23.7 Each set of parameters in an `[InlineData]` attribute for a `[Theory]` test creates a separate test run. In this example, a single `[Theory]` has three `[InlineData]` attributes, so it creates three tests, named according to the method name and the provided parameters.

`[InlineData]` isn't the only way to provide the parameters for your theory tests, though it's one of the most commonly used. You can also use a static property on your test class with the `[MemberData]` attribute, or a class itself using the `[ClassData]` attribute.[107]

You now have some tests for the happy path of the `ConvertToGbp()` method, and I even sneaked an edge case into listing 23.5 by testing the case where `value = 0`. The final concept I'll cover is testing error cases, where invalid values are passed to the method under test.

23.2.5 Testing failure conditions

A key part of unit testing is checking that the system under test handles edge cases and errors correctly. For the `CurrencyConverter`, that would mean checking how the class handles negative values, small or zero exchange rates, large values and rates, and so on.

[107] I describe how you to use the `[ClassData]` and `[MemberData]` attributes in a blog post at http://mng.bz/8ayP.

Some of these edge cases might be rare but valid cases, whereas other cases might be technically invalid. Calling `ConvertToGbp` with a negative `value` is probably valid; the converted result should be negative too. A negative exchange rate doesn't make sense conceptually, so should be considered an invalid value.

Depending on the design of the method, it's common to throw exceptions when invalid values are passed to a method. In listing 23.3 you saw that we throw an `ArgumentException` if the `exchangeRate` parameter is less than or equal to zero.

xUnit includes a variety of helpers on the `Assert` class for testing whether a method throws an exception of an expected type. You can then make further assertions on the exception, for example to test whether the exception had an expected message.

> **WARNING** **Take care not to tie your test methods too closely to the internal implementation of a method. Doing so can make your tests brittle, where trivial changes to a class break the unit tests.**

The following listing shows a `[Fact]` test to check the behavior of the `ConvertToGbp()` method when you pass it a zero `exchangeRate`. The `Assert.Throws` method takes a lambda function that describes the action to execute, which should throw an exception when run.

Listing 23.6 Using `Assert.Throws<>` to test whether a method throws an exception

```
[Fact]
public void ThrowsExceptionIfRateIsZero()
{
    var converter = new CurrencyConverter();
    const decimal value = 1;
    const decimal rate = 0;                                  #A
    const int dp = 2;
    var ex = Assert.Throws<ArgumentException>(               #B
        () => converter.ConvertToGbp(value, rate, dp));      #C

    // Further assertions on the exception thrown, ex
}
```

#A An invalid value
#B You expect an ArgumentException to be thrown.
#C The method to execute, which should throw an exception

The `Assert.Throws` method executes the lambda and catches the exception. If the exception thrown matches the expected type, the test will pass. If no exception is thrown or the exception thrown isn't of the expected type, then the `Assert.Throws` method will throw an exception and fail the test.

That brings us to the end of this introduction on unit testing with xUnit. The examples in this section described how to use the new .NET Test SDK, but we didn't cover anything specific to ASP.NET Core. In the rest of this chapter, we'll focus on testing ASP.NET Core projects specifically. We'll start by unit testing middleware.

23.3 Unit testing custom middleware

In this section you'll learn how to test custom middleware in isolation. You'll see how to test whether your middleware handled a request or whether it called the next middleware in the pipeline. You'll also see how to read the response stream for your middleware.

In chapter 19, you saw how to create custom middleware and how you could encapsulate middleware as a class with an `Invoke` function. In this section, you'll create unit tests for a simple health-check middleware, similar to the one in chapter 19. This is a basic implementation, but it demonstrates the approach you can take for more complex middleware components.

The middleware you'll be testing is shown in listing 23.7. When invoked, this middleware checks that the path starts with `/ping` and, if it does, returns a plain text "`pong`" response. If the request doesn't match, it calls the next middleware in the pipeline (the provided `RequestDelegate`).

Listing 23.7 `StatusMiddleware` to be tested, which returns a "`pong`" response

```
public class StatusMiddleware
{
    private readonly RequestDelegate _next;                     #A
    public StatusMiddleware(RequestDelegate next)               #A
    {
        _next = next;
    }
    public async Task Invoke(HttpContext context)               #B
    {
        if(context.Request.Path.StartsWithSegments("/ping"))    #C
        {                                                       #C
            context.Response.ContentType = "text/plain";        #C
            await context.Response.WriteAsync("pong");          #C
            return;                                             #C
        }                                                       #C
        await _next(context);        #D
    }
}
```

#A The RequestDelegate representing the rest of the middleware pipeline
#B Called when the middleware is executed
#C If the path starts with "/ping", a "pong" response is returned . . .
#D . . . otherwise, the next middleware in the pipeline is invoked.

In this section, you're only going to test two simple cases:

- When a request is made with a path of "`/ping`"
- When a request is made with a different path

> **WARNING** Where possible, I recommend you *don't* directly inspect paths in your middleware like this. A better approach is to use endpoint routing instead, as I discussed in chapter 19. The middleware in this section is for demonstration purposes only.

Middleware is slightly complicated to unit test because the `HttpContext` object is conceptually a *big* class. It contains all the details for the request and the response, which can mean there's a lot of surface area for your middleware to interact with. For that reason, I find unit tests tend to be tightly coupled to the middleware implementation, which is generally undesirable.

For the first test, you'll look at the case where the incoming request `Path` *doesn't* start with `/ping`. In this case, `StatusMiddleware` should leave the `HttpContext` unchanged, and should call the `RequestDelegate` provided in the constructor, which represents the next middleware in the pipeline.

You could test this behavior in several ways, but in listing 23.8 you test that the `RequestDelegate` (essentially a one-parameter function) is executed by setting a local variable to `true`. In the `Assert` at the end of the method, you verify the variable was set and therefore that the delegate was invoked. To invoke `StatusMiddleware`, create and pass in a `DefaultHttpContext`,[108] which is an implementation of `HttpContext`.

Listing 23.8 Unit testing `StatusMiddleware` when a nonmatching `path` is provided

```
[Fact]
public async Task ForNonMatchingRequest_CallsNextDelegate()
{
    var context = new DefaultHttpContext();      #A
    context.Request.Path = "/somethingelse";     #A
    var wasExecuted = false;                     #B
    RequestDelegate next = (HttpContext ctx) =>    #C
    {                                            #C
        wasExecuted = true;                      #C
        return Task.CompletedTask;               #C
    };                                           #C
    var middleware = new StatusMiddleware(next);     #D

    await middleware.Invoke(context);         #E

    Assert.True(wasExecuted);          #F
}
```

#A Creates a DefaultHttpContext and sets the path for the request
#B Tracks whether the RequestDelegate was executed
#C The RequestDelegate representing the next middleware, should be invoked in this example.
#D Creates an instance of the middleware, passing in the next RequestDelegate
#E Invokes the middleware with the HttpContext, should invoke the RequestDelegate
#F Verifies RequestDelegate was invoked

When the middleware is invoked, it checks the provided `Path` and finds that it doesn't match the required value of `/ping`. The middleware therefore calls the next `RequestDelegate` and returns.

[108] **The `DefaultHttpContext` derives from `HttpContext` and is part of the base ASP.NET Core framework abstractions. If you're so inclined, you can explore the source code for it at https://github.com/dotnet/aspnetcore/blob/v3.1.7/src/Http/Http/src/DefaultHttpContext.cs.**

The other obvious case to test is when the request Path is "/ping", and so the middleware should generate an appropriate response. You could test several different characteristics of the response:

- The response should have a 200 OK status code
- The response should have a Content-Type of text/plain
- The response body should contain the "pong" string

Each of these characteristics represents a different requirement, so you'd typically codify each as a separate unit test. This makes it easier to tell exactly which requirement hasn't been met when a test fails. For simplicity, in listing 23.9 I show all these assertions in the same test.

The positive case unit test is made more complex by the need to read the response body to confirm it contains "pong". DefaultHttpContext uses Stream.Null for the Response.Body object, which means anything written to Body is lost. To capture the response and read it out to verify the contents, you must replace the Body with a MemoryStream. After the middleware executes, you can use a StreamReader to read the contents of the MemoryStream into a string and verify it.

Listing 23.9 Unit testing StatusMiddleware when a matching Path is provided

```
[Fact]
public async Task ReturnsPongBodyContent()
{
    var bodyStream = new MemoryStream();          #A
    var context = new DefaultHttpContext();       #A
    context.Response.Body = bodyStream;           #A
    context.Request.Path = "/ping";               #B
    RequestDelegate next = (ctx) => Task.CompletedTask;    #C
    var middleware = new StatusMiddleware(next: next);     #C

    await middleware.Invoke(context);                          #D

    string response;                                           #E
    bodyStream.Seek(0, SeekOrigin.Begin);                      #E
    using (var stringReader = new StreamReader(bodyStream))    #E
    {                                                          #E
        response = await stringReader.ReadToEndAsync();       #E
    }                                                          #E

    Assert.Equal("pong", response);                               #F
    Assert.Equal("text/plain", context.Response.ContentType);     #G
    Assert.Equal(200, context.Response.StatusCode);               #H
}
```

#A Creates a DefaultHttpContext and initializes the body with a MemoryStream to capture the response
#B The path is set to the required value for the StatusMiddleware.
#C Creates an instance of the middleware and passes in a simple RequestDelegate
#D Invokes the middleware
#E Rewinds the MemoryStream and reads the response body into a string
#F Verifies the response has the correct value
#G Verifies the Content-Type response is correct
#H Verifies the Status Code response is correct

As you can see, unit testing middleware requires a lot of setup to get it working. On the positive side, it allows you to test your middleware in isolation, but in some cases, especially for simple middleware without any dependencies on databases or other services, integration testing can (somewhat surprisingly) be easier. In section 23.5, you'll create integration tests for this middleware to see the difference.

Custom middleware is common in ASP.NET Core projects, but far more common are Razor Pages and API controllers. In the next section, you'll see how you can unit test them in isolation from other components.

23.4 Unit testing API controllers

In this section you'll learn how to unit test API controllers. You'll learn about the benefits and difficulties of testing these components in isolation, and the situations when it can be useful.

Unit tests are all about isolating behavior; you want to test only the logic contained in the component itself, separate from the behavior of any dependencies. The Razor Pages and MVC/API *frameworks* use the filter pipeline, routing, and model binding systems, but these are all *external* to the controller or `PageModel`s. The `PageModel`s and controllers themselves are responsible for only a limited number of things. Typically,

- For invalid requests (that have failed validation, for example), return an appropriate `ActionResult` (API controllers) or redisplay a form (Razor Pages)
- For valid requests, call the required business logic services and return an appropriate `ActionResult` (API controllers), or show or redirect to a success page (Razor Pages).
- Optionally, apply resource-based authorization as required.

Controllers and Razor Pages generally shouldn't contain business logic themselves; instead, they should call out to other services. Think of them more as orchestrators, serving as the intermediary between the HTTP interfaces your app exposes and your business logic services.

If you follow this separation, you'll find it easier to write unit tests for your business logic, and you'll benefit from greater flexibility to change your controllers to meet your needs. With that in mind, there's often a drive to make your controllers and page handlers as thin as possible,[109] to the point where there's not much left to test!

All that said, controllers and actions are classes and methods, so you *can* write unit tests for them. The difficulty is deciding what you want to test! As an example, we'll consider the simple API controller in the following listing, which converts a value using a provided exchange rate, and returns a response.

[109] One of my first introductions to this idea was a series of posts by Jimmy Bogard. The following is a link to the last post in the series, but it contains links to all the earlier posts too. Jimmy Bogard is also behind the MediatR library (https://github.com/jbogard/MediatR), which makes creating thin controllers even easier. See https://lostechies.com/jimmybogard/2013/12/19/put-your-controllers-on-a-diet-posts-and-commands/.

Listing 23.10 The API controller under test

```
[Route("api/[controller]")]
public class CurrencyController : ControllerBase
{
    private readonly CurrencyConverter _converter              #A
       = new CurrencyConverter();                             #A

    [HttpPost]
    public ActionResult<decimal> Convert(InputModel model)    #B
    {
        if (!ModelState.IsValid)                              #C
        {                                                     #C
            return BadRequest(ModelState);                    #C
        }                                                     #C

        decimal result = _convert.ConvertToGbp(model)         #D

        return result;                                        #E
    }
}
```

#A The CurrencyConverter would normally be injected using DI. Created here for simplicity
#B The Convert method returns an ActionResult<T>
#C If the input is invalid, returns a 400 Bad Request result, including the ModelState.
#D If the model is valid, calculate the result
#E Return the result directly

Let's first consider the happy-path, when the controller receives a valid request. The following listing shows that you can create an instance of the API controller, call an action method, and you'll receive an `ActionResult<T>` response.

Listing 23.11 A simple API Controller unit test

```
public class CurrencyControllerTest
{
    [Fact]
    public void Convert_ReturnsValue()
    {
        var controller = new CurrencyController();                    #A
        var model = new ConvertInputModel                             #A
        {                                                             #A
            Value = 1,                                                #A
            ExchangeRate = 3,                                         #A
            DecimalPlaces = 2,                                        #A
        };                                                            #A

        ActionResult<decimal> result = controller.Convert(model);     #B
        Assert.NotNull(result);                                       #C
    }
}
```

#A Creates an instance of the ConvertController to test and a model to send to the API
#B Invokes the ConvertToGbp method and captures the value returned
#C Asserts that the IActionResult is a ViewResult

An important point to note here is that you're *only* testing the return value of the action, the `ActionResult<T>`, *not* the response that's sent back to the user. The process of serializing the result to the response is handled by the MVC formatter infrastructure, as you saw in chapter 9, not by the controller.

When you unit test controllers, you're testing them *separately* from the MVC infrastructure, such as formatting, model binding, routing, and authentication. This is obviously by design, but as with testing middleware in section 23.3, it can make testing some aspects of your controller somewhat complex.

Consider model validation. As you saw in chapter 6, one of the key responsibilities of action methods and Razor Page handlers is to check the `ModelState.IsValid` property and act accordingly if a binding model is invalid. Testing that your controllers and Page Models correctly handle validation failures seems like a good candidate for a unit tests.

Unfortunately, things aren't simple here either. The Razor Page/MVC framework automatically sets the `ModelState` property as part of the model binding process. In practice, when your action method or page handler is invoked in your running app, you know that the `ModelState` will match the binding model values. But in a unit test, there's no model binding, so you must set the `ModelState` yourself manually.

Imagine you're interested in testing the sad path for the controller in listing 23.10, where the model is invalid, and the controller should return `BadRequestObjectResult`. In a unit test, you can't rely on the `ModelState` property being correct for the binding model. Instead, you must *manually* add a model-binding error to the controller's `ModelState` before calling the action, as shown here.

Listing 23.12 Testing handling of validation errors in MVC Controllers

```
[Fact]
public void Convert_ReturnsBadRequestWhenInvalid()
{
    var controller = new CurrencyController();   #A
    var model = new ConvertInputModel            #B
    {                                            #B
        Value = 1,                               #B
        ExchangeRate = -2,                       #B
        DecimalPlaces = 2,                       #B
    };                                           #B

    controller.ModelState.AddModelError(              #C
        nameof(model.ExchangeRate),                   #C
        "Exchange rate must be greater than zero"     #C
    );                                                #C

    ActionResult<decimal> result = controller.Convert(model);    #D

    Assert.IsType<BadRequestObjectResult>(result.Result);        #E
}
```

#A Creates an instance of the Controller to test
#B Creates an invalid binding model by using a negative ExchangeRate
#C Manually adds a model error to the Controller's ModelState. This sets ModelState.IsValid to false.

#D Invokes the action method, passing in the binding models
#E Verifies the action method returned a BadRequestObjectResult

> **NOTE** In listing 23.12, I passed in an invalid model, but I could just as easily have passed in a *valid* model, or even `null`; the controller doesn't use the binding model if the `ModelState` isn't valid, so the test would still pass. But if you're writing unit tests like this one, I recommend trying to keep your model consistent with your `ModelState`, otherwise your unit tests aren't testing a situation that occurs in practice!

Personally, I tend to shy away from unit testing API controllers directly in this way[110]. As you've seen with model binding, the controllers are somewhat dependent on earlier stages of the MVC framework which you often need to emulate. Similarly, if your controllers access the `HttpContext` (available on the `ControllerBase` base classes), you may need to perform additional setup.

> **NOTE** I haven't discussed Razor Pages much in this section, as they suffer from many of the same problems, in that they are dependent on the supporting infrastructure of the framework. Nevertheless, if you do wish to test your Razor Page `PageModel`, you can read about it here: https://docs.microsoft.com/aspnet/core/test/razor-pages-tests.

Instead of using unit testing, I try to keep my controllers and Razor Pages as "thin" as possible. I push as much of the "behavior" in these classes into business logic services that can be easily unit tested, or into middleware and filters, which can be more easily tested independently.

> **NOTE** This is a personal preference. Some people like to get as close to 100% test coverage for their code base as possible, but I find testing "orchestration" classes is often more hassle than it's worth.

Although I often forgo *unit* testing controllers and Razor Pages, I often write *integration* tests that test them in the context of a complete application. In the next section, we look at ways to write integration tests for your app, so you can test its various components in the context of the ASP.NET Core framework as a whole.

23.5 Integration testing: testing your whole app in-memory

In this section you'll learn how to create integration tests that test component interactions. You'll learn to create a `TestServer` that sends HTTP requests in-memory to test custom middleware components more easily. You'll then learn how to run integration tests for a real application, using your real app's configuration, services, and middleware pipeline. Finally,

[110] You can read more about why I generally don't unit test my controllers here: https://andrewlock.net/should-you-unit-test-controllers-in-aspnetcore/.

you'll then learn how to use `WebApplicationFactory` to replace services in your app with test versions, to avoid depending on third-party APIs in your tests.

If you search the internet for the different types of testing, you'll find a host of different types to choose from. The differences between them are sometimes subtle and people don't universally agree upon the definitions. I chose not to dwell on it in this book—I consider unit tests to be isolated tests of a component and integration tests to be tests that exercise multiple components at once.

In this section, I'm going to show how you can write integration tests for the `StatusMiddleware` from section 23.3 and the API controller from section 23.4. Instead of isolating the components from the surrounding framework and invoking them directly, you'll specifically test them in a similar context to when you use them in practice.

Integration tests are an important part of confirming that your components function correctly, but they don't remove the need for unit tests. Unit tests are excellent for testing small pieces of logic contained in your components and are typically quick to execute. Integration tests are normally significantly slower, as they require much more configuration and may rely on external infrastructure, such as a database.

Consequently, it's normal to have far more unit tests for an app than integration tests. As you saw in section 23.2, unit tests typically verify the behavior of a component, using valid inputs, edge cases, and invalid inputs, to ensure that the component behaves correctly in all cases. Once you have an extensive suite of unit tests, you'll likely only need a few integration tests to be confident your application is working correctly.

You could write many different types of integration tests for an application. You could test that a service can write to a database correctly, that it can integrate with a third-party service (for sending emails, for example), or that it can handle HTTP requests made to it.

In this section, you're going to focus on the last point, verifying that your app can handle requests made to it, just as you would if you were accessing the app from a browser. For this, you're going to use a useful library provided by the ASP.NET Core team called Microsoft.AspNetCore.TestHost.

23.5.1 Creating a TestServer using the Test Host package

Imagine you want to write some integration tests for the `StatusMiddleware` from section 23.3. You've already written unit tests for it, but you want to have at least one integration test that tests the middleware in the context of the ASP.NET Core infrastructure.

You could go about this in many ways. Perhaps the most complete approach would be to create a separate project and configure `StatusMiddleware` as the only middleware in the pipeline. You'd then need to run this project, wait for it to start up, send requests to it, and inspect the responses.

This would possibly make for a good test, but it would also require a lot of configuration, and be fragile and error-prone. What if the test app can't start because it tries to use an already-taken port? What if the test app doesn't shut down correctly? How long should the integration test wait for the app to start?

The ASP.NET Core Test Host package lets you get close to this setup, without having the added complexity of spinning up a separate app. You add the Test Host to your test project by adding the Microsoft.AspNetCore.TestHost NuGet package, either using the Visual Studio NuGet GUI, Package Manager Console, or the .NET CLI. Alternatively, add the `<PackageReference>` element directly to your test project's .csproj file:

```
<PackageReference Include="Microsoft.AspNetCore.TestHost" Version="3.1.7"/>
```

In a typical ASP.NET Core app, you create a `HostBuilder` in your `Program` class, configure a web server (Kestrel) and define your application's configuration, services, and middleware pipeline (using a Startup file). Finally, you call `Build()` on the `HostBuilder` to create an instance of an `IHost` that can be run and will listen for requests on a given URL and port.

The Test Host package uses the same `HostBuilder` to define your test application, but instead of listening for requests at the network level, it creates an `IHost` that uses in-memory request objects instead, as shown in figure 23.8. It even exposes an `HttpClient` that you can use to send requests to the test app. You can interact with the `HttpClient` as though it were sending requests over the network, but in reality, the requests are kept entirely in memory.

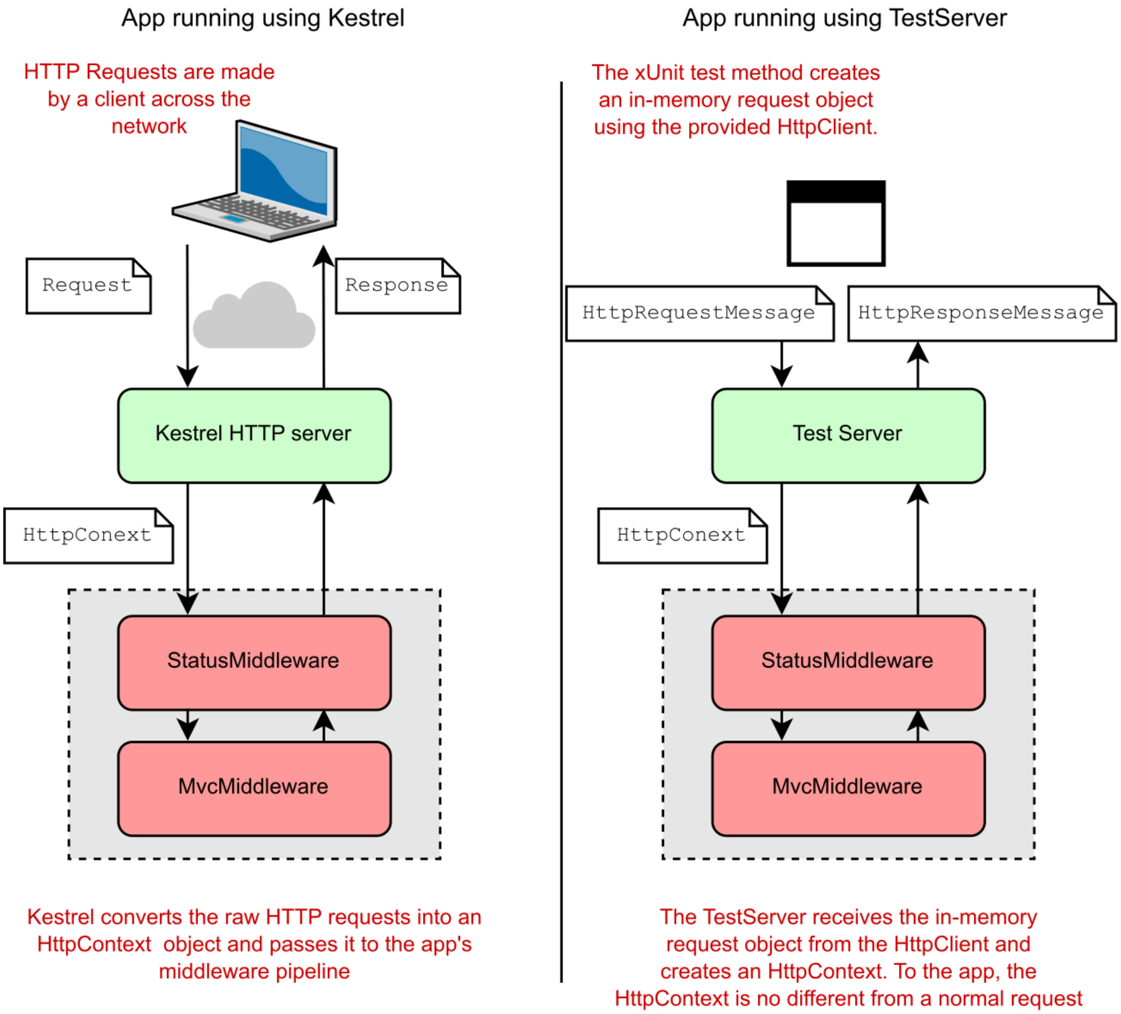

App running using Kestrel
HTTP Requests are made by a client across the network
Request
Response
Kestrel HTTP server
HttpConext
StatusMiddleware
MvcMiddleware
Kestrel converts the raw HTTP requests into an HttpContext object and passes it to the app's middleware pipeline
App running using TestServer
The xUnit test method creates an in-memory request object using the provided HttpClient.
HttpRequestMessage
HttpResponseMessage
Test Server
HttpConext
StatusMiddleware
MvcMiddleware
The TestServer receives the in-memory request object from the HttpClient and creates an HttpContext. To the app, the HttpContext is no different from a normal request

Figure 23.8 When your app runs normally, it uses the Kestrel server. This listens for HTTP requests and converts the requests into an `HttpContext`, which is passed to the middleware pipeline. The `TestServer` doesn't listen for requests on the network. Instead, you use an `HttpClient` to make in-memory requests. From the point of view of the middleware, there's no difference.

Listing 23.13 shows how to use the Test Host package to create a simple integration test for the `StatusMiddleware`. First, create a `HostBuilder` and call `ConfigureWebHost()` to define your application by adding middleware in the `Configure` method. This is equivalent to the `Startup.Configure()` method you would typically use to configure your application.

Call the UseTestServer() extension method in ConfigureWebHost(), which replaces the default Kestrel server with the TestServer from the Test Host package. The TestServer is the main component in the Test Host package, which makes all the magic possible. After configuring the HostBuilder, call StartAsync() to build and start the test application. You can then create an HttpClient using the extension method GetTestClient(). This returns an HttpClient configured to make in-memory requests to the TestServer.

Listing 23.13 Creating an integration test with TestServer

```
public class StatusMiddlewareTests
{
    [Fact]
    public async Task StatusMiddlewareReturnsPong()
    {
        var hostBuilder = new HostBuilder()                         #A
            .ConfigureWebHost(webHost =>                            #A
            {
                webHost.Configure(app =>                            #B
                    app.UseMiddleware<StatusMiddleware>());         #B
                webHost.UseTestServer();                            #C
            });

        IHost host = await hostBuilder.StartAsync();                #D
        HttpClient client = host.GetTestClient();                   #E

        var response = await client.GetAsync("/ping");              #F

        response.EnsureSuccessStatusCode();                          #G
        var content = await response.Content.ReadAsStringAsync();    #H
        Assert.Equal("pong", content);                               #H
    }
}
```

#A Configures a HostBuilder to define the in-memory test app
#B Add the StatusMiddleware as the only middleware in the pipeline
#C Configure the host to use the TestServer instead of Kestrel
#D Build and start the host
#E Creates an HttpClient, or you can interact directly with the server object
#F Makes an in-memory request, which is handled by the app as normal.
#G Verifies the response was a success (2xx) status code
#H Reads the body content and verifies that it contained "pong"

This test ensures that the test application defined by HostBuilder returns the expected value when it receives a request to the /ping path. The request is entirely in-memory, but from the point of view of StatusMiddleware, it's the same as if the request came from the network.

The HostBuilder configuration in this example is simple. Even though I've called this an integration test, you're specifically testing the StatusMiddleware on its own, rather than in the context of a "real" application. In many ways, I think this setup is preferable for testing custom middleware compared to the "proper" unit-tests I showed in section 23.3.

Regardless of what you call it, this test relies on very simple configuration for the test app. You may also want to test the middleware in the context of your *real* application, so that the result is representative of your app's *real* configuration.

If you want to run integration tests based on an existing app, then you don't want to have to configure the test `HostBuilder` manually like you did in listing 23.13. Instead, you can use another helper package, Microsoft.AspNetCore.Mvc.Testing.

23.5.2 Testing your application with WebApplicationFactory

Building up a `HostBuilder` and using the Test Host package, as you did in section 23.5.1, can be useful when you want to test isolated "infrastructure" components, such as middleware. It's also very common to want to test your "real" app, with the full middleware pipeline configured, as well as all the required services added to DI. This gives you the most confidence that your application is going to work in production.

The `TestServer` that provides the in-memory server can be used for testing your "real" app, but, in principle, there's a lot more configuration required. Your real app likely loads configuration files or web static files from disk, and may use Razor Pages and views. Prior to .NET Core 2.1, configuring all of these was cumbersome. Thankfully, the introduction of the Microsoft.AspNetCore.Mvc.Testing package and `WebApplicationFactory` largely solves these configuration issues for you.

You can use the `WebApplicationFactory` class (provided by the Microsoft.AspNetCore.Mvc.Testing NuGet package) to run an in-memory version of your real application. It uses the `TestServer` behind the scenes, but it uses your app's real configuration, DI service registration, and middleware pipeline. For example, the following listing shows an example that tests that when your application receives a "`/ping`" request, it responds with "`pong`".

Listing 23.14 Creating an integration test with `TestServer`

```
public class IntegrationTests:               #A
    IClassFixture<WebApplicationFactory<Startup>>       #A
{
    private readonly WebApplicationFactory<Startup> _fixture;       #B
    public StatusMiddlewareWebApplicationFactoryTests(     #B
        WebApplicationFactory<Startup> fixture)       #B
    {
        _fixture = fixture;       #B
    }

    [Fact]
    public async Task PingRequest_ReturnsPong()
    {
        HttpClient client = _fixture.CreateClient();     #C

        var response = await client.GetAsync("/ping");     #D

        response.EnsureSuccessStatusCode();        #D
        var content = await response.Content.ReadAsStringAsync();    #D
        Assert.Equal("pong", content);          #D
    }
}
```

#A Your test must implement the marker interface
#B Inject an instance of WebApplicationFactory<T>, where T is a class in your app
#C Create an HttpClient that sends request to the in-memory TestServer
#D Make requests and verify the response as before

One of the advantages of using `WebApplicationFactory` as shown in listing 23.14 is that it requires *less* manual configuration than using the `TestServer` directly, as shown in listing 23.13, despite performing *more* configuration behind the scenes. The `WebApplicationFactory` tests your app using the configuration defined in your Program.cs and Startup.cs files.

Listings 23.14 and 23.13 are *conceptually* quite different too. Listing 23.13 tests that the `StatusMiddleware` behaves as expected, in the context of a dummy ASP.NET Core app; listing 23.14 tests that *your app behaves as expected for a given input*. It doesn't say anything specific about *how* that happens. Your app doesn't have to use the `StatusMiddleware` for the test in listing 23.14 to pass, it just has to respond correctly to the given request. That means the test knows less about the internal implementation details of your app, and is only concerned with its *behavior*.

> **DEFINITION** **Tests that fail whenever you change your app slightly are called *brittle* or *fragile*. Try to avoid brittle tests by ensuring they aren't dependent on implementation details of your app.**

To create tests that use `WebApplicationFactory`:

- Install the Microsoft.AspNetCore.Mvc.Testing NuGet package in your project by running `dotnet add package Microsoft.AspNetCore.Mvc.Testing`, by using the NuGet explorer in Visual Studio, or by adding a `<PackageReference>` element to your project file as shown below

  ```
  <PackageReference Include="Microsoft.AspNetCore.Mvc.Testing"
      Version="3.1.7" />
  ```

- Update the `<Project>` element in your test project's .csproj file to the following:

  ```
  <Project Sdk="Microsoft.NET.Sdk.Web">
  ```

  This is required by `WebApplicationFactory` so that it can find your configuration files and static files

- Implement `IClassFixture<WebApplicationFactory<T>>` in your xUnit test class, where `T` is a class in your real application's project. By convention, you typically use your application's `Startup` class for `T`.
  - `WebApplicationFactory` uses the `T` reference to find your application's `Program.CreateHostBuilder()` method to build an appropriate `TestServer` for tests.

  - The `IClassFixture<TFixture>` is an xUnit marker interface, that tells xUnit to build an instance of `TFixture` before building the test class and to inject the instance into the test class's constructor. You can read more about fixtures at https://xunit.net/docs/shared-context.

- Accept an instance of `WebApplicationFactory<T>` in your test class's constructor. You can use this fixture to create an `HttpClient` for sending in-memory requests to the `TestServer`. Those requests emulate your application's production behaviour, as your application's real configuration, services, and middleware are all used.

The big advantage of `WebApplicationFactory` is that you can easily test your real app's behavior. That power comes with responsibility—your app will behave just as it would in real life, so it will write to a database and send to third-party APIs! Depending on what you're testing, you may want to replace some of your dependencies to avoid this, as well as to make testing easier.

23.5.3 Replacing dependencies in WebApplicationFactory

When you use `WebbApplicationFactory` to run integration tests on your app, your app will be running in-memory, but other than that, it's as through you're running your application using `dotnet run`. That means, any connection strings, secrets, or API keys that can be loaded locally will also be used to run your application!

> **TIP By default, `WebApplicationFactory` uses the `"Development"` hosting environment, the same as when you run locally.**

On the plus side, that means you have a genuine test that your application can start correctly. For example, if you've forgotten to register a required DI dependency that is detected on application startup, any tests that use `WebApplicationFactory` will fail.

On the downside, that means all your tests will be using the same database connection and services as when you run your application locally. It's common to want to replace those with alternative "test" versions of your services.

As a simple example, lets imagine the `CurrencyConverter` that you've been testing in this app uses `IHttpClientFactory` to call a third-party API to retrieve the latest exchange rates. You don't want to hit that API repeatedly in your integration tests, so you want to replace the `CurrencyConverter` with your own `StubCurrencyConverter`.

The first step is to ensure the service `CurrencyConverter` implements an interface, `ICurrencyConverter` for example, and that your app uses this interface throughout, not the implementation. For our simple example, the interface would probably look like the following:

```
public interface ICurrencyConverter
{
    decimal ConvertToGbp(decimal value, decimal rate, int dps);
}
```

You would register the service in `Startup.ConfigureServices()` using:

```
services.AddScoped<ICurrencyConverter, CurrencyConverter>();
```

Now that your application only indirectly depends on `CurrencyConverter`, you can provide an alternative implementation in your tests.

> **TIP** Using an interface decouples your application services from a specific implementation, allowing you to substitute alternative implementations. This is a key practice for making classes testable.

We'll create a simple alternative implementation of `ICurrencyConverter` for our tests, that always returns the same value, `3`. It's obviously not very useful as an actual converter, but that's not the point: you have complete control! Create the following class in your test project:

```
public class StubCurrencyConverter : ICurrencyConverter
{
    public decimal ConvertToGbp(decimal value, decimal rate, int dps)
    {
        return 3;
    }
}
```

You now have all the pieces you need to replace the implementation in your tests. To achieve that, we'll use a feature of `WebApplicationFactory` that lets you customize the DI container before starting the test server.

> **TIP** It's important to remember you *only* want to replace the implementation when running in the test project. I've seen some people try and configure their *real* apps to replace live services for fake services when a specific value is set for example. That is generally unnecessary, bloats your apps with "test" services, and generally adds confusion!

`WebApplicationFactory` exposes a method, `WithWebHostBuilder`, that allows you to customize your application before the in-memory `TestServer` starts. The following listing shows an integration test that uses this builder to replace the "default" `ICurrencyConverter` implementation with our test stub.

Listing 23.15 Replacing a dependency in an integration test using WithWebHostBuilder

```
public class IntegrationTests:                                       #A
    IClassFixture<WebApplicationFactory<Startup>>                    #A
{
    private readonly WebApplicationFactory<Startup> _fixture;        #A
    public StatusMiddlewareWebApplicationFactoryTests(               #A
        WebApplicationFactory<Startup> fixture)                      #A
    {
        _fixture = fixture;                                          #A
    }

    [Fact]
    public async Task ConvertReturnsExpectedValue()
    {
        var customFactory = _fixture.WithWebHostBuilder(               #B
            (IWebHostBuilder hostBuilder) =>                        #B
        {
            hostBuilder.ConfigureTestServices(services =>           #C
            {
                services.RemoveAll<ICurrencyConverter>();           #D
                services.AddSingleton
                    <ICurrencyConverter, StubCurrencyConverter>();  #E
            });
        });

        HttpClient client = customFactory.CreateClient();           #F

        var response = await client.GetAsync("/api/currency");      #G

        response.EnsureSuccessStatusCode();                         #G
        var content = await response.Content.ReadAsStringAsync();   #G

        Assert.Equal("3", content);                                 #H
    }
}
```

#A Implement the required interface, and inject it into the constructor
#B Create a custom factory with the additional configuration
#C ConfigureTestServices executes after all other DI services are configured in your real app
#D Removes all implementations of ICurrencyConverter from the DI container
#E Adds the test service as a replacement
#F Calling CreateClient bootstraps the application and starts the TestServer
#G Invoke the currency converter endpoint
# H As the test converter always returns 3, so does the API endpoint

There are a couple of important points to note in this example

- `WithWebHostBuilder()` returns a *new* `WebApplicationFactory` instance. The new instance has your custom configuration, while the original injected `_fixture` instance remains unchanged.
- `ConfigureTestServices()` is called after your real app's `ConfigureServices()` method. That means you can replace services that have been previously been registered. You can also use this to override configuration values, as you'll see in section 23.6.

`WithWebHosBuilder()` is handy when you want to replace a service for a single test. But what if you wanted to replace the `ICurrencyConverter` in every test. All that boilerplate would quickly become cumbersome. Instead, you can create a custom `WebApplicationFactory`.

23.5.4 Reducing duplication by creating a custom WebApplicationFactory

If you find yourself writing `WithWebHosBuilder()` a lot in your integration tests, it might be worth creating a custom `WebApplicationFactory` instead. The following listing shows how to centralize the test service we used in listing 23.15 into a custom `WebApplicationFactory`.

Listing 23.16 Creating a custom `WebApplicationFactory` to reduce duplication

```
public class CustomWebApplicationFactory                            #A
```

```
    : WebApplicationFactory<Startup>                              #A
{
    protected override void ConfigureWebHost(                     #B
        IWebHostBuilder builder)                                  #B
    {
        builder.ConfigureTestServices(services =>                 #C
        {                                                         #C
            services.RemoveAll<ICurrencyConverter>();             #C
            services.AddSingleton                                 #C
                <ICurrencyConverter, StubCurrencyConverter>();    #C
        });                                                   #C
    }
}
```

#A Derive from WebApplicationFactory
#B There are many functions available to override. This is equivalent to calling WithWebHostBuilder
#C Add custom configuration for your application

In this example, we override `ConfigureWebHost` and configure the test services for the factory[111]. You can use your custom factory in any test by injecting it as an `IClassFixture`, as you have before. For example, the following listing shows how you would update listing 23.15 to use the custom factory defined in listing 23.16.

Listing 23.17 Using a custom WebApplicationFactory in an integration test

```
public class IntegrationTests:                                     #A
    IClassFixture<CustomWebApplicationFactory>                     #A
{
    private readonly CustomWebApplicationFactory _fixture;         #B
    public IntegrationTests(CustomWebApplicationFactory fixture)    #B
    {
        _fixture = fixture;
    }

    [Fact]
    public async Task ConvertReturnsExpectedValue()
    {
        HttpClient client = _fixture.CreateClient();              #C

        var response = await client.GetAsync("/api/currency");

        response.EnsureSuccessStatusCode();
        var content = await response.Content.ReadAsStringAsync();

        Assert.Equal("3", content);                              #D
    }
}
```

#A Implement the IClassFixture interface for the custom factory
#B Inject an instance of the factory in the constructor

[111] WebApplicationFactory has many other services you could implement for other scenarios. For details see https://docs.microsoft.com/aspnet/core/test/integration-tests.

#C The client already contains the test service configuration
#D The result confirms the test service was used

You can also combine your custom `WebApplicationFactory` that substitutes services that you always want to replace, with the `WithWebHostBuilder()` method to override additional services on a per-test basis. That combination gives you the best of both worlds: reduced duplication with the custom factory, and control with the per-test configuration.

Running integration tests using your real app's configuration provides about the closest you'll get to a guarantee that your app is working correctly. The sticking point in that guarantee is nearly always external dependencies, such as third-party APIs and databases.

In the final section of this chapter, we'll look at how to use the SQLite provider for EF Core with an in-memory database. You can use this approach to write tests for services that use an EF Core database context, without needing access to a real database.

23.6 Isolating the database with an in-memory EF Core provider

In this section you'll learn how to write unit tests for code that relies on an EF Core `DbContext`. You'll learn how to create an in-memory database, and the difference between the in-memory provider and the SQLite in-memory provider. Finally, you'll see how to use the in-memory SQLite provider to create fast, isolated tests for code that relies on a `DbContext`.

As you saw in chapter 12, EF Core is an ORM that is used primarily with relational databases. In this section, I'm going to discuss one way to test services that depend on an EF Core `DbContext`, without having to configure or interact with a real database.

> **NOTE** To learn more about testing your EF Core code, see *Entity Framework Core in Action* by Jon P Smith (Manning, 2021), http://mng.bz/k0dz.

The following listing shows a highly stripped-down version of the `RecipeService` you created in chapter 12 for the recipe app. It shows a single method to fetch the details of a recipe using an injected EF Core `DbContext`.

Listing 23.18 `RecipeService` to test, which uses EF Core to store and load entities

```
public class RecipeService
{
    readonly AppDbContext _context;              #A
    public RecipeService(AppDbContext context)   #A
    {                                            #A
        _context = context;                      #A
    }                                            #A
    public RecipeViewModel GetRecipe(int id)
    {
        return _context.Recipes                  #B
            .Where(x => x.RecipeId == id)
            .Select(x => new RecipeViewModel
            {
                Id = x.RecipeId,
                Name = x.Name
            })
            .SingleOrDefault();
    }
}
```

#A An EF Core DbContext is injected in the constructor.
#B Uses the DbSet<Recipes> property to load recipes and creates a RecipeViewModel

Writing unit tests for this class is a bit of a problem. Unit tests should be fast, repeatable, and isolated from other dependencies, but you have a dependency on your app's `DbContext`. You probably don't want to be writing to a real database in unit tests, as it would make the tests slow, potentially unrepeatable, and highly dependent on the configuration of the database: a fail on all three requirements!

> **NOTE** Depending on your development environment, you *may* want to use a real database for your integration tests, despite these drawbacks. Using a database like the one you'll use in production increases the likelihood you'll detect any problems in your tests. You can find an example of using Docker to achieve this here: https://docs.microsoft.com/en-us/dotnet/architecture/microservices/multi-container-microservice-net-applications/test-aspnet-core-services-web-apps.

Luckily, Microsoft ships two *in-memory* database providers for this scenario. Recall from chapter 12 that when you configure your app's `DbContext` in `Startup.ConfigureServices()`, you configure a specific database provider, such as SQL Server, for example:

```
services.AddDbContext<AppDbContext>(options =>
   options.UseSqlServer(connectionSttring);
```

The in-memory database providers are alternative providers designed *only for testing*. Microsoft includes two in-memory providers in ASP.NET Core:

- *Microsoft.EntityFrameworkCore.InMemory*—This provider doesn't simulate a database. Instead, it stores objects directly in memory. It isn't a relational database as such, so it doesn't have all the features of a normal database. You can't execute SQL against it directly, and it won't enforce constraints, but it's fast.
- *Microsoft.EntityFrameworkCore.Sqlite*—SQLite is a relational database. It's limited in features compared to a database like SQL Server, but it's a true relational database, unlike the in-memory database provider. Normally, a SQLite database is written to a file, but the provider includes an in-memory mode, in which the database stays in memory. This makes it much faster and easier to create and use for testing.

Instead of storing data in a database on disk, both of these providers store data in memory, as shown in figure 23.9. This makes them fast, easy to create and tear down, and allows you to create a new database for every test, to ensure your tests stay isolated from one another.

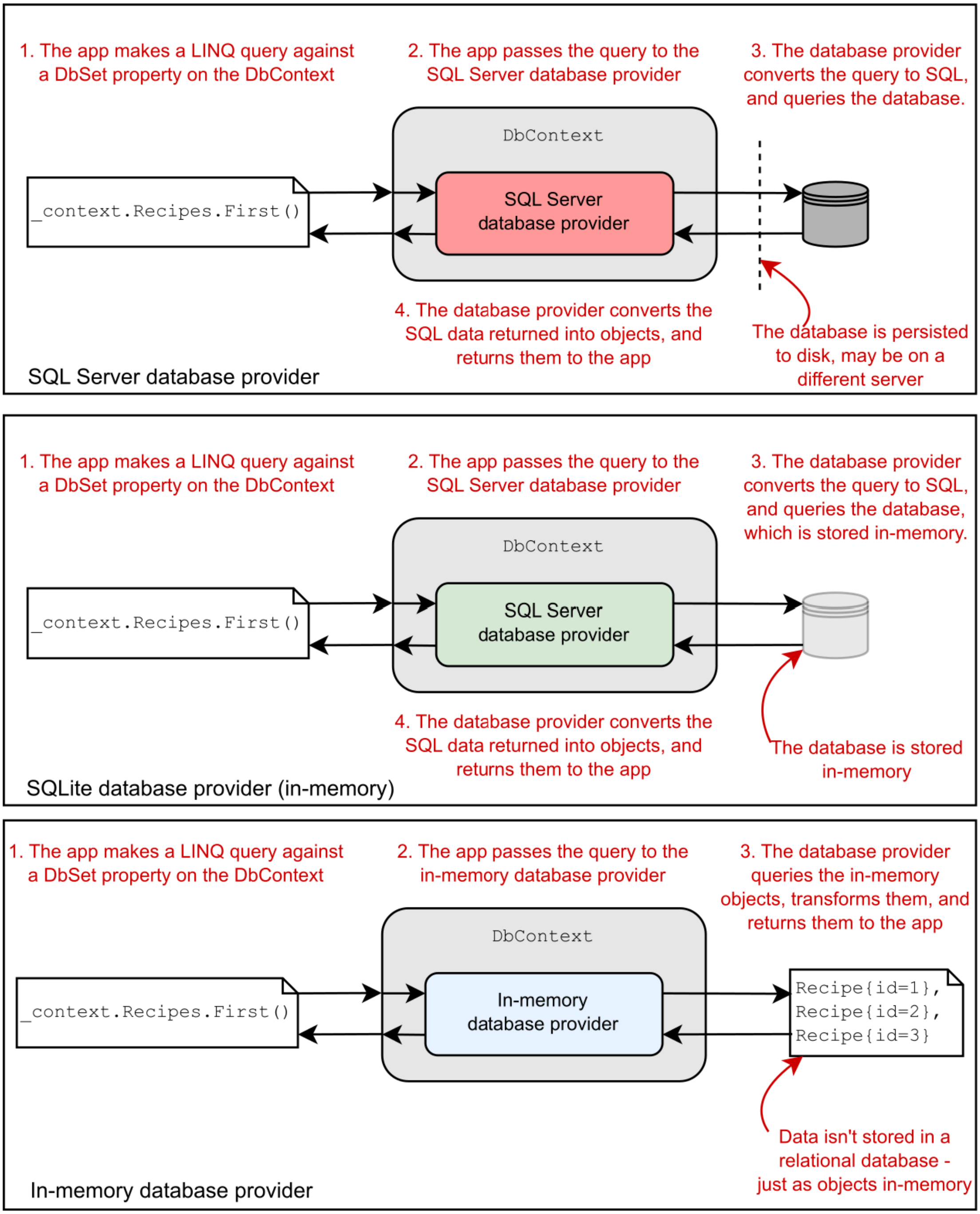

1. The app makes a LINQ query against a DbSet property on the DbContext
2. The app passes the query to the SQL Server database provider
3. The database provider converts the query to SQL, and queries the database.
DbContext
_context.Recipes.First()
SQL Server database provider
4. The database provider converts the SQL data returned into objects, and returns them to the app
The database is persisted to disk, may be on a different server
SQL Server database provider
1. The app makes a LINQ query against a DbSet property on the DbContext
2. The app passes the query to the SQL Server database provider
3. The database provider converts the query to SQL, and queries the database, which is stored in-memory.
DbContext
_context.Recipes.First()
SQL Server database provider
4. The database provider converts the SQL data returned into objects, and returns them to the app
The database is stored in-memory
SQLite database provider (in-memory)
1. The app makes a LINQ query against a DbSet property on the DbContext
2. The app passes the query to the in-memory database provider
3. The database provider queries the in-memory objects, transforms them, and returns them to the app
DbContext
_context.Recipes.First()
In-memory database provider
Recipe{id=1},
Recipe{id=2},
Recipe{id=3}
Data isn't stored in a relational database - just as objects in-memory
In-memory database provider

Figure 23.9 The in-memory database provider and SQLite provider (in-memory mode) compared to the SQL Server database provider. The in-memory database provider doesn't simulate a database as such. Instead, it stores objects in memory and executes LINQ queries against them directly.

> **NOTE** In this post, I describe how to use the SQLite provider as an in-memory database, as it's more fully featured than the in-memory provider. For details on using the in-memory provider see http://mng.bz/hdlq.

To use the SQLite provider in memory, add the Microsoft.EntityFrameworkCore.Sqlite package to your test project's .csproj file. This adds the `UseSqlite()` extension method, which you'll use to configure the database provider for your unit tests.

Listing 23.19 shows how you could use the in-memory SQLite provider to test the `GetRecipe()` method of `RecipeService`. Start by creating a `SqliteConnection` object and using the `"DataSource=:memory:"` connection string. This tells the provider to store the database in memory and then open the connection.

> **WARNING** The in-memory database is destroyed when the connection is closed. If you don't open the connection yourself, EF Core will close the connection to the in-memory database when you dispose the `DbContext`. If you want to share an in-memory database between `DbContexts`, you must explicitly open the connection yourself.

Next, pass the `SqlLiteConnection` instance into the `DbContextOptionsBuilder<>` and call `UseSqlite()`. This configures the resulting `DbContextOptions<>` object with the necessary services for the SQLite provider and provides the connection to the in-memory database. By passing this options object into an instance of `AppDbContext`, all calls to the `DbContext` result in calls to the in-memory database provider.

Listing 23.19 Using the in-memory database provider to test an EF Core `DbContext`

```
[Fact]
public void GetRecipeDetails_CanLoadFromContext()
{
    var connection = new SqliteConnection("DataSource=:memory:");    #A
    connection.Open();                                               #B

    var options = new DbContextOptionsBuilder<AppDbContext>()        #C
        .UseSqlite(connection)                                       #C
        .Options;                                                    #C

    using (var context = new AppDbContext(options))                  #D
    {
        context.Database.EnsureCreated();                            #E
        context.Recipes.AddRange(                                    #F
            new Recipe { RecipeId = 1, Name = "Recipe1" },           #F
            new Recipe { RecipeId = 2, Name = "Recipe2" },           #F
            new Recipe { RecipeId = 3, Name = "Recipe3" });          #F
        context.SaveChanges();                                       #G
    }
    using (var context = new AppDbContext(options))             #H
    {
        var service = new RecipeService(context);               #I
        var recipe = service.GetRecipe (id: 2);                 #J
        Assert.NotNull(recipe);                   #K
        Assert.Equal(2, recipe.Id);               #K
        Assert.Equal("Recipe2", recipe.Name);     #K
    }
}
```

#A Configures an in-memory SQLite connection using the special "in-memory" connection string
#B Opens the connection so EF Core won't close it automatically
#C Creates an instance of DbContextOptions<> and configures it to use the SQLite connection
#D Creates a DbContext and passes in the options
#E Ensures the in-memory database matches EF Core's model (similar to running migrations)
#F Adds some recipes to the DbContext
#G Saves the changes to the in-memory database
#H Creates a fresh DbContext to test that you can retrieve data from the DbContext
#I Creates the RecipeService to test and pass in the fresh DbContext
#J Executes the GetRecipe function. This executes the query against the in-memory database.
#K Verifies that you correctly retrieved the recipe from the in-memory database

This example follows the standard format for any time you need to test a class that depends on an EF Core `DbContext`:

1. Create a `SqliteConnection` with the `"DataSource=:memory:"` connection string and open the connection.
2. Create a `DbContextOptionsBuilder<>` and call `UseSqlite()`, passing in the open connection.
3. Retrieve the `DbContextOptions` object from the `Options` property.
4. Pass the options to an instance of your `DbContext` and ensure the database matches EF Core's model by calling `context.Database.EnsureCreated()`. This is similar to running migrations on your database but should *only* be used on test databases. Create and add any required test data to the in-memory database and call `SaveChanges()` to persist the data.
5. Create a new instance of your `DbContext` and inject it into your test class. All queries will be executed against the in-memory database.

By using two separate `DbContext`s, you can avoid bugs in your tests due to EF Core caching data without writing it to the database. With this approach, you can be sure that any data read in the second `DbContext` was persisted to the underlying in-memory database provider.

This was a very brief introduction to using the SQLite provider as an in-memory database provider, and EF Core testing in general, but if you follow the setup shown in listing 23.19, it should take you a long way. The source code for this chapter shows how you can combine this code with a custom `WebApplictaionFactory` to use an in-memory database for your integration tests. For more details on testing EF Core, including additional options and strategies, see *Entity Framework Core in Action* by Jon P Smith (Manning, 2021).

23.7 Summary

- Unit test apps are console apps that have a dependency on the .NET Test SDK, a test framework such as xUnit, MSTest, or NUnit, and a test runner adapter. You can run the tests in a test project by calling `dotnet test` from the command line in your test project or by using the Test Explorer in Visual Studio.
- Many testing frameworks are compatible with the .NET Test SDK, but xUnit has emerged as an almost *de facto* standard for ASP.NET Core projects. The ASP.NET Core team themselves use it to test the framework.
- To create an xUnit test project, choose xUnit Test Project (.NET Core) in Visual Studio or use the `dotnet new xunit` CLI command. This creates a test project containing the Microsoft.NET.Test.Sdk, xunit, and xunit.runner.visualstudio NuGet packages.
- xUnit includes two different attributes to identify test methods. `[Fact]` methods should be public and parameterless. `[Theory]` methods can contain parameters, so they can be used to run a similar test repeatedly with different parameters. You can provide the data for each `[Theory]` run using the `[InlineData]` attribute.
- Use assertions in your test methods to verify that the system under test (SUT) returned an expected value. Assertions exist for most common scenarios, including verifying that a method call raised an exception of a specific type. If your code raises an unhandled exception, the test will fail.
- Use the `DefaultHttpContext` class to unit test your custom middleware components. If you need access to the response body, you must replace the default `Stream.Null` with a `MemoryStream` instance and manually read the stream after invoking the middleware.
- API controllers and Razor Page models can be unit tested just like other classes, but they should generally contain little business logic, so it may not be worth the effort. For example, the API controller is tested independently of routing, model validation, and filters, so you can't easily test logic that depends on any of these aspects.
- Integration tests allow you to test multiple components of your app at once, typically within the context of the ASP.NET Core framework itself. The Microsoft.AspNetCore.TestHost package provides a `TestServer` object that you can use to create a simple web host for testing. This creates an in-memory server that you can make requests to and receive responses from. You can use the `TestServer` directly when you wish to create integration tests for custom components like middleware.
- For more extensive integration tests of a real application, you should use the `WebApplicationFactory` class in the Microsoft.AspNetCore.Mvc.Testing package. Implement `IClassFixture<WebApplicationFactory<Startup>>` on your test class and inject an instance of `WebApplicationFactory<Startup>` into the constructor. This creates an in-memory version of your whole app, using the same configuration, DI services, and middleware pipeline. You can send in-memory requests to your app to get the best idea of how your application will behave in production.
- To customize the `WebApplicationFactory`, call `WithWebHostBuilder()` and call `ConfigureTestServices()`. This method is invoked after your app's standard DI

configuration. This enables you to add or remove the default services for your app, for example to replace a class that contacts a third-party API with a stub implementation.

- If you find you need to customise the services for every test, you can create a custom `WebApplicationFactory` by deriving from it and overriding the `ConfigureWebHost` method. You can place all your configuration in the custom factory and implement `IClassFixture<CustomWebApplicationFactory>` in your test classes, instead of calling `WithWebHostBuilder()` in every test method.
- You can use the EF Core SQLite provider as an in-memory database to test code that depends on an EF Core database context. You configure the in-memory provider by creating a `SqliteConnection` with a `"DataSource=:memory:"` connection string. Create a `DbContextOptionsBuilder<>` object and call `Use-Sqlite()`, passing in the connection. Finally, pass `DbContextOptions<>` into an instance of your app's `DbContext` and call `context.Database.EnsureCreated()` to prepare the in-memory database for use with EF Core.
- The SQLite in-memory database is maintained as long as there's an open `SqliteConnection`. By opening the connection manually, the database can be used with multiple `DbContext`s. If you don't call `Open()` on the connection, EF Core will close the connection (and delete the in-memory database) when the `DbContext` is disposed.

Appendix A

Preparing your development environment

This appendix covers

- **Installing the .NET Core SDK**
- **Choosing an editor or IDE**

For .NET developers in a Windows-centric world, Visual Studio was pretty much a developer requirement in the past. But with .NET and ASP.NET Core going cross-platform, that's no longer the case.

All of ASP.NET Core (creating new projects, building, testing, and publishing) can be run from the command line for any supported operating system. All you need is the .NET SDK, which provides the .NET Command Line Interface (CLI). Alternatively, if you're on Windows, and not comfortable with the command line, you can still use File > New Project in Visual Studio to dive straight in. With ASP.NET Core, it's all about choice!

In a similar vein, you can now get a great editing experience outside of Visual Studio thanks to the OmniSharp project.[112] This is a set of libraries and editor plugins that provide code suggestions and autocomplete (IntelliSense) across a wide range of editors and operating systems. How you setup your environment will likely depend on which operating system you're using and what you're used to.

[112] Information about the OmniSharp project can be found at www.omnisharp.net. Source code can be found at https://github.com/omnisharp.

Remember that for .NET Core and .NET 5, the operating system you choose for development has no bearing on the final systems you can run on—whether you choose Windows, macOS, or Linux for development, you can deploy to any supported system.

In this appendix I show how to install the .NET SDK so you can build, run, and publish .NET apps. I'll also discuss some of the integrated development environment (IDE) and editor options available for you to build applications.

A.1 Installing the .NET SDK

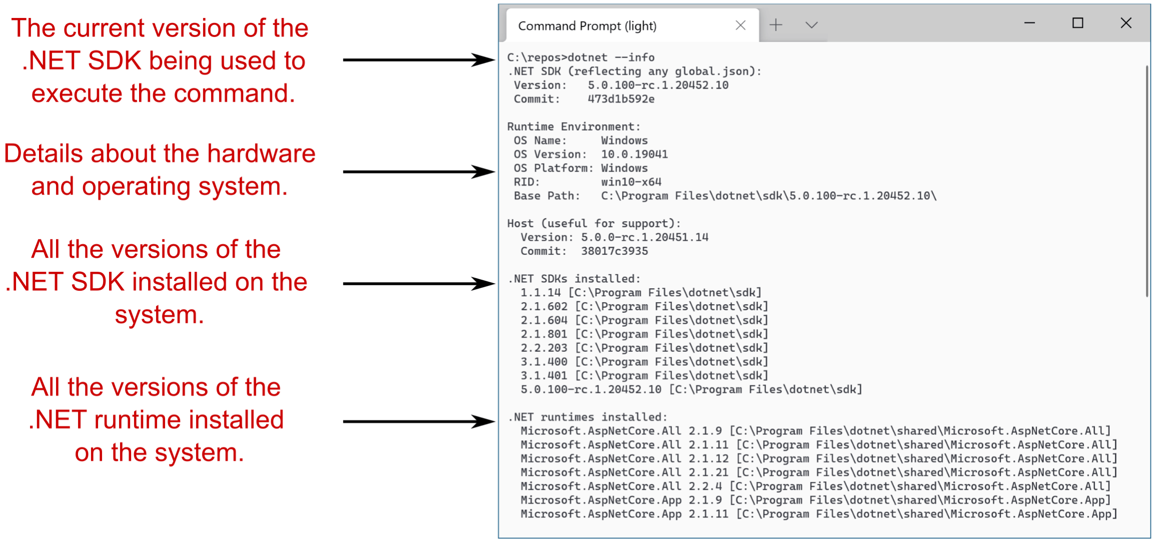
The most important thing you need for .NET Core and .NET 5 development is the .NET SDK. In this section I describe how to install the .NET SDK and how to check which version you have installed.

To start programming with .NET, you need to install the .NET SDK (previously called the .NET Core SDK). This contains the base libraries, tooling, and the compiler you need to create .NET applications.

You can install the .NET SDK from https://dotnet.microsoft.com/download. This contains links to download the latest version of .NET for your operating system. If you're using Windows or macOS, this page contains installer download links; if you're using Linux, there are instructions for installing .NET using your distributions package manager, as a Snap package, or as a manual download.

WARNING Make sure you download the .NET *SDK* not the .NET *Runtime*. The .NET runtime is used to execute .NET applications, but it can't be used to build them. The .NET SDK includes a copy of the runtime, so it can run your applications, but it can also build, test, and publish them.

After installing the .NET SDK, you can run commands with the .NET CLI using the `dotnet` command. Run `dotnet --info` to see information about the version of the .NET SDK currently in use, as well as the .NET SDKs and .NET runtimes you have installed, as shown in figure A.1.



The current version of the .NET SDK being used to execute the command.
Details about the hardware and operating system.
All the versions of the .NET SDK installed on the system.
All the versions of the .NET runtime installed on the system.
Command Prompt (light)

```
C:\repos>dotnet --info
.NET SDK (reflecting any global.json):
 Version:   5.0.100-rc.1.20452.10
 Commit:    473d1b592e

Runtime Environment:
 OS Name:     Windows
 OS Version:  10.0.19041
 OS Platform: Windows
 RID:         win10-x64
 Base Path:   C:\Program Files\dotnet\sdk\5.0.100-rc.1.20452.10\

Host (useful for support):
  Version: 5.0.0-rc.1.20451.14
  Commit:  38017c3935

.NET SDKs installed:
  1.1.14 [C:\Program Files\dotnet\sdk]
  2.1.602 [C:\Program Files\dotnet\sdk]
  2.1.604 [C:\Program Files\dotnet\sdk]
  2.1.801 [C:\Program Files\dotnet\sdk]
  2.2.203 [C:\Program Files\dotnet\sdk]
  3.1.400 [C:\Program Files\dotnet\sdk]
  3.1.401 [C:\Program Files\dotnet\sdk]
  5.0.100-rc.1.20452.10 [C:\Program Files\dotnet\sdk]

.NET runtimes installed:
  Microsoft.AspNetCore.All 2.1.9 [C:\Program Files\dotnet\shared\Microsoft.AspNetCore.All]
  Microsoft.AspNetCore.All 2.1.11 [C:\Program Files\dotnet\shared\Microsoft.AspNetCore.All]
  Microsoft.AspNetCore.All 2.1.12 [C:\Program Files\dotnet\shared\Microsoft.AspNetCore.All]
  Microsoft.AspNetCore.All 2.1.21 [C:\Program Files\dotnet\shared\Microsoft.AspNetCore.All]
  Microsoft.AspNetCore.All 2.2.4 [C:\Program Files\dotnet\shared\Microsoft.AspNetCore.All]
  Microsoft.AspNetCore.App 2.1.9 [C:\Program Files\dotnet\shared\Microsoft.AspNetCore.App]
  Microsoft.AspNetCore.App 2.1.11 [C:\Program Files\dotnet\shared\Microsoft.AspNetCore.App]
```

Figure A.1. Use `dotnet --info` to check which version of the .NET SDK is currently used, and which versions are available. Use this command to check that you have installed the .NET SDK correctly. This screenshot shows I am currently using a preview version of .NET 5.

As you can see in figure A.1, I have multiple versions of the .NET SDK (previously, the .NET Core SDK) installed. This is perfectly fine, but not necessary. Newer versions of the .NET SDK can build applications that target older versions of .NET Core. For example, the .NET 5 SDK can build .NET 5, .NET Core 3.x, .NET Core 2.x and .NET Core 1.x applications. In contrast, the .NET Core 3.1 SDK *can't* build .NET 5 applications.

> **TIP** Some IDEs, such as Visual Studio, can automatically install .NET 5 as part of their installation process. There is no problem installing multiple versions of .NET Core and .NET 5 side-by-side, so you can always install the .NET SDK manually, whether your IDE installs a different version or not.

By default, when you run `dotnet` commands from the command line, you'll be using the latest version of the .NET SDK you have installed. You can control that, and use an older version of the SDK, by adding a global.json file to the folder. For an introduction to this file, how to use it, and understanding .NET's versioning system, see https://andrewlock.net/exploring-the-new-rollforward-and-allowprerelease-settings-in-global-json/.

Once you have the .NET SDK installed, it's time to choose an IDE or editor. The choices available will depend on which operating system you're using and will largely be driven by personal preference.

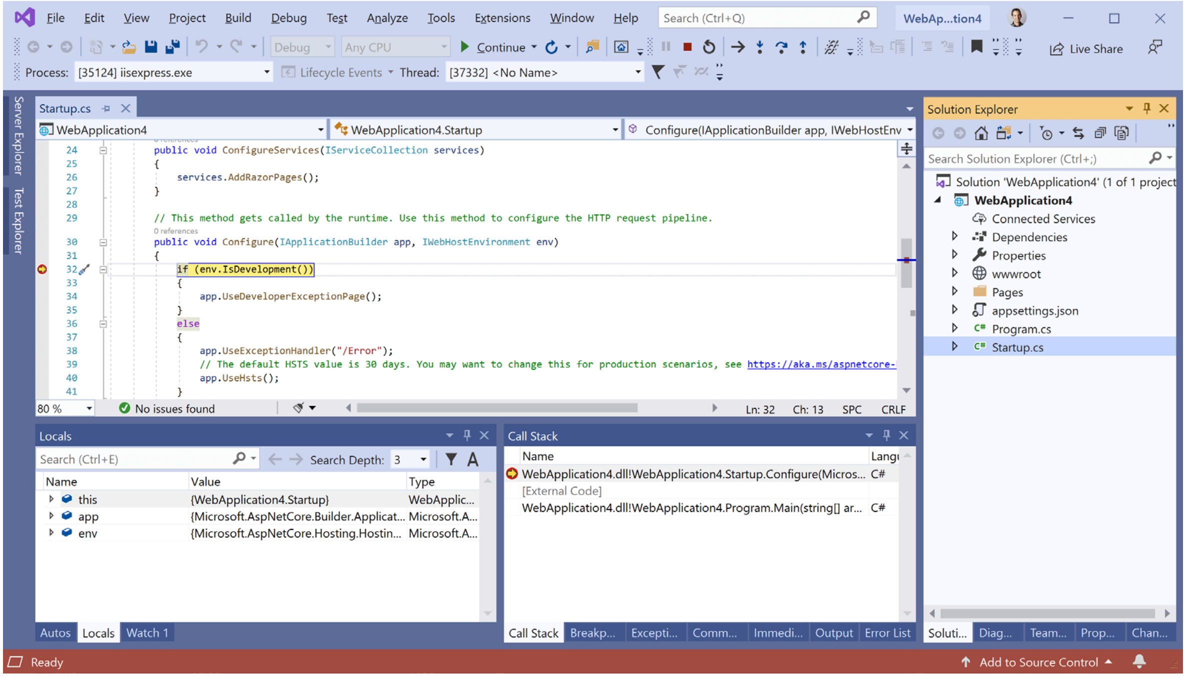
A.2 Choosing an IDE or editor

In this section I describe a few of the most popular IDEs and editors for .NET development and how to install them. Choosing an IDE is a very personal choice, so this section only describes a few of the options. If your favorite IDE isn't listed here, check the documentation to see if .NET is supported.

A.2.1 Visual Studio (Windows only)

For a long time, Windows has been the best system for building .NET applications, and with the availability of Visual Studio that's arguably still the case.

Visual Studio (figure A.2) is a full-featured integrated development environment, which provides one of the best all-around experiences for developing ASP.NET Core applications. Luckily, the Visual Studio Community edition is now free for open source, students, and small teams of developers.



```
public void ConfigureServices(IServiceCollection services)
{
    services.AddRazorPages();
}

// This method gets called by the runtime. Use this method to configure the HTTP request pipeline.
0 references
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    if (env.IsDevelopment())
    {
        app.UseDeveloperExceptionPage();
    }
    else
    {
        app.UseExceptionHandler("/Error");
        // The default HSTS value is 30 days. You may want to change this for production scenarios, see https://aka.ms/aspnetcore-
        app.UseHsts();
    }
```

Name	Value	Type
this	{WebApplication4.Startup}	WebApplic...
app	{Microsoft.AspNetCore.Builder.Applicat...	Microsoft.A...
env	{Microsoft.AspNetCore.Hosting.Hostin...	Microsoft.A...

Name	Langu
WebApplication4.dll!WebApplication4.Startup.Configure(Micros...	C#
[External Code]	
WebApplication4.dll!WebApplication4.Program.Main(string[] ar...	C#

Figure A.2 Visual Studio provides one of the most complete ASP.NET Core development environments for Windows users.

Visual studio comes loaded with a whole host of templates for building new projects, best-in-class debugging, and publishing, without ever needing to touch a command prompt. It's especially suited if you're publishing to Azure, as it has many direct hooks into Azure features to make development and deployment easier.

You can install Visual Studio by visiting https://visualstudio.microsoft.com/vs/ and clicking Download Visual Studio. Choose the Community Edition (unless you have a license for the Professional or Enterprise version) and follow the prompts to install Visual Studio.

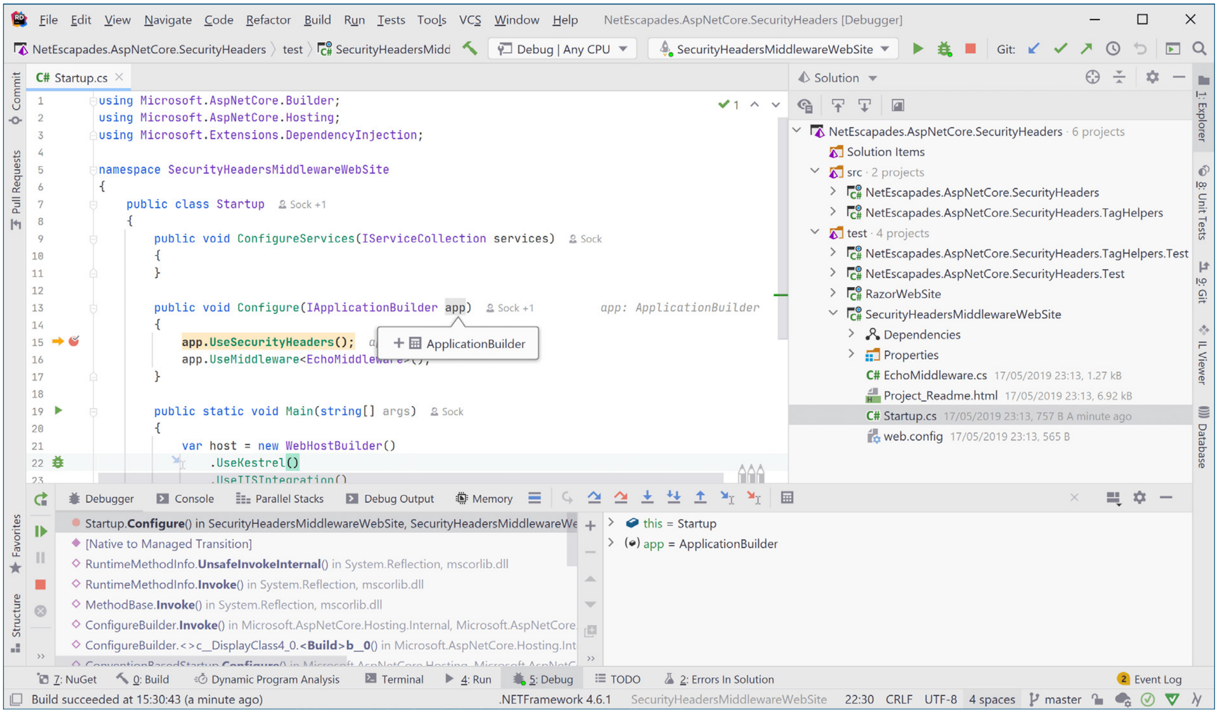
The Visual Studio *installer* is an application in-and-of-itself and will ask you to select *workloads* to install. You can select as many as you like, but for ASP.NET Core development, ensure you select at a minimum:

- ASP.NET and web development
- .NET Core cross-platform development

After selecting these workloads, click Download, and fetch a beverage of your choice. Despite having been on a diet recently, Visual Studio still requires many GB to be downloaded and installed! Once it's finished, you'll be ready to start building ASP.NET Core applications.

A.2.2 JetBrains Rider (Windows, Linux, macOS)

Rider (figure A.3), from the company JetBrains, is a cross-platform IDE alternative to Visual Studio. Released in 2017, Rider is another full-featured IDE, based on the venerable ReSharper plugin. If you're used to using Visual Studio with the ReSharper plugin, and the multitude of refactorings this plugin provides, then I strongly suggest investigating Rider. Similarly, if you're familiar with JetBrains' IntelliJ products, you will feel at home in Rider.


File Edit View Navigate Code Refactor Build Run Tests Tools VCS Window Help
NetEscapades.AspNetCore.SecurityHeaders [Debugger]
NetEscapades.AspNetCore.SecurityHeaders 〉 test 〉 SecurityHeadersMidd
Debug | Any CPU
SecurityHeadersMiddlewareWebSite
Git:
Commit
Pull Requests
Favorites
Structure
1: Explorer
8: Unit Tests
9: Git
IL Viewer
Database
Startup.cs
Solution

```
using Microsoft.AspNetCore.Builder;
using Microsoft.AspNetCore.Hosting;
using Microsoft.Extensions.DependencyInjection;

namespace SecurityHeadersMiddlewareWebSite
{
    public class Startup  Sock +1
    {
        public void ConfigureServices(IServiceCollection services)  Sock
        {
        }

        public void Configure(IApplicationBuilder app)  Sock +1        app: ApplicationBuilder
        {
            app.UseSecurityHeaders();  a
            app.UseMiddleware<EchoMiddleware>();
        }

        public static void Main(string[] args)  Sock
        {
            var host = new WebHostBuilder()
                .UseKestrel()
                .UseIISIntegration()
```

+ ApplicationBuilder

NetEscapades.AspNetCore.SecurityHeaders · 6 projects
Solution Items
src · 2 projects
NetEscapades.AspNetCore.SecurityHeaders
NetEscapades.AspNetCore.SecurityHeaders.TagHelpers
test · 4 projects
NetEscapades.AspNetCore.SecurityHeaders.TagHelpers.Test
NetEscapades.AspNetCore.SecurityHeaders.Test
RazorWebSite
SecurityHeadersMiddlewareWebSite
Dependencies
Properties
EchoMiddleware.cs 17/05/2019 23:13, 1.27 kB
Project_Readme.html 17/05/2019 23:13, 6.92 kB
Startup.cs 17/05/2019 23:13, 757 B A minute ago
web.config 17/05/2019 23:13, 565 B

Startup.**Configure**() in SecurityHeadersMiddlewareWebSite, SecurityHeadersMiddlewareWe
[Native to Managed Transition]
RuntimeMethodInfo.**UnsafeInvokeInternal**() in System.Reflection, mscorlib.dll
RuntimeMethodInfo.**Invoke**() in System.Reflection, mscorlib.dll
MethodBase.**Invoke**() in System.Reflection, mscorlib.dll
ConfigureBuilder.**Invoke**() in Microsoft.AspNetCore.Hosting.Internal, Microsoft.AspNetCore
ConfigureBuilder.<>c__DisplayClass4_0.<**Build**>b__0() in Microsoft.AspNetCore.Hosting.Int

this = Startup
app = ApplicationBuilder

Build succeeded at 15:30:43 (a minute ago)

Figure A.3 Rider is a cross-platform .NET IDE from JetBrains. It is based on the ReSharper plugin for Visual Studio, so includes many of the same refactoring features, as well as a debugger, test runner, and all the other integration features you would expect from a full-featured IDE.

To install Rider visit https://www.jetbrains.com/rider/ and click Download. Rider comes with a 30-day free trial, after which you will need to purchase a license. If you already have a ReSharper license, you may already have a license for Rider. They also offer discounts or free licenses for various users, such as students and startups, so it's worth looking into.

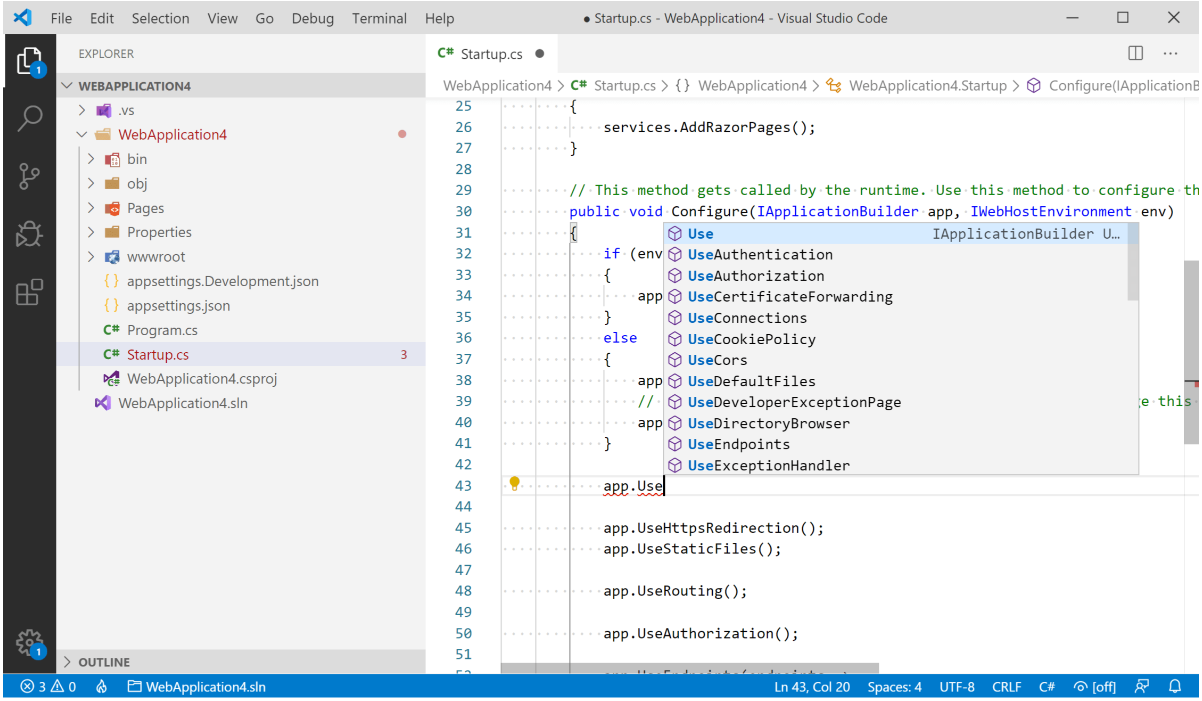
A.2.3 Visual Studio for Mac (macOS)

Despite the branding, Visual Studio for Mac is a completely different product to Visual Studio. Rebranded and extended from its Xamarin Studio precursor, you can now use Visual Studio for Mac to build ASP.NET Core applications on macOS. Visual Studio for Mac generally has fewer features than Visual Studio or Rider, but it offers a native IDE, and is under active development.

To install Visual Studio for Mac, visit https://visualstudio.microsoft.com/vs/mac/, click Download Visual Studio for Mac, and download and run the installer.

A.2.4 Visual Studio Code (Windows, Linux, macOS)

Sometimes, you don't want a full-fledged IDE. Maybe you want to quickly view or edit a file, or you don't like the sometimes-unpredictable performance of Visual Studio. In those cases, a simple editor may be all you want or need, and Visual Studio Code is a great choice. Visual Studio Code (figure A.4) is an open source, lightweight editor that provides editing, IntelliSense, and debugging for a wide range of languages, including C# and ASP.NET Core.



```
        {
            services.AddRazorPages();
        }

        // This method gets called by the runtime. Use this method to configure th
        public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
        {
            if (env
            {
                app
            }
            else
            {
                app
                //                                                          e this
                app
            }

            app.Use

            app.UseHttpsRedirection();
            app.UseStaticFiles();

            app.UseRouting();

            app.UseAuthorization();
```

Figure A.4 Visual Studio Code provides cross-platform IntelliSense and debugging.

To install Visual Studio Code, visit https://code.visualstudio.com/, click Download, and run the downloaded installer. The first time you open a folder containing a C# project or solution file with Visual Studio Code, you'll be prompted to install a C# extension. This provides the IntelliSense and integration between Visual Studio Code and the .NET SDK.

The extension model of VS Code is one of its biggest assets, as you can add a huge amount of additional functionality. Whether you're working with Azure, AWS, or any other technology, be sure to check the extension marketplace at https://marketplace.visualstudio.com/vscode to see what's available. If you search for ".NET Core", you'll also find a huge array of extensions that can bring VS Code closer to that full-blown IDE experience if you wish.

In this book, I use Visual Studio for most of the examples, but you’ll be able to follow along using any of the tools I’ve mentioned. The book assumes you’ve successfully installed .NET 5 and an editor on your computer.

Appendix B
Understanding the .NET ecosystem

This appendix covers

- **The history of .NET leading to the development of .NET Core**
- **The position of .NET 5 in the .NET ecosystem**
- **Sharing code between projects with .NET Standard**
- **The future of .NET Standard with .NET 5**

The .NET ecosystem has changed a lot since .NET was first introduced, but the development of .NET Core and .NET 5 has resulted in a particularly large degree of churn and the introduction of many new concepts.

This churn isn't surprising given Microsoft's newfound transparency regarding the development process and building in the open on GitHub. Unfortunately, it can be confusing for developers new to .NET, and even to seasoned veterans! In this appendix, I try to straighten out some of the terms that developers new to .NET often find confusing, as well as provide some context for the changes.

In this appendix I discuss the history the .NET ecosystem, how it has evolved, and the issues Microsoft was attempting to solve. As part of this, I'll discuss the similarities and differences between .NET 5, .NET Core, and .NET Framework.

.NET Core wasn't developed in isolation, and one of its primary design goals was to improve the ability to share code between multiple frameworks. In section B.2, I describe how this was achieved in pre-.NET Core/.NET 5 days, using Portable Class Libraries (PCLs) and the successor approach using .NET Standard. Finally, in section B.3, I discuss what .NET 5 means for .NET Standard.

B.1 The evolution of .NET into .NET 5

In this section I discuss the history or .NET 5 and .NET Core and why they were created. You'll learn about the various .NET platforms around in the early 2010s and why their sharding prompted the development of .NET Core as a new cross-platform runtime. Finally, you'll learn how .NET 5 has grown out of .NET Core, and the future of .NET.

B.1.1 Exploring the .NET platforms that prompted .NET Core

If you're a .NET developer, chances are you're already familiar with the .NET Framework. The .NET Framework, version 4.8 at the time of writing, is a Windows-only development platform that you can use for both desktop and web development. It's installed by default on Windows and was historically used for most desktop and server .NET development.

If you're a mobile developer, you might also be familiar with the Xamarin framework, which, until recently, used the cross-platform Mono implementation of the .NET Framework. This is an alternative *platform* to the .NET Framework that you can use to build mobile applications on Windows, Android, and iOS.

Historically, these two platforms were completely separate, but they consisted of many similar components and implemented similar APIs. Each platform contained libraries and app-models specific to their platform, but they use similar fundamental libraries and types, as shown in figure B.1.

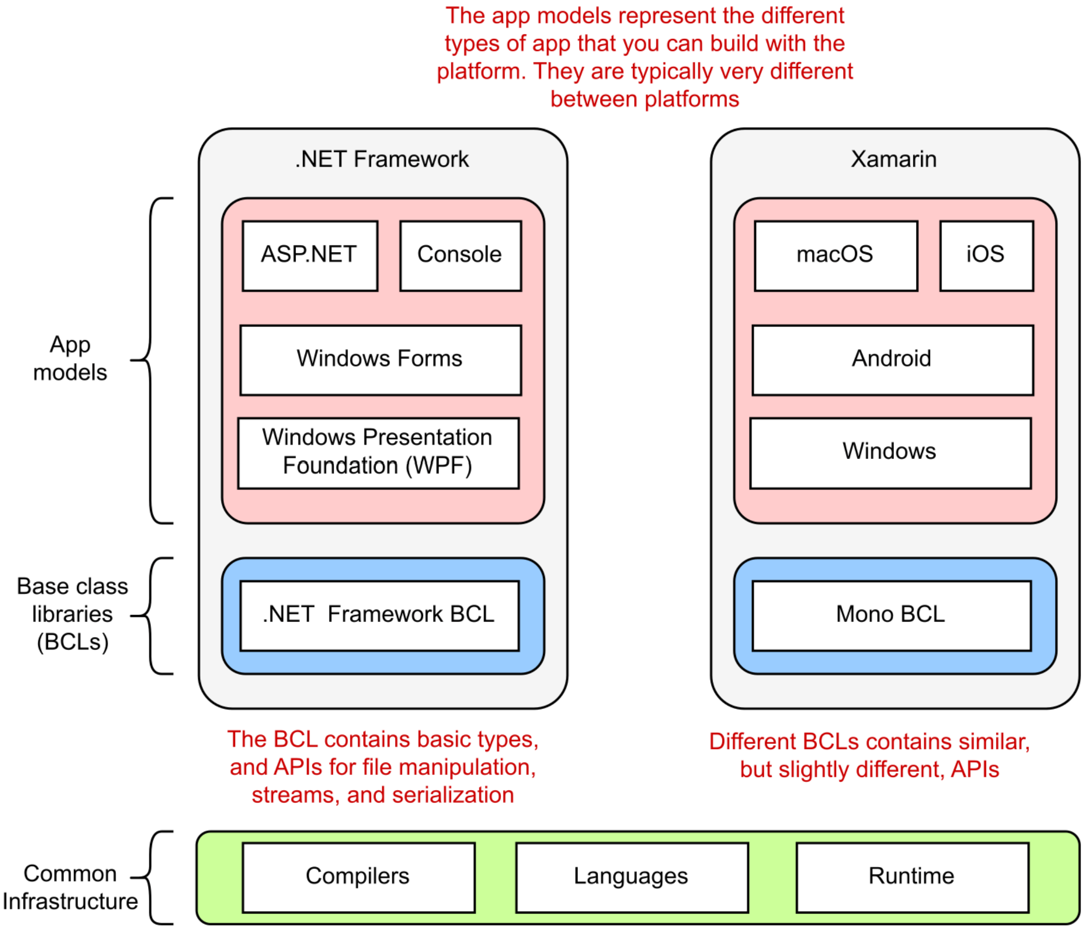

The app models represent the different types of app that you can build with the platform. They are typically very different between platforms
.NET Framework
Xamarin
App models
ASP.NET
Console
Windows Forms
Windows Presentation Foundation (WPF)
macOS
iOS
Android
Windows
Base class libraries (BCLs)
.NET Framework BCL
Mono BCL
The BCL contains basic types, and APIs for file manipulation, streams, and serialization
Different BCLs contains similar, but slightly different, APIs
Common Infrastructure
Compilers
Languages
Runtime

Figure B.1 The layers that make up the .NET Framework. Each builds on the capabilities of the layer below, with the highest layer providing the app models that you'll use to build your applications.

At the bottom of each stack is the tooling that allows you to compile and run .NET applications such as the compiler and the common language runtime (CLR). At the top of each stack, you have the app-specific libraries that you use to build applications for your platform. For example, you could build a Windows Forms app on the .NET Framework, but not using the Xamarin platform, and vice-versa for an iOS app.

In the middle of each stack you have the Base Class Libraries (BCL). These are the fundamental .NET types you use in your apps on a daily basis: the `int` and `string` types, the file-reading APIs, the `Task` APIs, and so on. Although both .NET platforms have many similar types, they’re fundamentally different, so you can’t guarantee a type will exist on both platforms, or that it will expose the same methods and properties.

I’ve only discussed two platforms so far, the .NET Framework and Xamarin, but .NET has *many* different implementations, of which these are only two. Windows also has the Windows 8/8.1 platform and the Universal Windows Platform (UWP). On phones, in addition to Xamarin, there’s the Windows Phone 8.1 and Silverlight Phone platforms. The list goes on and on (Unity, .NET Compact Framework (CF), .NET Micro …)!

Each of these platforms uses a slightly different set of APIs (classes and methods) in their BCL. Platforms have a certain number of similar APIs between them in their BCLs, but the intersection is patchy. On top of that, the libraries that make up the BCL of a platform are fundamentally not interoperable. Any source code written for a given set of APIs must be specifically recompiled for each target platform.

Several years ago, Microsoft realized this sharding of .NET was a problem. Developers had to know a *slightly* different set of APIs for each platform, and sharing code so that it could be used on more than one platform was a pain.

On top of that, the primary web development platform of the .NET Framework was showing its age. The software industry was moving toward small, lightweight, cloud-native frameworks that you could deploy in cross-platform environments. The centrally installed Windows-only .NET Framework was not designed for these scenarios. Microsoft set about developing a new framework, called “Project K” during development, which ultimately became .NET Core.

B.1.2 Introducing .NET Core

The .NET Core platform was Microsoft’s solution to the centrally installed, Windows-only .NET Framework. .NET Core is highly modular, can be deployed side-by-side with other .NET Core installations (or alternatively, distributed with the app), and is cross-platform. The term .NET Core is somewhat overloaded, in that it was used through development as a general umbrella term to describe a variety of changes. The .NET Core platform consists of

- *A cross-platform BCL*—The BCL libraries of the .NET Core platform, historically called CoreFX, contain all the primitive types and libraries for building .NET Core applications.
- *A new cross-platform runtime*—The runtime for .NET Core, called CoreCLR, which executes .NET Core applications.
- *The .NET CLI tooling*—The `dotnet` tool used for building and publishing apps.
- *The ASP.NET Core libraries*—The “app-layer” libraries, used to build ASP.NET Core applications.

These components make up the .NET Core platform and find their analogs to the various components that make up the .NET Framework and Xamarin platforms you saw in figure B.1. By creating a new platform, Microsoft was able to maintain backward compatibility for apps that used the .NET Framework, which allowed new apps to be developed using .NET Core and take advantage of its cross-platform and isolated deployment story.

NOTE You might be thinking, "Wait, they had too many .NET platforms, so they created *another* one?" If so, you're on the ball. But luckily, with .NET Core, came .NET Standard.

On its own, .NET Core would've meant *yet another* BCL of APIs for .NET developers to learn. But as part of the development of .NET Core, Microsoft introduced .NET Standard. .NET Standard, as the name suggests, ensures a *standard set* of APIs is available on every .NET platform. You no longer had to learn the specific set of APIs available for the flavor of .NET you were using; if you could use the .NET Standard APIs, you knew you'd be fine on multiple platforms. I'll talk more about .NET Standard in section B.2.

.NET Standard was a good stop-gap solution for writing code that could work on multiple platforms, but it didn't address one fundamental issue: there were still multiple platforms. Every platform had its *own separate code* that must be maintained by Microsoft, despite being *almost* identical in many places.

Microsoft was innovating quickly in .NET Core, introducing new C# features such as Async Enumerables and `Span<T>`, as well as providing many performance improvements.[113] Unfortunately, none of the other platforms could take advantage of these without significant work. Microsoft's vision for tackling this head-on was "One .NET".

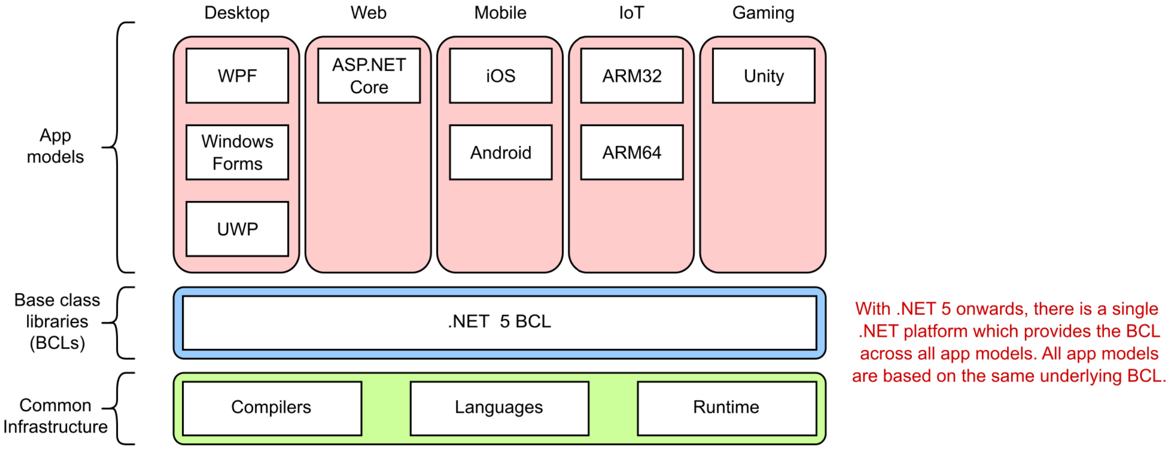
B.1.3 .NET 5: the first step in the One .NET vision

In May 2019, Microsoft announced[114] that the next major version of .NET Core after 3.0 would be .NET 5. This was the first step in their attempt to unify the .NET platform.

Previously, as I discussed in section B.1.1, you had to use .NET Framework to build Windows Desktop apps, Xamarin to build iOS or Android apps, and .NET Core to build cross-platform web apps. Each app-model was tied to the underlying platform and used a distinct BCL. The "One .NET" vision which started with.NET 5 is to have a *single* .NET platform, with a *single* BCL, which can be used with every app model: Windows Desktop apps, iOS or Android apps, as well as cross-platform web apps, as shown in figure B.2.

[113] There is a blog post on the .NET blog detailing the vast low-level improvements made to .NET Core. These are fascinating if you are into that sort of thing! You can find the .NET 5 blog post here: https://devblogs.microsoft.com/dotnet/performance-improvements-in-net-5/.

[114] You can find the announcement blog post here: https://devblogs.microsoft.com/dotnet/introducing-net-5/. This contains a lot of detail of future plans, so I strongly suggest reading it.



With .NET 5 onwards, there is a single .NET platform which provides the BCL across all app models. All app models are based on the same underlying BCL.

Figure B.2. .NET 5 provides a single platform for running multiple app models. Instead of each app model requiring a separate .NET platform, with a separate BCL, all app models will be able to use the same underlying .NET 5 platform and BCL.

Practically speaking .NET 5 really is "just" the next version of .NET Core. There are very few breaking changes moving an ASP.NET Core 3.1 application to .NET 5[115], and for the most part, the upgrade is very easy. .NET 5 adds additional features (such as gRPC and Blazor), but fundamentally not much has changed for most ASP.NET Core applications.

> **NOTE** A common point of confusion is the name: .NET 5. The "Core" moniker was dropped to try and signify "there is only one version of .NET now". Also, version 4 was skipped, to avoid confusion between the new version and .NET Framework version 4. Hopefully this naming decision will pay off in the long run, even if it's confusing now!

.NET 5 represents the first step on the road to One .NET. The hope is that basing all future development effort on one platform will reduce duplication of effort and provide both greater stability and progress for the platform. With that in mind, Microsoft have committed to a regular release cadence, so you can easily plan how to keep your apps up to date as new versions of .NET are released.

[115] You can see the list of breaking changes at https://docs.microsoft.com/en-us/dotnet/core/compatibility/3.1-5.0.

B.1.4 The future: .NET 6 and beyond

As with many open source projects, developing in the open is often associated with a faster release cycle than with the traditional .NET Framework. This was certainly the case with .NET Core, with new releases (major and minor) coming regularly for the first few years of development.

While many developers like this faster cadence and the new features it brings, it can lead to some uncertainty. Is it worth spending time upgrading to the latest version now if a new version is going to be released next week?

To counteract the potential churn, and give users confidence in continued support, each .NET Core (and subsequently, .NET) release falls into one of two *support tracks*:

- *Long Term Support (LTS).* These releases are supported for three years from their first release.
- *Current*. These releases are supported until three months after the *next* LTS or current release.

Having two supported tracks leaves you with a simple choice: if you want more features, and are happy to commit to updating your app more frequently, choose Current releases; if you want fewer updates but also fewer features, choose LTS[116].

The two-track approach went some way to alleviating uncertainty, but it still left users unsure *exactly* when a new release would occur, and hence how long the current version would be supported.

With .NET 5, Microsoft committed to a well-defined release cycle consisting of shipping a new major version of .NET every year, alternating between LTS releases and Current releases, as shown in figure B.3. Minor updates are not intended to be common but will occur in interstitial months if required.

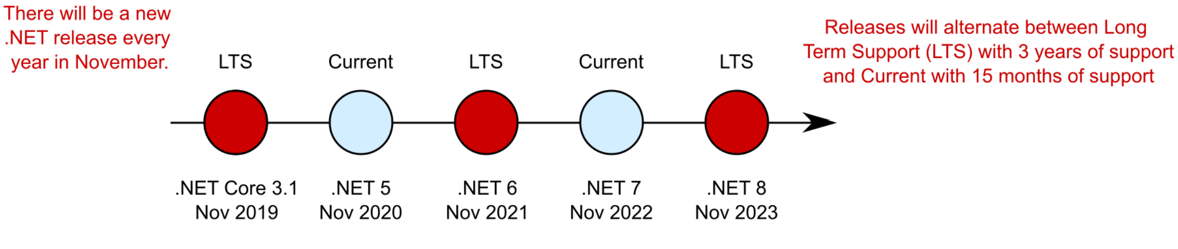

There will be a new .NET release every year in November.
LTS
Current
LTS
Current
LTS
Releases will alternate between Long Term Support (LTS) with 3 years of support and Current with 15 months of support
.NET Core 3.1 Nov 2019
.NET 5 Nov 2020
.NET 6 Nov 2021
.NET 7 Nov 2022
.NET 8 Nov 2023

Figure B.3 The timeline for releases of new .NET versions. A new .NET version will be released every year in November. Releases will alternate between Long Term Support (LTS) versions and Current release versions.

[116] For more details on .NET support policies, see https://dotnet.microsoft.com/platform/support/policy/dotnet-core.

With this timeline, you know how long a version of .NET will be supported. If you use a Current track release (such as .NET 5) you know you will be supported until 3 months after the release of .NET 6 in November 2021. As an LTS release, .NET 6 will be supported until November 2024.

The unification of multiple .NET platforms in .NET 5 means that there will be less need in future to share code between multiple platforms: that’s one of the big selling points of One .NET. Nevertheless, you will no doubt need to share code with existing legacy applications for many years, so code sharing is still a concern.

As I described in section B.1.2 .NET Standard was introduced with .NET Core as a way of sharing code between .NET Core applications and existing legacy applications. Before I dig into the details of .NET Standard, I’ll briefly discuss its predecessor, Portable Class Libraries, and why they’re now obsolete thanks to .NET Standard.

B.2 Sharing code between projects

In this section I discuss the history of sharing code between .NET platforms using Portable Class Libraries. I then introduce .NET Standard as an alternative solution that was introduced with .NET Core.

With so many different .NET implementations, the .NET ecosystem needed a way to share code between libraries, long before .NET Core was envisaged. What if you wanted to use the same classes in both your ASP.NET .NET Framework project and your Silverlight project? You’d have to create a separate project for each platform, copy and paste files between them, and recompile your code for each platform. The result was two different libraries from the same code. Portable Class Libraries (PCLs) were the initial solution to this problem.

B.2.1 Finding a common intersection with Portable Class Libraries

PCLs were introduced to make the process of compiling and sharing code between multiple platforms simpler. When creating a library, developers could specify the platforms they wanted to support, and the project would only have access to the set of APIs common among all of them. Each additional platform supported would reduce the API surface to only those APIs available in *all* the selected platforms, as shown in figure B.4.

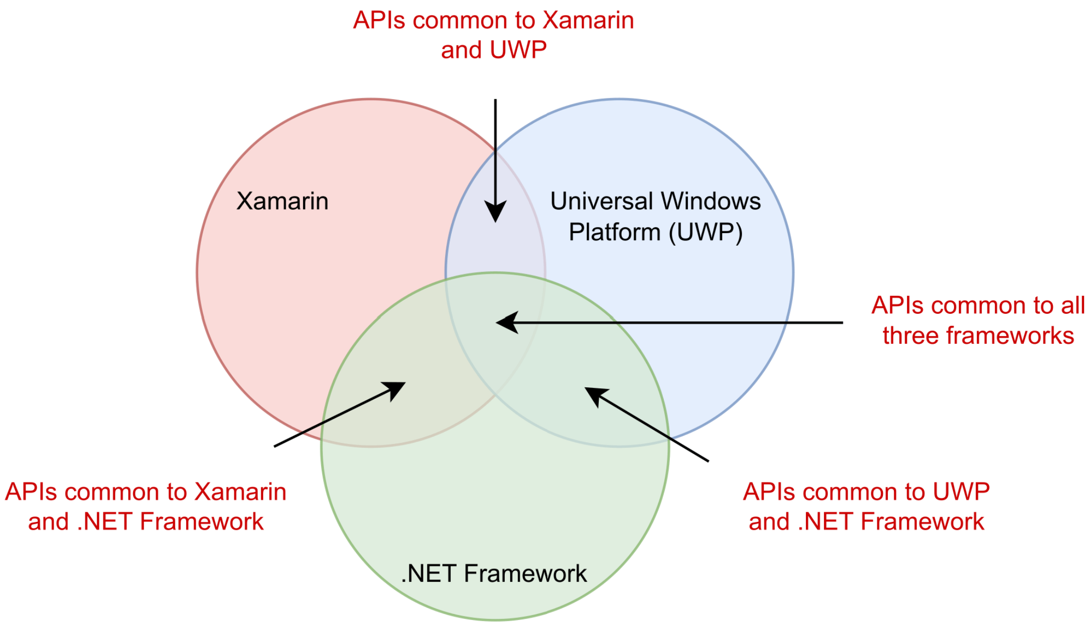

APIs common to Xamarin and UWP
Xamarin
Universal Windows Platform (UWP)
APIs common to all three frameworks
APIs common to Xamarin and .NET Framework
APIs common to UWP and .NET Framework
.NET Framework

Figure B.4 Each additional framework that must be supported by a PCL reduces the APIs available to your application. If you support multiple frameworks you have vastly fewer APIs available to you.

To create a PCL library, you'd create a library that targeted a specific PCL "profile". This profile contained a precomputed list of APIs known to be available on the associated platforms. That way, you could create one library that you could share across your selected platforms. You could have a single project and a single resulting package—no copy and paste or duplicate projects required.

This approach was a definite improvement over the previous option, but creating PCLs was often tricky. There were inherent tooling complexities to contend with and understanding the APIs available for each different combination of platforms that made up a PCL profile was difficult.[117]

On top of these issues, every additional platform you targeted would reduce the BCL API surface available for you to use in your library. For example, the .NET Framework might contain APIs A, B, and C. But if Xamarin only has API A and Windows Phone only has API C, then your library can't use any of them, as shown in figure B.5.

[117] See here for the full horrifying list: https://portablelibraryprofiles.stephencleary.com/.

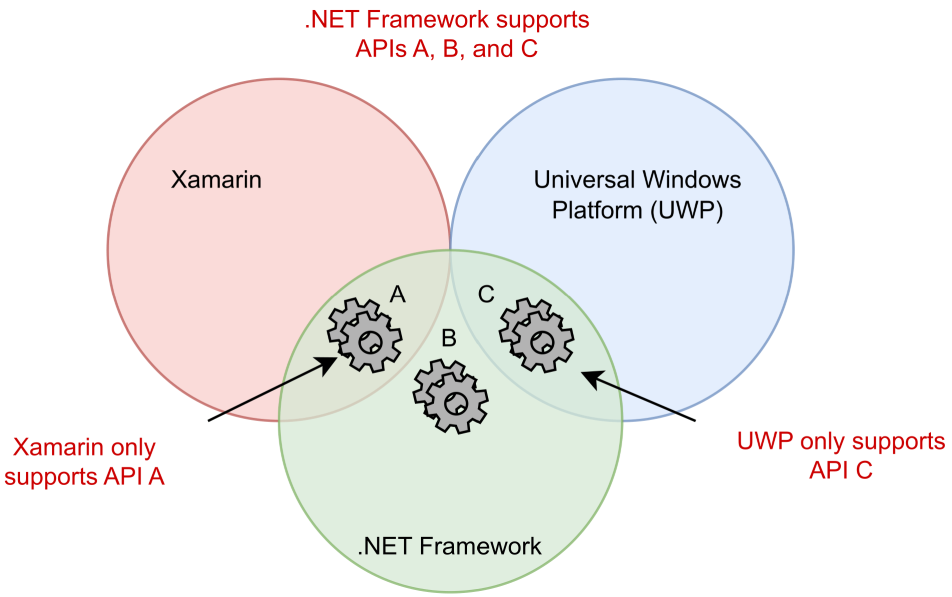


Figure B.5 Each platform exposes slightly different APIs. When creating PCLs, only those APIs that are available in all the targeted platforms are available. In this case, none of the APIs, A, B, or C, is available in all targeted platforms, so none of them can be used in the PCL.

One additional issue with PCL libraries was that they were inherently tied to the underlying platforms they targeted. In order to work with a new target platform, you'd have to recompile the PCL, even if no source code changes were required.

Say you're using a PCL library that supports Windows Phone 8.1 and .NET Framework 4.5. If Microsoft were to release a new platform, let's say, .NET Fridge, which exposes the same API as Windows Phone 8.1, you wouldn't be able to use the existing library with your new .NET Fridge application. Instead, you'd have to wait for the library author to recompile their PCL to support the new platform, and who knows when that would be!

PCLs had their day, and they solved a definite problem, but for modern development .NET Standard provides a much cleaner approach.

B.2.2 .NET Standard: a common interface for .NET

As part of the development of .NET Core, Microsoft announced .NET Standard as the successor to PCL libraries. .NET Standard takes the PCL relationship between platform support and APIs available, and flips it on its head:

- *PCLs*—A PCL profile targets a specific set of *platforms*. The APIs available to a PCL library are the common APIs shared by all the platforms in the profile.
- *.NET Standard*—A .NET Standard version defines a specific set of *APIs*. These APIs are

always available in a .NET Standard library. Any platform that implements all these APIs supports that version of .NET Standard.

.NET Standard isn't something you download. Instead, it's a list of APIs that a .NET Standard-compatible platform must implement.[118] You can create libraries that target .NET Standard, and you can use that library in any app that targets a .NET Standard-compatible platform.

.NET Standard has multiple *versions*, each of which is a superset of the previous versions. For example, .NET Standard 1.2 includes all the APIs from .NET Standard 1.1, which in turn includes all the APIs from .NET Standard 1.0, as shown in figure B.6.

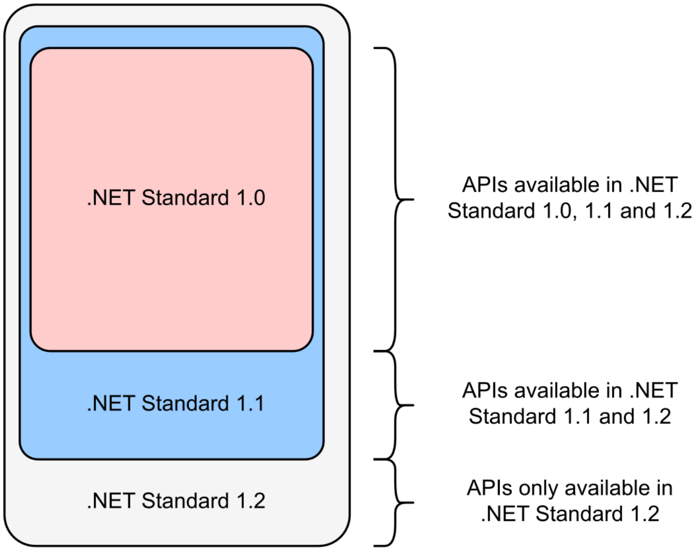

.NET Standard 1.0
.NET Standard 1.1
.NET Standard 1.2
APIs available in .NET Standard 1.0, 1.1 and 1.2
APIs available in .NET Standard 1.1 and 1.2
APIs only available in .NET Standard 1.2

Figure B.6 Each version of .NET Standard includes all the APIs from previous versions. The smaller the version of .NET Standard, the smaller the number of APIs.

When you create a .NET Standard library, you target a specific version of .NET Standard and can reference any library that targets that version or earlier. If you're writing a library that targets .NET Standard 1.2, you can reference packages that target .NET Standard 1.2, 1.1, or 1.0. Your package can in turn be referenced by any library that targets .NET Standard 1.2 or later or any library that targets a *platform that implements* .NET Standard 1.2 or later.

[118] It is, literally, a list of APIs. You can view the APIs included in each version of .NET Standard on GitHub here: https://github.com/dotnet/standard/tree/master/docs/versions. For example you can see the APIs include in .NET Standard 1.0 here: https://github.com/dotnet/standard/blob/master/docs/versions/netstandard1.0.md.

A platform implements a specific version of .NET Standard if it contains all the APIs required by that version of .NET Standard. By extension, a platform that supports a specific version of .NET Standard also supports all previous versions of .NET Standard. For example, UWP version 10 supports .NET Standard 1.4, which means it also supports .NET Standard versions 1.0-1.3, as shown in figure B.7.

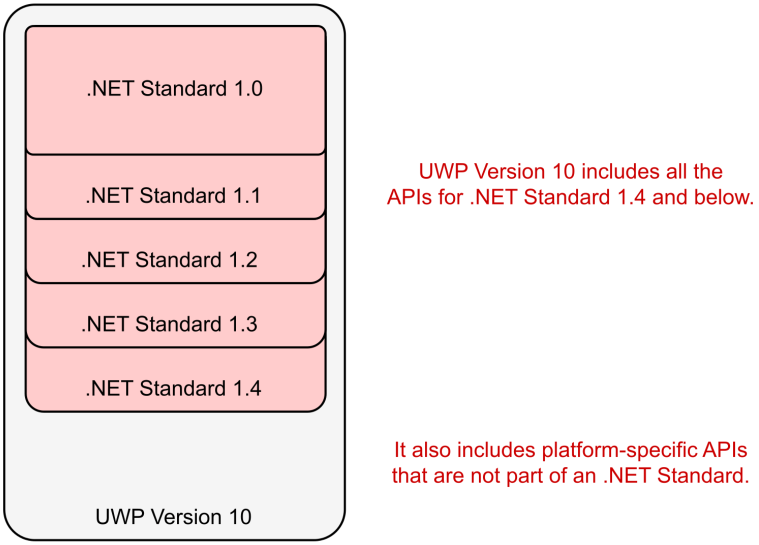

.NET Standard 1.0
.NET Standard 1.1
.NET Standard 1.2
.NET Standard 1.3
.NET Standard 1.4
UWP Version 10
UWP Version 10 includes all the APIs for .NET Standard 1.4 and below.
It also includes platform-specific APIs that are not part of an .NET Standard.

Figure B.7 The UWP Platform version 10 supports .NET Standard 1.4. That means it contains all the APIs required by the .NET Standard specification version 1.4. That means it also contains all the APIs in earlier versions of .NET Standard. It also contains additional platform-specific APIs that aren't part of any version of .NET Standard.

Each version of a platform supports a different version of .NET Standard. .NET Framework 4.5 supports .NET Standard 1.1, but .NET Framework 4.7.1 supports .NET Standard 2.0. Table B.1 shows some of the versions supported by various .NET platforms. For a more complete list, see https://docs.microsoft.com/dotnet/standard/net-standard.

Table B.1 Highest supported .NET Standard version for various .NET platform versions. A blank cell means that version of .NET Standard isn't supported on the platform.

.NET Standard Version	1.0	1.1	1.2	1.3	1.4	1.5	1.6	2.0	2.1
.NET Core	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	3.0
.NET Framework	4.5	4.5	4.5.1	4.6	4.6.1	4.6.2		4.7.1	

Mono	4.6	4.6	4.6	4.6	4.6	4.6	4.6	5.4	6.4
Windows	8.0	8.0	8.1						
Windows Phone	8.1	8.1	8.1						

A version of this table is often used to explain .NET Standard, but for me, the relationship between .NET Standard and a .NET Platform all made sense when I saw an example that explained .NET Standard in terms of C# constructs.[119]

You can think of each version of .NET Standard as a series of inherited interfaces, and the .NET platforms as implementations of one of these interfaces. In the following listing, I use the last two rows of table B.1 to illustrate this, considering .NET Standard 1.0-1.2 and looking at the Windows 8.0 platform and Windows Phone 8.1.

Listing B.1 An interpretation of .NET Standard in C#

```
interface NETStandard1_0        #A
{
   void SomeMethod();
}

interface NETStandard1_1 : NETStandard1_0       #B
{
    void OtherMethod();          #C
}

interface NETStandard1_2 : NETStandard1_1         #D
{
    void YetAnotherMethod(); #E
}

class Windows8 : NETStandard1_1                      #F
{
   void SomeMethod () { /* Method implementation */ }     #G
   void OtherMethod() { /* Method implementation */ }     #G

   void ADifferentMethod() { /* Method implementation */      #H
}

class WindowsPhone81 : NETStandard1_2          #I
{
   void SomeMethod () { /* Method implementation */ }         #J
   void OtherMethod() { /* Method implementation */ }         #J
   void YetAnotherMethod () { /* Method implementation */ }   #J

   void ExtraMethod1() { /* Method implementation */ }       #K
```

[119] The example was originally provided by David Fowler from the ASP.NET team. You can view an updated version of this metaphor here: https://github.com/dotnet/standard/blob/master/docs/metaphor.md/.

```
    void ExtraMethod2() { /* Method implementation */ }        #K
}
```

#A Defines the APIs available in .NET Standard 1.0
#B .NET Standard 1.1 inherits all the APIs from .NET Standard 1.0.
#C APIs available in .NET Standard 1.1 but not in 1.0
#D .NET Standard 1.2 inherits all the APIs from .NET Standard 1.1.
#E APIs available in .NET Standard 1.2 but not in 1.1 or 1.0
#F Windows 8.0 implements .NET Standard 1.1.
#G Implementations of the APIs required by .NET Standard 1.1 and 1.0
#H Additional APIs that aren't part of .NET Standard, but exist on the Windows 8.0 platform
#I Windows Phone 8.1 implements .NET Standard 1.2.
#J Implementations of the APIs required by .NET Standard 1.2, 1.1, and 1.0
#K Additional APIs that aren't part of .NET Standard, but exist on the Windows Phone 8.1 platform

In the same way that you write programs to use interfaces rather than specific implementations, you can target your *libraries* against a .NET Standard interface without worrying about the individual implementation details of the platform. You can then use your library with any platform that implements the required interface version.

One of the advantages you gain by targeting .NET Standard is the ability to target new platforms without having to recompile any of your libraries or wait for dependent library authors to recompile theirs. It also makes reasoning about the exact APIs available far simpler—the higher the .NET Standard version you target, the more APIs will be available to you.

> **WARNING** Even if a platform implements a given version of .NET Standard, the method implementation might throw a `PlatformNotSupportedException`. For example, some reflection APIs might not be available on all platforms. .NET 5 includes Roslyn Analyzer support to detect this situation and will warn you of the issue at build time. See https://devblogs.microsoft.com/dotnet/automatically-find-latent-bugs-in-your-code-with-net-5/ for more details about analyzers introduced in .NET 5.

Unfortunately, things are never as simple as you want them to be. Although .NET Standard 2.0 is a strict superset of .NET Standard 1.6, apps targeting .NET Framework 4.6.1 can reference .NET Standard 2.0 libraries, *even though it technically only implements .NET Standard 1.4, as shown in Table B.1*.[120]

> **WARNING** Even though .NET Framework 4.6.1 technically only implements .NET Standard 1.4, it can reference .NET Standard 2.0 libraries. This is a special case and applies only to versions 4.6.1-4.7.0. .NET Framework 4.7.1 implements .NET Standard 2.0, so it can reference .NET Standard 2.0 libraries natively.

[120] The reasoning behind this move was laid out in a post on the .NET blog which I highly recommend reading: https://devblogs.microsoft.com/dotnet/introducing-net-standard/.

The reasoning behind this move was to counteract a chicken-and-egg problem. One of the early complaints about .NET Core 1.x was how few APIs were available, which made porting projects to .NET Core tricky. Consequently, in .NET Core 2.0, Microsoft added thousands of APIs that were available in .NET Framework 4.6.1, the most widely installed .NET Framework version, and added these APIs to .NET Standard 2.0. The intention was for .NET Standard 2.0 to provide the same APIs as .NET Framework 4.6.1.

Unfortunately, .NET Framework 4.6.1 *doesn't* contain the APIs in .NET Standard 1.5 or 1.6. Given .NET Standard 2.0 is a strict superset of .NET Standard 1.6, .NET Framework 4.6.1 can't support .NET Standard 2.0 directly.

This left Microsoft with a problem. If the most popular version of the .NET Framework didn't support .NET Standard 2.0, no one would write .NET Standard 2.0 libraries, which would hamstring .NET Core 2.0 as well. Consequently, Microsoft took the decision to *allow .NET Framework 4.6.1 to reference .NET Standard 2.0 libraries*, as shown in figure B.8.

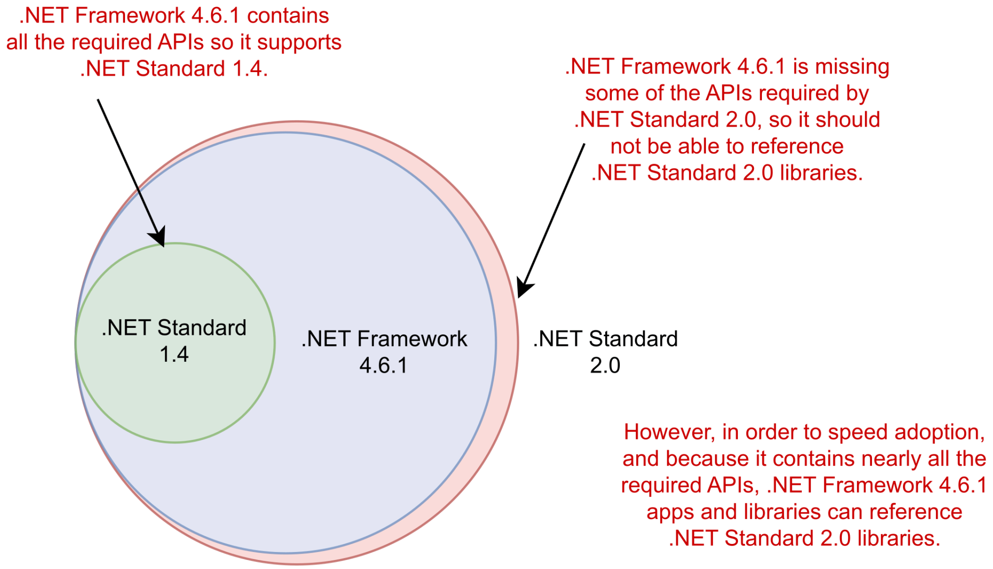

.NET Framework 4.6.1 contains all the required APIs so it supports .NET Standard 1.4.
.NET Framework 4.6.1 is missing some of the APIs required by .NET Standard 2.0, so it should not be able to reference .NET Standard 2.0 libraries.
.NET Standard 1.4
.NET Framework 4.6.1
.NET Standard 2.0
However, in order to speed adoption, and because it contains nearly all the required APIs, .NET Framework 4.6.1 apps and libraries can reference .NET Standard 2.0 libraries.

Figure B.8 NET Framework 4.6.1 doesn't contain the APIs required for .NET Standard 1.5, 1.6, or 2.0. But it contains *nearly* all the APIs required for .NET Standard 2.0. In order to speed up adoption and to make it easier to start using .NET Standard 2.0 libraries, you can reference .NET Standard 2.0 libraries for a .NET Framework 4.6.1 app.

All this leads to some fundamental technical difficulties. .NET Framework 4.6.1 can reference .NET Standard 2.0 libraries, even though it *technically* doesn't support them, but you must have the .NET Core 2.0 SDK installed to ensure everything works correctly.

To blur things even further, libraries compiled against .NET Framework 4.6.1 can be referenced by .NET Standard libraries through the use of a compatibility shim, as I describe in the next section.

B.2.3 Fudging .NET Standard 2.0 support with the compatibility shim

Microsoft's plan for .NET Standard 2.0 was to make it easier to build .NET Core apps. If users built libraries targeting .NET Standard 2.0, then they could still use them in their .NET Framework 4.6.1 apps, but they could also use the libraries in their .NET Core apps.

The problem was that when .NET Standard 2.0 was first released, no libraries (NuGet packages) would implement it yet. Given .NET Standard libraries can only reference other .NET Standard libraries, you'd have to wait for all your dependencies to update to .NET Standard, who would have to wait for *their* dependencies first, and so on.

To speed things up, Microsoft created a compatibility shim. This shim allows a .NET Standard 2.0 library to *reference .NET Framework 4.6.1 libraries*. Ordinarily, this sort of reference wouldn't be possible; .NET Standard libraries can only reference .NET Standard libraries of an equal or lower version, as shown in figure B.9.[121]

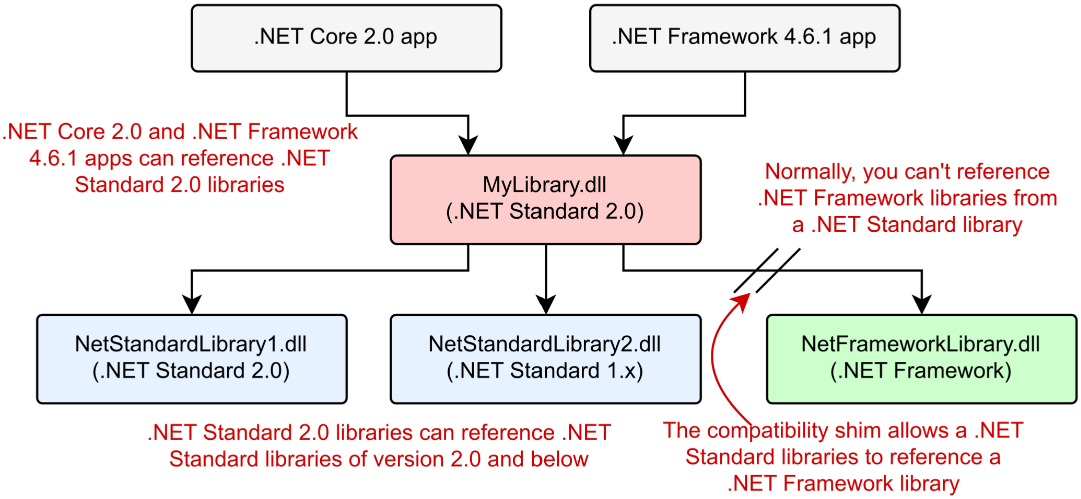

.NET Core 2.0 app
.NET Framework 4.6.1 app
.NET Core 2.0 and .NET Framework 4.6.1 apps can reference .NET Standard 2.0 libraries
MyLibrary.dll (.NET Standard 2.0)
Normally, you can't reference .NET Framework libraries from a .NET Standard library
NetStandardLibrary1.dll (.NET Standard 2.0)
NetStandardLibrary2.dll (.NET Standard 1.x)
NetFrameworkLibrary.dll (.NET Framework)
.NET Standard 2.0 libraries can reference .NET Standard libraries of version 2.0 and below
The compatibility shim allows a .NET Standard libraries to reference a .NET Framework library

Figure B.9 By default, .NET Standard libraries can only reference other .NET Standard libraries, targeting the same .NET Standard version or lower. With the compatibility shim, .NET Standard libraries can also reference libraries compiled against .NET Framework 4.6.1.

[121] The process by which this magic is achieved is complicated. This article describes the process of assembly unification in detail: https://github.com/dotnet/standard/blob/master/docs/planning/netstandard-2.0/README.md

By enabling this shim, suddenly .NET Core 2.0 apps could use any of the many .NET Framework 4.6.1 (or lower) NuGet libraries available. As long as the referenced library stuck to APIs which are part of .NET Standard 2.0, you'd be able to reference .NET Framework libraries in your .NET Core 2+ apps or .NET Standard 2.0 libraries, even if your app runs cross-platform on Linux or macOS.

> **WARNING** If the library uses .NET Framework-specific APIs, you'll get an exception at runtime. There's no easy way of knowing whether a library is safe to use, short of examining the source code, so the .NET tooling will raise a warning every time you build. Be sure to thoroughly test your app if you rely on this shim.

If your head is spinning at this point, I don't blame you. This was a particularly confusing point in the evolution of .NET Standard, in which rules were being bent to fit the current environment. This inevitably led to various caveats and hand-waving, followed by bugs and fixes[122]! Luckily, if your development is focused on .NET 5, .NET Standard is not something you will generally have to worry about.

B.3 .NET 5 and the future of .NET Standard

In this section I discuss what .NET 5 means for the future of .NET Standard and the approach you should take for new applications targeting .NET 5.

> **NOTE** The advice in this section is based on official guidance from Microsoft regarding the future of .NET Standard here https://devblogs.microsoft.com/dotnet/the-future-of-net-standard/.

.NET Standard was necessary when .NET Core was a young framework, to ensure you still had access to the existing NuGet package ecosystem. .NET 5 is an evolution of .NET Core, so you can take advantage of that same ecosystem in .NET 5.

.NET 5 implements .NET Standard 2.1, the latest version of the standard, which is also implemented by .NET Core 3.0. That means .NET 5 applications can reference:

- Any NuGet package or library that implements .NET Standard 1.0-2.1.
- Any.NuGet package or library that implements .NET Core 1.x-3.x

.NET Standard was designed to handle code-sharing between multiple .NET platforms. But the release of .NET 5, and the "One .NET" vision, specifically aims to have only a *single* platform. Is .NET Standard still useful?

Yes and no. From .NET 5 onwards, no more versions of .NET Standard are planned, as subsequent versions of .NET (for example. .NET 7) will already be able to reference libraries targeting earlier versions of .NET (such as .NET 5 and .NET 6).

[122] You can find an example of one such issue here, but there were, unfortunately, many similar cases: https://github.com/dotnet/runtime/issues/29314.

.NET Standard will remain useful when you need to share code between .NET 5+ applications and legacy (.NET Core, .NET Framework, Xamarin) applications. .NET Standard remains the mechanism for this cross-.NET platform code sharing.

B.4 Summary

- .NET has many different implementations, including the .NET Framework, Mono, and Unity. Each of these is a separate platform with separate Base Class Libraries (BCLs) and app models. .NET Core is another separate platform.
- Each platform has a BCL that provides fundamental .NET types and classes such as strings, file manipulation, and streams. Each platform has a slightly different BCL.
- .NET 5 is the first step in unifying these platforms, most notable Mono (and hence Xamarin) and .NET Core, under the One .NET vision. App models currently associated with other platforms will be made available on the new .NET 5+ platform.
- .NET will see a new major release every year. These will alternate between Long Term Support releases, which receive 3 years of support, and Current releases, which receive 15 months support.
- Portable Class Libraries (PCLs) attempted to solve the problem of sharing code between .NET platforms by allowing you to write code to the logical intersection of each platform's BCL. Each additional platform you targeted meant fewer BCL APIs in common.
- .NET Standard defines a standard set of APIs that are available across all platforms that support it. You can write libraries that target a specific version of .NET Standard and they'll be compatible with any platform that supports that version of .NET Standard.
- Each version of .NET Standard is a superset of the previous. For example, .NET Standard 1.2 includes all the APIs from .NET Standard 1.1, which in turn includes all the APIs from .NET Standard 1.0.
- Each version of a platform supports a specific version of .NET Standard. For example, .NET Framework 4.5.1 supports .NET Standard 1.2 (and hence also .NET Standard 1.1 and 1.0).
- .NET Framework 4.6.1 technically only supports .NET Standard 1.4. Thanks to a compatibility shim, you can reference .NET Standard 2.0 libraries from a .NET Framework 4.6.1 app. Similarly, you can reference a .NET Framework library from a .NET Standard 2.0 library, which wouldn't be possible without the shim.
- If you rely on the compatibility shim to reference a .NET Framework 4.6.1 library from a .NET Standard 2.0 library, and the referenced library uses .NET Framework-specific APIs, you'll get an exception at runtime.
- An app must target a .NET platform implementation, such as .NET 5 or .NET Core 3.1. It can't target .NET Standard.
- .NET 5 supports .NET Standard 2.1. It can reference any .NET Standard library, and any .NET Core library.

Appendix C
Useful references

In this appendix, I provide a number of links and references that I've found useful for learning about .NET Core/.NET 5, .NET Standard, and ASP.NET Core.

C.1 Relevant books

In this book, we touched on several topics and aspects of the .NET ecosystem that are somewhat peripheral to building ASP.NET Core applications. For a deeper understanding of those topics, I recommend the books in this section. They cover areas that you'll inevitably encounter when building ASP.NET Core applications:

- Khorikov, Vladimir. Unit Testing Principles, Patterns, and Practices. Manning, 2020. https://livebook.manning.com/book/unit-testing. Learn to refine your unit tests using modern best practices in this excellent book that contains examples in C#.
- Metzgar, Dustin. *.NET Core in Action*. Manning, 2018. https://livebook.manning.com/book/dotnet-core-in-action. ASP.NET Core apps are built using .NET Core and .NET 5. .NET Core in Action provides everything you need to know about running on the platform.
- Osherove, Roy. *The Art of Unit Testing*, second edition. Manning, 2013. https://livebook.manning.com/book/the-art-of-unit-testing-second-edition. In this book (*ASP.NET Core in Action*), I discuss the mechanics of unit testing ASP.NET Core applications. For a deeper discussion of how to create your tests, I recommend *The Art of Unit Testing*.
- Sainty, Chris. *Blazor in Action*. Manning, 2021. https://livebook.manning.com/book/blazor-in-action. Blazor is an exciting new framework that uses the power of industry standard WebAssembly to run .NET in the browser. With Blazor you can build single-page applications, just as you would with a JavaScript framework like Angular or React, but using the C# language and tooling that

you already know.

- Smith, Jon P. *Entity Framework Core in Action,* second edition. Manning, 2021*.* https://livebook.manning.com/book/entity-framework-core-in-action-second-edition. If you're using EF Core in your apps, I highly recommend *Entity Framework Core in Action*. It covers all the features and pitfalls of EF Core, as well as how to tune your app for performance.
- Van Deursen, Steven, and Mark Seemann, *Dependency Injection Principles, Practices, and Patterns*. Manning, 2019. https://livebook.manning.com/book/dependency-injection-principles-practices-patterns. Dependency injection is a core aspect of ASP.NET Core, so *Dependency Injection Principles, Practices, and Patterns* is especially relevant now. It introduces the patterns and antipatterns of dependency injection in the context of .NET and the C# language.

C.2 Announcement blog posts

When Microsoft releases a new version of ASP.NET Core or .NET Core, they typically write an announcement blog post. These posts provide a high-level overview of the topic, with many examples of new features. They're a great place to start if you want to quickly get acquainted with a topic:

- De la Torre, Cesar. "Web Applications with ASP.NET Core Architecture and Patterns guidance (Updated for .NET Core 2.0)," *.NET Blog* (blog), Microsoft, August 9, 2017, http://mng.bz/t415. Blog post introducing a free e-book on how to architecture modern web apps using ASP.NET Core and Azure.
- Fritz, Jeffrey T. "Announcing ASP.NET Core 2.0," *.NET Blog* (blog), Microsoft, August 14, 2017, http://mng.bz/0004. Announcement blog post for ASP.NET Core 2.0. Describes how to upgrade a project from 1.x to 2.0 and introduces some of the features specific to ASP.NET Core 2.0.
- Lander, Rich. "Announcing .NET Core 2.0," *.NET Blog* (blog), Microsoft, August 14, 2017, https://blogs.msdn.microsoft.com/dotnet/2017/08/14/ announcing-net-core-2-0/. Announcement blog post for .NET Core 2.0, describing the new features compared to .NET Core 1.x.
- Lander, Rich. "Introducing .NET 5". *.NET Blog (blog)*, Microsoft, May 6, 2019, https://devblogs.microsoft.com/dotnet/introducing-net-5/. The announcement blog post for .NET 5, describing the vision for the platform.
- Landwerth, Immo. "The future of .NET Standard," *.NET Blog* (blog), Microsoft, September 15, 2020, https://devblogs.microsoft.com/dotnet/the-future-of-net-standard/. A discussion on what .NET 5 means for the future of .NET Standard, including guidance for library authors.
- Landwerth, Immo. ".NET Standard—Demystifying .NET Core and .NET Standard," *Microsoft Developer Network*, Microsoft, September, 2017, https://msdn.microsoft.com/en-us/magazine/mt842506.aspx. Long post explaining

introducing .NET Core and explaining where .NET Standard fits in the .NET -ecosystem.

- Microsoft, ".NET Core and .NET 5 Support Policy,"
- Microsoft Docs, ".NET Core and .NET 5 Support Policy." Microsoft. https://dotnet.microsoft.com/platform/support/policy/dotnet-core. Microsoft's official support policy for .NET Core and .NET 5.

C.3 Microsoft documentation

Historically, Microsoft documentation has been poor, but with ASP.NET Core there has been a massive push to ensure the docs are useful and current. You can find walkthroughs, targeted documentation for specific features, documentation for supported APIs, and even an in-browser C# compiler:

- Microsoft Docs, ".NET API Browser." Microsoft Docs. https://docs.microsoft.com/dotnet/api/. This is an API browser, which can be used to work out which .NET APIs are available on which .NET platforms.
- Miller, Rowan, Brice Lambson, Maria Wenzel, Diego Vega, and Martin Milan. "Entity Framework Core Quick Overview." Microsoft Docs. September 20, 2020. https://docs.microsoft.com/ef/core/. This is the official documentation for EF Core.
- Microsoft. "Introduction to ASP.NET Core." Microsoft Docs. https://docs.microsoft.com/aspnet/core/. This is the official documentation for ASP.NET Core.
- Microsoft Docs, "Cross-platform targeting", Microsoft Docs. https://docs.microsoft.com/dotnet/standard/library-guidance/cross-platform-targeting. The official guidance on choosing a target framework for your libraries.

C.4 Security-related links

Security is an important aspect of modern web development. This section contains some of the references I refer to regularly, which describe some best practices for web development, as well as practices to avoid:

- Allen, Brock, and Dominick Baier. "IdentityServer4 1.0.0 documentation." https://identityserver4.readthedocs.io/. Documentation for IdentityServer, the OpenID Connect and OAuth 2.0 framework for ASP.NET Core.
- Baier, Dominick. *Dominick Baier on Identity & Access Control* (blog). https://leastprivilege.com/. The personal blog of Dominick Baier, co-author of IdentityServer. A great resource when working with authentication and authorization in ASP.NET Core.
- Microsoft Docs. "Overview of ASP.NET Core Security." Microsoft Docs. October 24, 2018. https://docs.microsoft.com/aspnet/core/security/. The home page of the official ASP.NET Core documentation for all things security related.
- Helme, Scott. *Scott Helme* (blog). https://scotthelme.co.uk/. Scott Helme's blog, with advice on security standards, especially security headers you can add to your

application.

- Helme, Scott. "SecurityHeaders.io—Analyse your HTTP response headers.". https://securityheaders.com/. Test your website's security headers, and get advice on why and how you should add them to your app.
- Hunt, Troy. *Troy Hunt* (blog). https://www.troyhunt.com. Personal blog of Troy Hunt with security-related advice for web developers, particularly .NET developers.

C.5 ASP.NET Core GitHub repositories

ASP.NET Core is entirely open source and developed on GitHub. One of the best ways I've found to learn about the framework is to browse the source code itself. This section contains the main repositories for ASP.NET Core, .NET Core, and EF Core:

- .NET Foundation. ".NET Runtime." The .NET CoreCLR runtime and BCL libraries, as well as extension libraries. https://github.com/dotnet/runtime.
- .NET Foundation. ".NET SDK and CLI." The .NET command line interface (CLI), assets for building the .NET SDK, and project templates. https://github.com/dotnet/sdk.
- .NET Foundation. "ASP.NET Core" The framework libraries that make up ASP.NET Core. https://github.com/dotnet/aspnetcore.
- .NET Foundation. "Entity Framework Core." The EF Core library. https://github.com/dotnet/efcore.

C.6 Tooling and services

This section contains links to tools and services you can use to build ASP.NET Core projects:

- .NET SDK: https://dotnet.microsoft.com/download.
- Cloudflare is a global content delivery network you can use to add caching and HTTPS to your applications for free https://www.cloudflare.com/.
- Let's Encrypt is a free, automated, and open Certificate Authority. You can use it to obtain free SSL certificates to secure your application: https://letsencrypt.org/.
- Rehan Saeed, Muhammed. ".NET Boxed" https://github.com/Dotnet-Boxed/Templates. A comprehensive collection of templates to get started with ASP.NET Core, preconfigured with many best practices.
- Visual Studio, Visual Studio for Mac, and Visual Studio Code: https://www.visualstudio.com/.
- JetBrains Rider: https://www.jetbrains.com/rider/.

C.7 ASP.NET Core blogs

This section contains blogs that focus on ASP.NET Core. Whether you're trying to get an overview of a general topic, or trying to solve a specific problem, it can be useful to have multiple viewpoints on a topic.

- .NET Team. *.NET Blog (blog)*. Microsoft, https://blogs.msdn.microsoft.com/dotnet. The

.NET team’s blog, lots of great links.

- Alcock, Chris. *The Morning Brew (blog)*. http://blog.cwa.me.uk/. A collection of .NET-related blog posts, curated daily.
- Boden, Damien. *Software Engineering (blog)*. https://damienbod.com/. Excellent blog by Microsoft MVP Damien Boden on ASP.NET Core, lots of posts about ASP.NET Core with Angular.
- Brind, Mike. *Mikesdotnetting (blog).* https://www.mikesdotnetting.com/*.* Mike Brind has many posts on ASP.NET Core, especially focused on ASP.NET Core Razor Pages.
- Hanselman, Scott. *Scott Hanselman (blog)*. https://www.hanselman.com/blog/. Renowned speaker Scott Hanselman’s personal blog. A highly diverse blog focused predominantly on .NET.
- Lock, Andrew. *.NET Escapades (blog).* https://andrewlock.net*.* My personal blog focused on ASP.NET Core.
- Pine, David. *IEvangelist (blog)*. http://davidpine.net/. Personal blog of Microsoft MVP David Pine, with lots of posts on ASP.NET Core.
- Rehan Saeed, Muhammed. *Muhammed Rehan Saeed (blog)*. https://rehansaeed.com. Personal blog of Muhammad Rehan Saeed, Microsoft MVP and author of the .NET Boxed project (linked in section C.6).
- Strahl, Rick. *Rick Strahl’s Web Log (blog)*. https://weblog.west-wind.com/. Excellent blog by Rick Strahl covering a wide variety of ASP.NET Core topics.
- Gordon, Steve. *Steve Gordon – Code with Steve (blog)*. https://www.stevejgordon.co.uk/. Personal blog of Steve Gordon focused on .NET. Often focused on writing high-performance code with .NET.
- Wojcieszyn, Filip. *StrathWeb (blog)*. https://www.strathweb.com. Lots of posts on ASP.NET Core and ASP.NET from Filip, a Microsoft MVP.
- Abuhakmeh, Khalid. *Abuhakmeh (blog)*. https://khalidabuhakmeh.com/. A wide variety of posts from Khalid, focused on .NET and software development in general.

C.8 Video links

If you prefer video for learning a subject, I recommend checking out the links in this section. In particular, the ASP.NET Core community standup provides great insight into the changes you’ll see in future ASP.NET Core versions, straight from the team building the framework.

- .NET Foundation. “.NET Community Standup.” https://dotnet.microsoft.com/platform/community/standup. Weekly videos with the ASP.NET Core team discussing development of the framework. Also includes standups with the .NET team, the Xamarin team, and the EF Core team.
- Landwerth, Immo. “.NET Standard—Introduction.” YouTube video, 10:16 minutes. Posted November 28, 2016 https://www.youtube.com/watch?v=YI4MurjfMn8. The first video in an excellent series on .NET standard.
- Microsoft. “Channel 9: Videos for developers from the people building Microsoft

products and services." https://channel9.msdn.com/. Microsoft's official video channel. Contains a huge number of videos on .NET and ASP.NET Core, among many others.

- Wildermuth, Shawn. "Building a Web App with ASP.NET Core, MVC, Entity Framework Core, Bootstrap, and Angular." Pluralsight course, 9:52 hours. Posted October 7, 2019. https://www.pluralsight.com/courses/aspnetcore-mvc-efcore-bootstrap-angular-web. Shawn Wildermuth's course on building an ASP.NET Core application.
- Gordon, Steve, "Integration Testing ASP.NET Core Applications: Best Practices". Pluralsight course, 3:25 hours. Posted July 15, 2020. https://www.pluralsight.com/courses/integration-testing-asp-dot-net-core-applications-best-practices. One of several courses from Steve Gordon providing guidance and advice on building ASP.NET Core applications