

EVERYTHING YOU NEED
TO BUILD REAL PROJECTS
WITH REDUX



THE COMPLETE **REDUX** BOOK

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The Complete Redux Book

Everything you need to build real projects with Redux

Ilya Gelman and Boris Dinkevich

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Should I Read This Book?

There are many tutorials and blog posts about Redux on the Internet. The library also has great official documentation. This book isn't supposed to be either a tutorial or documentation. The goal is to provide a methodical explanation of Redux core concepts and how those can be extended and used in large and complex Redux applications.

As a frontend consultancy, we help dozens of companies build great projects using Redux. Many projects face the same problems and ask the same questions. How should we structure the application? What is the best way to implement server communication? What is the best solution for form validation? Where should we handle side effects? How will Redux benefit our applications?

This book is intended to serve as a companion for developers using Redux on a daily basis. It aims to give answers to many of the above questions and provide solutions to the most common problems in real-world applications. It can be used to learn Redux from the ground up, to better understand the structure of a large application, and as a reference during development.

The book is structured in a way that doesn't force the reader to read it start to finish but rather allows you to skip parts and come back to them when you face the problem at hand or have free time to deepen your knowledge. We love Redux, and we have tried to share our excitement about it in this book. We hope that you will find it useful.

How to Read This Book

While Redux in itself is a small library, the underlying concepts and the ecosystem around it are large and complex. In this book we cover the core and common concepts and methods a developer needs to work with Redux on both small and large-scale applications.

The book is separated into three parts. In the first part you will learn the basics of Redux. [Chapter 1](#) covers the core concepts behind Redux, introducing the different “actors” and how it is built. In [Chapter 2](#), we build an example project step by step; here, you will learn how to use Redux in a project.

The second part of the book is about examples and use cases from real applications. Redux has a great ecosystem, and there are a lot of tips, tricks, and libraries that can be applied to many projects of different scale. We provide you with solutions for common problems including server communications, authorization, internationalization, routing, forms, wizards, and more.

The third part is a deep dive into Redux usage. It is separated into chapters by Redux entity types: actions, middleware, reducers, and the store and store enhancers. The chapters in this section include advanced explanations of Redux internals and how to properly use them in complex scenarios, and they are a must-read for anyone considering building large applications with Redux.

It is highly recommended that you start by reading the first part as a whole. Even if you already have knowledge of Redux and have used it, the opening chapters will clarify all the underlying concepts and lay down the groundwork for the code we will use throughout the second and third parts of the book.

No matter who you are—an explorer learning about Redux for fun, or a hard-working professional who needs to solve real problems fast—this book will provide new ideas and insights to help you on your path.

Acknowledgements

Writing a technical book on a popular JavaScript library nowadays isn't a simple task. New techniques, best practices and opinions keep popping up every other week. Combined with daily job and a family makes it even harder. The only way we could succeed is with a help from other awesome people along the way.

To Redux creators, Dan Abramov and Andrew Clark, as well as to many contributors to Redux and its ecosystem, thank you for improving data management and making this book relevant.

To our technical copyeditor, [Rachel Head](#)¹, thank you so much for fixing our English and making this book more understandable.

To all our colleagues at [500Tech](#)², thanks for being awesome and making us feel good everyday.

And obviously thank you, our dear reader, for deciding to spend your time and money on reading this book. We hope you enjoy reading it as much as we did writing it.

Boris & Ilya

¹<https://fr.linkedin.com/in/rachel-head-a45258a2>

²<http://500tech.com>

Code Repository

The code samples from this book are available in the book repository on Github and should work in all modern browsers.

<https://github.com/redux-book>

Part 1. Introduction to Redux

Chapter 1. Core Concepts of Flux and Redux

Penicillin, x-rays, and the pacemaker are famous examples of [unintended discoveries](#)³. Redux, in a similar way, wasn't meant to become a library, but turned out to be a great Flux implementation. In May 2015, one of its authors, [Dan Abramov](#)⁴, submitted a talk to the ReactEurope conference about “hot reloading and time travel.” He admits he had no idea how to implement time travel at that point. With some help from [Andrew Clark](#)⁵ and inspired by some elegant ideas from the [Elm](#)⁶ language, Dan eventually came up with a very nice architecture. When people started catching on to it, he decided to market it as a library.

In less than half a year, that small (only 2 KB) library became the go-to framework for React developers, as its tiny size, easy-to-read code, and very simple yet neat ideas were much easier to get to grips with than competing Flux implementations. In fact, Redux is not exactly a Flux library, though it evolved from the ideas behind Facebook's Flux architecture. The official definition of [Redux](#)⁷ is a *predictable state container for JavaScript applications*. This simply means that you store all of your application state in one place and can know what the state is at any given point in time.

What Is Flux?

Before diving into Redux, we should get familiar with its base and predecessor, the *Flux architecture*. “Flux” is a generic architecture or pattern, rather than a specific implementation. Its ideas were first introduced publicly by Bill Fisher and Jing Chen at the Facebook F8 conference in April 2014. Flux was touted as redefining the previous ideas of MVC (Model–View–Controller) and MVVM (Model–View–ViewModel) patterns and two-way data binding introduced by other frameworks by suggesting a new flow of events on the frontend, called the *unidirectional data flow*.

In Flux events are managed one at a time in a circular flow with a number of actors: dispatcher, stores, and actions. An *action* is a structure describing any change in the system: mouse clicks, timeout events, Ajax requests, and so on. Actions are sent to a *dispatcher*, a single point in the system where anyone can submit an action for handling. The application state is then maintained in *stores* that hold parts of the application state and react to commands from the dispatcher.

³<http://www.businessinsider.com/these-10-inventions-were-made-by-mistake-2010-11?op=1&IR=T>

⁴<http://survivejs.com/blog/redux-interview/>

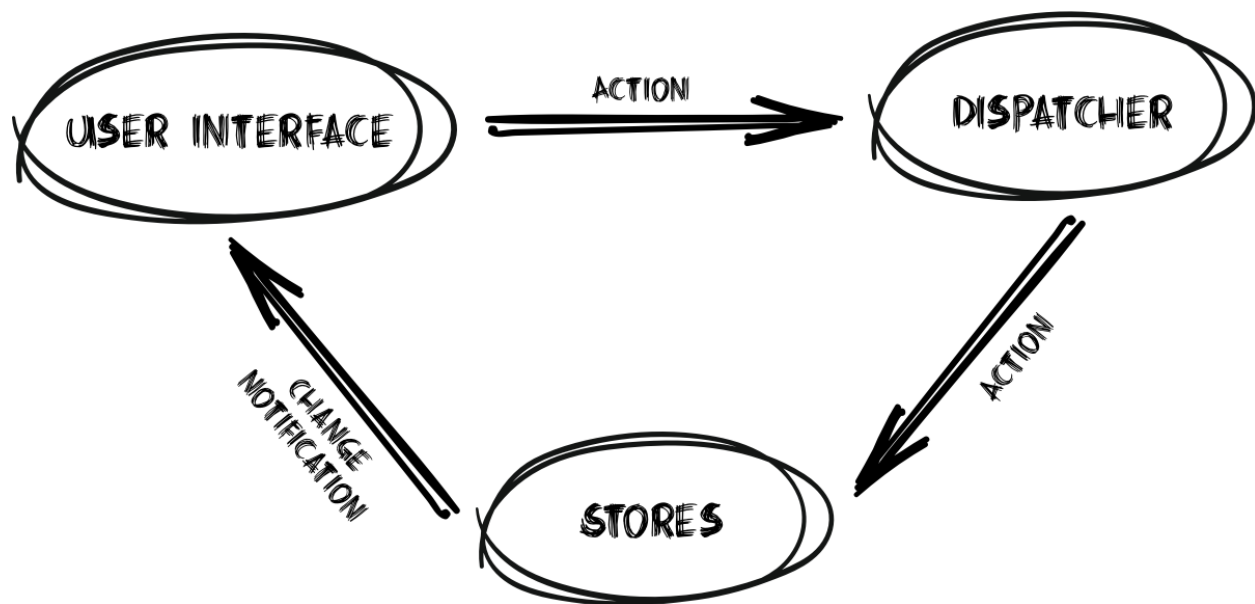
⁵<https://twitter.com/acdlite>

⁶<http://elm-lang.org>

⁷<http://redux.js.org/>

Here is the simplest Flux flow:

1. Stores subscribe to a subset of actions.
2. An action is sent to the dispatcher.
3. The dispatcher notifies subscribed stores of the action.
4. Stores update their state based on the action.
5. The view updates according to the new state in the stores.
6. The next action can then be processed.



Flux overview

This flow ensures that it's easy to reason about how actions flow in the system, what will cause the state to change, and how it will change.

Consider an example from a jQuery or AngularJS application. A click on a button can cause multiple callbacks to be executed, each updating different parts of the system, which might in turn trigger updates in other places. In this scenario it is virtually impossible for the developer of a large application to know how a single event might modify the application's state, and in what order the changes will occur.

In Flux, the click event will generate a single action that will mutate the store and then the view. Any actions created by the store or other components during this process will be queued and executed only after the first action is done and the view is updated.

Facebook's developers did not initially open-source their implementation of Flux, but rather released only parts of it, like the dispatcher. This caused a lot of open-source implementations to be built by the community, some of them significantly different and some only slightly changing the original

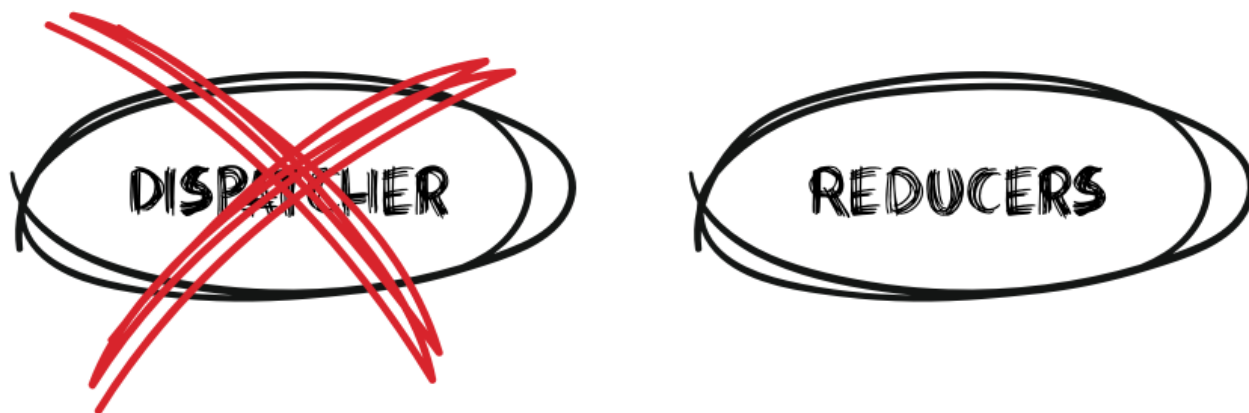
patterns. For example, some moved to having multiple dispatchers or introduced dependencies between stores.



Dmitri Voronianski has a good comparison of various Flux implementations on [GitHub](https://github.com/voronianski/flux-comparison)⁸.

Redux and Flux

While Redux derives from Flux concepts, there are a few distinctions between the two architectures. In contrast to Flux, Redux only has a single store that holds no logic by itself. Actions are dispatched and handled directly by the store, eliminating the need for a standalone dispatcher. In turn, the store passes the actions to state-changing functions called *reducers*, a new type of actor added by Redux.



Dispatcher out, reducers in

To better understand Redux, let's imagine an application that helps us manage a recipe book. The Redux *store* is where the recipe book itself will be saved, in a structure that might be a list of recipes and their details.

The app will allow us to perform different actions like adding a recipe, adding ingredients to a recipe, changing the quantity of an ingredient, and more. To make our code generic, we can create a number of *services*. Each service will know how to handle a group of actions. For example, the *book service* will handle all the add/remove recipe actions, the *recipe service* will handle changing recipe information, and the *recipe-ingredients service* will handle the actions to do with ingredients. This will allow us to better divide our code and in the future easily add support for more actions.

To make it work, our store could call each of our services and pass them two parameters: the current recipe book and the action we want to perform. Each service in turn will modify the book if the action is one it knows how to handle. Why pass the action to all the services? Maybe some actions

⁸<https://github.com/voronianski/flux-comparison>

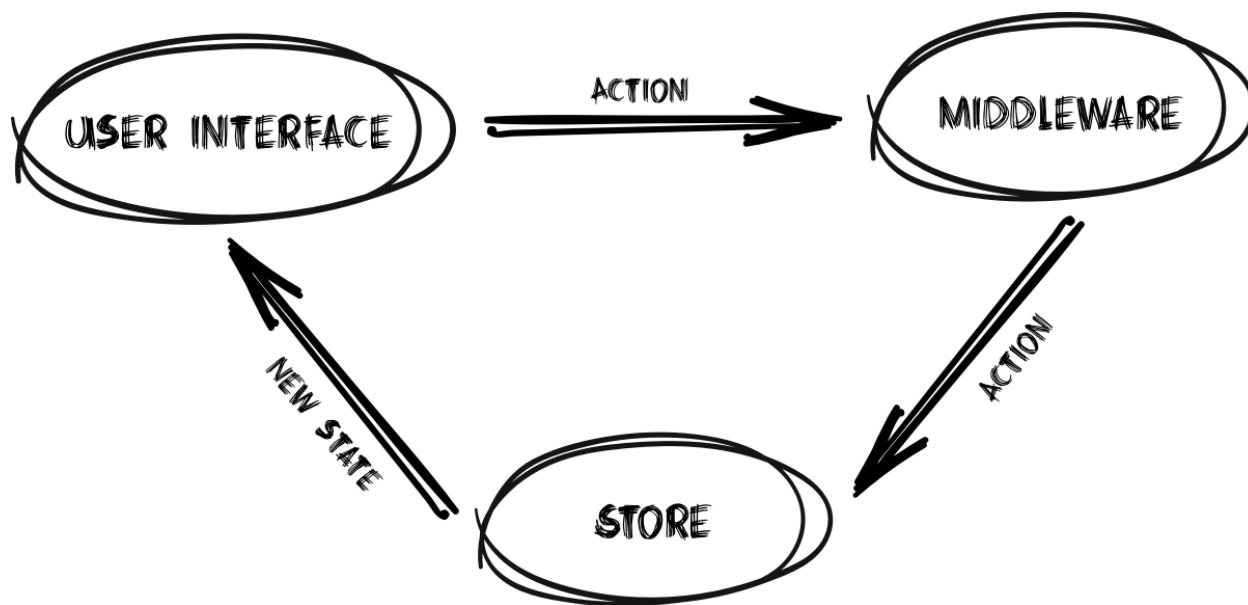
affect more than one service. For example, changing the measurements from grams to ounces will cause the ingredients service to recalculate the amounts and the recipe service to mark the recipe as using imperial measurements. In Redux, these services are the *reducers*.

We might want to add another layer, the *middleware*. Every action will be first passed through a list of middleware. Unlike reducers, middleware can modify, stop, or add more actions. Examples might include: a logging middleware, an authorization middleware that checks if the user has permissions to run the action, or an API middleware that sends something to the server.

This simple example shows the base of Redux. We have a single store to control the state, actions to describe the changes we want to make, reducers (*services*, in our example) that know how to mutate the state based on the requested action, and middleware to handle the housekeeping tasks.

What makes Redux special, and sometimes hard to understand, is that reducers never change the state (in our case, the recipe book), since it is immutable. Instead, the reducers must create a new copy of the book, make the needed changes to the copy, and return the new, modified book to the store. This approach allows Redux and the view layers to easily do change detection. In later chapters we will discuss in detail why and how this approach is used.

It is important to note that the whole application state is kept in a single location, the store. Having a single source of data provides enormous benefits during debugging, serialization, and development, as will become apparent in the examples in this book.



Redux overview

Redux Terminology

Actions and Action Creators

The only way for an application to change the state is by processing actions. In most cases, actions in Redux are nothing more than plain JavaScript objects passed to the store that hold all the information needed for the store to be able to modify the state:

Example of an action object

```
1 {  
2   type: 'INCREMENT',  
3   payload: {  
4     counterId: 'main',  
5     amount: -10  
6   }  
7 }
```

Since these objects might have some logic and be used in multiple places in an application, they are commonly wrapped in a function that can generate the objects based on a parameter:

A function that creates an action object

```
1 function incrementAction(counterId, amount) {  
2   return {  
3     type: 'INCREMENT',  
4     payload: {  
5       counterId,  
6       amount  
7     }  
8   };  
9 };
```

As these functions create action objects, they are aptly named *action creators*.

Reducers

Once an action is sent to the store, the store needs to figure out how to change the state accordingly. To do so, it calls a function, passing it the current state and the received action:

A function that calculates the next state

```
1 function calculateNextState(currentState, action) {  
2   ...  
3   return nextState;  
4 }
```

This function is called a *reducer*. In real Redux applications, there will be one *root reducer* function that will call additional reducer functions to calculate the nested state.

A simple reducer implementation

```
1 function rootReducer(state, action) {  
2   switch (action.type) {  
3  
4     case 'INCREMENT':  
5       return { ...state, counter: state.counter + action.payload.amount };  
6  
7     default:  
8       return state;  
9   }  
10 }
```



Reducers never modify the state; they always create a new copy with the needed modifications.

Middleware

Middleware is a more advanced feature of Redux and will be discussed in detail in later chapters. The middleware act like interceptors for actions before they reach the store: they can modify the actions, create more actions, suppress actions, and much more. Since the middleware have access to the actions, the `dispatch()` function, and the store, they are the most versatile and powerful entities in Redux.

Store

Unlike many other Flux implementations, Redux has a single store that holds the application information but no user logic. The role of the store is to receive actions, pass them through all the registered middleware, and then use reducers to calculate a new state and save it.

When it receives an action that causes a change to the state, the store will notify all the registered listeners that a change to the state has been made. This will allow various parts of the system, like the UI, to update themselves according to the new state.

General Concepts

Redux is about functional programming and pure functions. Understanding these concepts is crucial to understanding the underlying principles of Redux.

Functional programming has become a trendy topic in the web development domain lately, but it was invented around the 1950s. The paradigm centers around avoiding changing state and mutable data—in other words, making your code predictable and free of side effects.

JavaScript allows you to write code in a functional style, as it treats functions as first-class objects. This means you can store functions in variables, pass them as arguments to other functions, and return them as values of other functions. But since JavaScript was not designed to be a functional programming language per se, there are some caveats that you will need to keep in mind. In order to get started with Redux, you need to understand pure functions and mutation.

Pure and Impure Functions

A *pure function* returns values by using only its arguments: it uses no additional data and changes no data structures, touches no storage, and emits no external events (like network calls). This means that you can be completely sure that every time you call the function with the same arguments, you will always get the same result. Here are some examples of pure functions:

An example of a pure function

```
1 function square(x) {  
2   return x * x;  
3 }  
4  
5 Math.sin(y);  
6  
7 arr.map((item) => item.id);
```

If a function uses any variables not passed in as arguments or creates side effects, the function is *impure*. When a function depends on variables or functions outside of its lexical scope, you can never be sure that the function will behave the same every time it's called. For example, the following are impure functions:

An example of an impure function

```
1 function getUser(userId) {  
2   return UsersModel.fetch(userId).then((result) => result);  
3 }  
4  
5 Math.random();  
6  
7 arr.map((item) => calculate(item));
```

Mutating Objects

Another important concept that often causes headaches for developers starting to work with Redux is *immutability*. JavaScript has limited tooling for managing immutable objects, and we are often required to use external libraries.

Immutability means that something can't be changed, guaranteeing developers that if you create an object, it will have the same properties and values forever. For example, let's declare a simple object as a constant:

Object defined as constant in JavaScript

```
1 const colors = {  
2   red: '#FF0000',  
3   green: '#00FF00',  
4   blue: '#0000FF'  
5 };
```

Even though the `colors` object is a constant, we can still change its content, as `const` will only check if the *reference* to the object is changed:

JavaScript allows changes of `const` defined objects

```
1 colors = {};  
2 console.log(colors);  
3  
4 colors.red = '#FFFFFF';  
5 console.log(colors.red);
```

Try writing this in the developer console. You will see that you can't reassign an empty object to `colors`, but you can change its internal value.

To make the `colors` object appear immutable, we can use the `Object.freeze()` method:

Making a plain object immutable

```
1 Object.freeze(colors);
2
3 colors.red = '#000000';
4
5 console.log(colors.red);
```

The value of the red property will now be '#FFFFFF'. If you thought that the value should be '#FF0000', you missed that we changed the red property before we froze the object. This is a good example of how easy it is to miss this kind of thing in real applications.

Here, once we used `Object.freeze()`, the `colors` object became immutable. In practice things are often more complicated, though. JavaScript does not provide good native ways to make data structures fully immutable. For example, `Object.freeze()` won't freeze nested objects:

`Object.freeze()` does not freeze nested objects

```
1 const orders = {
2   bread: {
3     price: 10
4   },
5   milk: {
6     price: 20
7   }
8 };
9
10 Object.freeze(orders);
11
12 orders.milk.price -= 15;
13
14 console.log(orders.milk.price);
```

To work around the nature of our beloved language, we have to use third-party libraries like [deep-freeze](https://github.com/substack/deep-freeze)⁹ or [ImmutableJS](https://facebook.github.io/immutable-js/)¹⁰. We will talk about different immutable libraries later in the book.

Redux and React

Redux started out as a companion to React, but has started to gather a major following with other frameworks like Angular. At its base Redux is fully framework-agnostic, and it can easily be used with any JavaScript framework to handle state and changes.

⁹<https://github.com/substack/deep-freeze>

¹⁰<https://facebook.github.io/immutable-js/>

The connection to different frameworks is done with the help of third-party libraries that provide a set of convenience functions for each framework in order to seamlessly connect to Redux. The library that we will use to connect Redux and React is called `react-redux`, and we will be covering it extensively later in the book.

Basic Redux Implementation

People love Redux because of its simplicity. In fact, it is so simple that we can implement most of it in a handful of lines of code. Thus, unlike with other frameworks, where the only way to learn is to study the API, here we can start by implementing Redux ourselves.

The basic premise behind Redux is the idea that all the application state is saved in one place, the store. To use this idea in applications we will need to find a way to:

1. Modify the state as a result of events (user-generated or from the server).
2. Monitor state changes so we can update the UI.

The first part can be split into two blocks of functionality:

1. Notify the store that an action has happened.
2. Help the store figure out how to modify the state according to our application's logic.

Using this structure, let's build a simple application that will implement a counter. Our application will use pure JavaScript and HTML and require no additional libraries. We are going to have two buttons that allow us to increment and decrement a simple counter, and a place where we can see the current counter value:

The `index.html` file

```
1 <div>
2   Counter:
3   <span id='counter'></span>
4 </div>
5
6 <button id='inc'>Increment</button>
7 <button id='dec'>Decrement</button>
```

Our application state will simply hold the counter value:

A simple state holding a counter

```
1 let state = {  
2   counter: 3  
3 };
```

To make our demo functional, let's create a click handler for each button that will use a `dispatch()` function to notify our store that an action needs to be performed:

A basic dispatch API

```
1 function dispatch(action) { ... };
```

Connect click events to dispatch

```
1 // Listen to click events  
2 document.querySelector('#inc').onclick = () => dispatch('INC');  
3 document.querySelector('#dec').onclick = () => dispatch('DEC');
```

We will come back to its implementation later in this chapter. Also, let's define a function that will update the counter's value in the HTML based on application state received as an argument:

Code to update the counter in the DOM

```
1 // Update view (this might be React or Angular2 in a real app)  
2 function updateView() {  
3   document.querySelector('#counter').innerText = state.counter;  
4 }
```

Since we want our view to represent the current application state, we need it to be updated every time the state (and the counter) changes. For that, we will use the `subscribe()` function, which we will also implement a bit later. The role of the function will be to call our callback every time anything in the state changes:

Subscribe to changes API

```
1 subscribe(updateView);
```

We have now created a basic application structure with a simple state, implemented a function that will be responsible for updating the HTML based on the state, and defined two “magic” functions—`dispatch()` and `subscribe()`—to dispatch actions and subscribe to changes in state. But there is

still one thing missing. How will our mini-Redux know how to handle the events and change the application state?

For this, we define an additional function. On each action dispatched, Redux will call our function, passing it the current state and the action. To be compliant with Redux's terminology, we will call the function a reducer. The job of the reducer will be to understand the action and, based on it, create a new state.

In our simple example our state will hold a counter, and its value will be incremented or decremented based on the action:

Simple reducer for INC and DEC actions

```
1 // Our mutation (reducer) function creates a new state based on the action passed
2 function reducer(state, action) {
3   switch (action) {
4     case 'INC':
5       return { ...state, counter: state.counter + 1 };
6     case 'DEC':
7       return { ...state, counter: state.counter - 1 };
8     default:
9       return state;
10  }
11 }
```

An important thing to remember is that reducers must always return a new, modified copy of the state. They shouldn't mutate the existing state, like in this example:

Incorrect way to change state

```
1 // This is wrong!
2 state.counter = state.counter + 1;
```

Later in the book you will learn how you can avoid mutations in JavaScript with and without the help of external libraries.

Now it's time to implement the actual change of the state. Since we are building a generic framework, we will not include the code to increment/decrement the counter (as it is application-specific) but rather will call a function that we expect the user to supply, called `reducer()`. This is the reducer we mentioned before.

The `dispatch()` function calls the `reducer()` implemented by the application creator, passing it both the current state and the action it received. This information should be enough for the `reducer()` function to calculate a new state. We then check if the new state differs from the old one, and if it does, we replace the old state and notify all the listeners of the change:

Implementation of the dispatch API

```
1 let state = null;
2
3 function dispatch(action) {
4   const newState = reducer(state, action);
5
6   if (newState !== state) {
7     state = newState;
8
9     listeners.forEach(listener => listener());
10  }
11 }
```

Again, it is very important to note that we expect a reducer to create a *new state* and not just modify the existing one. We will be using a simple comparison by reference to check whether the state has changed.

One remaining task is to notify our view of the state change. In our example we only have a single listener, but we already can implement full listener support by allowing multiple callbacks to register for the “state change” event. We will implement this by keeping a list of all the registered callbacks:

Implementation of the subscribe API

```
1 const listeners = [];
2
3 function subscribe(callback) {
4   listeners.push(callback);
5 }
```

This might surprise you, but we have just implemented the major part of the Redux framework. The [real code](https://github.com/reactjs/redux/tree/master/src)¹¹ isn’t much longer, and we highly recommended that you take half an hour to read it.

Using the Real Redux

To complete our example, let’s switch to the real Redux library and see how similar the solution remains. First we’ll add the Redux library, for now using CDNJS:

¹¹<https://github.com/reactjs/redux/tree/master/src>

Adding Redux to a project

```
1 <script src="https://cdnjs.cloudflare.com/ajax/libs/redux/3.6.0/redux.min.js" />
```

We will change our previous state definition to be a constant that only defines the initial value of the state:

The initial state

```
1 const initialState = {  
2   counter: 3  
3 };
```

Now we can use it to create a Redux store:

Creating a Redux store

```
1 const store = Redux.createStore(reducer, initialState);
```

As you can see, we are using our reducer from before. The only change that needs to be made to the reducer is the switch statement. Instead of doing:

Previous reducer code

```
1 switch (action)
```

Changes to

New reducer code

```
1 switch (action.type)
```

The reason behind this is that actions in Redux are objects that have the special type property, which makes reducer creation and action data more consistent.

The Redux store will also give us all the features we implemented ourselves before, like `subscribe()` and `dispatch()`. Thus, we can safely delete these methods.

To subscribe to store changes, we will simply call the `subscribe()` method of the store:

Subscribing to store updates

```
1 store.subscribe(updateView);
```

Since `subscribe()` does not pass the state to the callback, we will need to access it via `store.getState()`:

Update view by getting the state out of the store

```
1 // Update view (this might be React in a real app)
2 function updateView() {
3   document.querySelector('#counter').innerText = store.getState().counter;
4 }
5
6 store.subscribe(updateView);
```

The last change is in the `dispatch()` method. As mentioned previously, our actions now need to have the `type` property. Thus, instead of simply sending the string `'INC'` as the action, we now need to send `{ type: 'INC' }`.

The Complete Example

The HTML

```
1 <script src="https://cdnjs.cloudflare.com/ajax/libs/redux/3.6.0/redux.min.js" />
2
3 <div>
4   Counter:
5   <span id='counter'> </span>
6 </div>
7
8 <button id='inc'>Increment</button>
9 <button id='dec'>Decrement</button>
```

The JavaScript

```
1 // Our mutation (Reducer) function,
2 // create a _new_ state based on the action passed
3 function reducer(state, action) {
4   switch(action.type) {
5     case 'INC':
6       return { ...state, counter: state.counter + 1 };
7     case 'DEC':
8       return { ...state, counter: state.counter - 1 };
9     default:
10      return state;
11   }
12 }
13
14 const initialState = {
15   counter: 3
16 };
17
18 const store = Redux.createStore(reducer, initialState);
19
20 // Update view (this might be React in a real app)
21 function updateView() {
22   document.querySelector('#counter').innerText = store.getState().counter;
23 }
24
25 store.subscribe(updateView);
26
```

```
27 // Update view for the first time
28 updateView();
29
30 // Listen to click events
31 document.getElementById('inc').onclick = () => store.dispatch({ type: 'INC' });
32 document.getElementById('dec').onclick = () => store.dispatch({ type: 'DEC' });
```

Summary

In this chapter we briefly covered the history of Redux and Flux, and learned how Redux works at its core. We also learned a bit about basic functional programming principles, such as pure functions and immutability. As they are very important for our real-world applications, we will talk about these concepts more later in the book. In the next chapter we are going to see how to actually work with Redux by building a simple recipe book application.

Chapter 2. Your First Redux Application

In the previous chapter we learned what Redux is and how it works. In this chapter we will learn how to use it for a simple project. The code base created in this chapter will be used as the base for all the examples in the rest of this book. It is highly recommended that you follow along with and fully understand this chapter and its code before moving on to more advanced topics.

Starter Project

Modern client-side applications often require a set of so-called *boilerplate* in order to make development easier. The boilerplate may include things such as directory structure, code transformation tools like SCSS and ES2016 compilers, testing infrastructure, and production pipeline tools for tasks such as minification, compression, and concatenation.

To ease the chore of setting up a new project, the open-source community has created dozens of different starter projects. The larger ones, like [react-redux-starter-kit](https://github.com/davezuko/react-redux-starter-kit)¹², consist of over a hundred files. We will use a much simpler boilerplate, just enough to cover all the concepts explained in this book.

As our project will be pure Redux, it will require no React or related libraries. We will use [Webpack](https://webpack.js.org/)¹³ as our main tool to handle all code transformation and production flow tasks.

Skeleton Overview

To start things off, let's clone the starter project, install the needed packages, and verify that our environment is ready:

Setting up the starter project

```
1 git clone http://github.com/redux-book/starter
2 cd starter
3 npm install
4 npm start
```

¹²<https://github.com/davezuko/react-redux-starter-kit>

¹³<https://webpack.js.org/>

If everything went smoothly, you should be able to access <http://localhost:8080>¹⁴ and see a page showing “A simple Redux starter” and a running counter. If you open the JavaScript console in the Developer Tools, you should also see “Redux started” output. Our project is ready!

Time to open the code editor and go over the five files currently making up the project:

1. *.gitignore* – A list of filename patterns for Git to ignore when managing our repository.
2. *package.json* – A list of all properties of our project and packages used.
3. *webpack.config.js* – Webpack configuration.
4. *app/index.html* – The HTML entry point for the project.
5. *app/app.js* – The JavaScript entry point to our code.
6. *app/assets/stylesheets/main.css* – Some basic CSS for the sample project.

.gitignore

This is a special configuration file for [Git](https://git-scm.com/)¹⁵ version control system, this file instructs Git which files and directories should not be managed by it (for example, `node_modules`).

package.json

While the majority of the fields in this file are irrelevant at this point, it is important to note two sections, `devDependencies` and `dependencies`. The former is the list of all the tools needed to build the project. It currently includes only `webpack-tools` and the Babel transpiler, required to transpile ES2016. The `dependencies` section lists all the packages we will bundle with our application. It includes only the `redux` library itself.

webpack.config.js

This is the main Webpack configuration file. This settings file instructs Webpack how to chain transpile tools and how to build packages, and holds most of the configuration of our project’s tooling. In our simple project there is only one settings file (larger projects might have more granular files for testing, development, production, etc.). Our `webpack.config.js` file sets up Babel to transpile ES2016 into ES5 and defines the entry point of our application.

index.html / app.js

Single-page applications, unlike their server-generated cousins, have a single entry point. In our project every part and page of the application will be rendered starting from `index.html` and all the JavaScript-related startup code will be in `app.js`.

¹⁴<http://localhost:8080>

¹⁵<https://git-scm.com/>

Our First Application

To learn how to use different parts of Redux, we will be building a Recipe Book application. It will allow adding recipes and ingredients for each recipe, and will fetch an initial recipe list from a remote server. In accordance with Redux principles, the application will keep all its state in our global store, including some parts of the UI.

The first step with any Redux-based app is to plan how data will be arranged in the store. Our recipe object will start out holding only the recipe's name (we will add more fields as needed). To store the current list, we can use a regular array:

Simple state

```
1 recipes = [  
2   { name: 'Omelette' },  
3   ...  
4 ];
```

Ingredients for each recipe will contain a name and a quantity. Connecting them to the state will be a bigger challenge. There are three general approaches to make this connection.

The *nested objects* approach is to hold the ingredients as an array inside a recipe itself:

Nested objects state

```
1 state = {  
2   recipes: [  
3     {  
4       name: 'omelette',  
5       ingredients: [  
6         {  
7           name: 'eggs',  
8           quantity: 2  
9         }  
10      ]  
11    },  
12    ...  
13  ]  
14 };
```

The *nested reference* approach is to store the recipe ingredient information directly in the state and hold an array of “recipe ingredient IDs” in each recipe:

Nested reference state

```
1 state = {  
2   recipes: [  
3     {  
4       name: 'omelette',  
5       ingredients: [2, 3]  
6     }  
7   ],  
8   ingredients: {  
9     2: {  
10      name: 'eggs',  
11      quantity: 2  
12    },  
13    3: {  
14      name: 'milk',  
15      quantity: 1  
16    }  
17  }  
18 };
```

The *separate object* approach is to store the ingredients as a standalone array in the state, and put the ID of the recipe the array is connected to inside of it:

Separate objects state

```
1 state = {  
2   recipes: [  
3     {  
4       id: 10,  
5       name: 'omelette'  
6     }  
7   ],  
8   ingredients: [  
9     {  
10      recipe_id: 10,  
11      name: 'eggs',  
12      quantity: 2  
13    },  
14    {  
15      recipe_id: 10,  
16      name: 'milk',  
17      quantity: 1  
18    }  
19  ]  
20 };
```



```
18     }  
19   ]  
20 };
```

While all the approaches have their upsides and downsides, we will quickly discover that in Redux, keeping the structure as flat and normalized as possible (as in the second and third examples shown here) makes the code cleaner and simpler. The state’s structure implies the use of two separate reducers for recipes and ingredients. We can process both independently.

The biggest difference between the second and third options is how the link is made (who holds the ID of whom). In the second example, adding an ingredient will require an update in two different parts of the state—in both the `recipes` and `ingredients` subtrees—while in the third approach, we can always update only one part of the tree. In our example we will use this method.



The subject of state management is covered in detail in the [State Management Chapter](#) in Part 2.

Setting Up the Store

We will start by creating the store. In Redux there is only one store, which is created and initialized by the `createStore()` method. Let’s open our `index.js` file and create the store:

Creating the Redux store

```
1 import { createStore } from 'redux';  
2  
3 const reducer = (state, action) => state;  
4 const store = createStore(reducer);
```

The `createStore()` function can receive a number of parameters, with only one being required—the reducer. In our example, the reducer simply returns the same state regardless of the action.

To make things more interesting, we can provide a default state to the store. This is useful when learning, but the real use of this feature is mainly with server rendering, where you precalculate the state of the application on the server and then can create the store with the precalculated state on the client.

Create store with an initial state

```
1  const initialState = {
2    recipes: [
3      {
4        name: 'Omelette'
5      }
6    ],
7    ingredients: [
8      {
9        recipe: 'Omelette',
10       name: 'Egg',
11       quantity: 2
12     }
13   ]
14 };
15
16 const reducer = (state, action) => state;
17 const store = createStore(reducer, initialState);
18
19 window.store = store;
```

In the last line we make the store globally available by putting it on the window object. If we go to the JavaScript console, we can now try playing with it:

Trying out the APIs in the console

```
1  store.getState()
2  // Object {recipes: Array[1], ingredients: Array[1]}
3
4  store.subscribe(() => console.log("Store changed"));
5
6  store.dispatch({ type: 'ACTION' });
7  // Store changed
```

As you can see, we can use the store object to access the current state using `getState()`, subscribe to get notifications on store changes using `subscribe()`, and send actions using `dispatch()`.

Adding Recipes

To implement adding recipes, we need to find a way to modify our store. As we learned in the previous chapter, store modifications can only be done by *reducers* in response to *actions*. This means we need to define an action structure and modify our (very lean) reducer to support it.

Actions in Redux are nothing more than plain objects that have a mandatory `type` property. We will be using strings to name our actions, with the most appropriate in this case being `'ADD_RECIPE'`. Since a recipe has a `name`, we will add it to the action's data when dispatching:

Dispatching a Redux object

```
1 store.dispatch({ type: 'ADD_RECIPE', name: 'Pancake' });
```

Let's modify our reducer to support the new action. A simple approach might appear to be the following:

Reducer that supports ADD_RECIPE

```
1 const reducer = (state, action) => {
2   switch (action.type) {
3     case 'ADD_RECIPE':
4       state.recipes.push({ name: action.name });
5   }
6
7   return state;
8 };
```

While this looks correct (and works when tested in our simple example), this code violates the basic Redux principle of *store immutability*. Our reducers must *never change* the state, but only create a new copy of it, with any modifications needed. Thus, our reducer code needs to be modified:

Correct way to build a reducer

```
1 const reducer = (state, action) => {
2   switch (action.type) {
3     case 'ADD_RECIPE':
4       return Object.assign({}, state, {
5         recipes: state.recipes.concat({ name: action.name })
6       });
7   }
8
9   return state;
10 };
```

The `'ADD_RECIPE'` case has become more complex but works exactly as expected. We are using the `Object.assign()` method `Object.assign({}, state, { key: value })` to create a new object that has all the key/value pairs from our old state, but overrides the `recipes` key with a new value. To calculate the list of new recipes we use `concat()` instead of `push()`, as `push()` modifies the original array while `concat()` creates a new array containing the original values and the new one.

More information about the `Object.assign()` method is available in the [Reducers Chapter](#).

Adding Ingredients

Similar to adding recipes, this step will require us to modify the reducer again to add support for adding ingredients:

Adding `ADD_INGREDIENT` to the reducer

```
1  const reducer = (state, action) => {
2    switch (action.type) {
3      case 'ADD_RECIPE':
4        return Object.assign({}, state, {
5          recipes: state.recipes.concat({ name: action.name })
6        });
7
8      case 'ADD_INGREDIENT':
9        const newIngredient = {
10          name: action.name,
11          recipe: action.recipe,
12          quantity: action.quantity
13        };
14        return Object.assign({}, state, {
15          ingredients: state.ingredients.concat(newIngredient)
16        });
17    }
18
19    return state;
20  };
```

One problem you might encounter while dispatching actions from the console to test the store is that it's hard to remember the properties that need to be passed in the action object. This, among other reasons, is why in Redux we use the concept of *action creators*: functions that create the action object for us.

A function to create the action object

```
1  const addIngredient = (recipe, name, quantity) => ({
2    type: 'ADD_INGREDIENT', recipe, name, quantity
3  });
4
5  store.dispatch(addIngredient('Omelette', 'Eggs', 3));
```

This function both hides the structure of the action from the user and allows us to modify the action, setting default values for properties, performing cleanup, trimming names, and so on.



For more information on action creators, consult the [Actions and Action Creators Chapter](#) in Part 3.

Structuring the Code

Having all our code in a single file is obviously a bad idea. In Redux, it's common for the directory structure to follow the names of the Redux “actors.” Reducers are placed in the *reducers* directory, and the main reducer (commonly called the *root reducer*) is placed in the *root.js* file. Action creators go in the *actions* directory, divided by the type of object or data they handle—in our case, *actions/recipes.js* and *actions/ingredients.js*. Since we only have a single store, we can put all its code in one file: *store/store.js*.

After all the changes, the *index.js* file should look like the following:

Final *index.js*

```
1 import store from './store/store';
2 import { addRecipe } from './actions/recipes';
3 import { addIngredient } from './actions/ingredients';
4
5 store.dispatch(addRecipe('Pancake'));
6 store.dispatch(addIngredient('Pancake', 'Eggs', 3));
7
8 window.store = store;
```

A Closer Look at Reducers

If you open the *reducers/root.js* file, you will find that the same reducer is now taking care of different parts of our state tree. As our application grows, more properties will be added to both the *recipes* and the *ingredients* subtrees. Since the code in both handlers is not interdependent, we can split it further into three reducers, each one responsible for a different part of the state:

Multi-responsibility reducer

```
1  const recipesReducer = (recipes, action) => {
2    switch (action.type) {
3      case 'ADD_RECIPE':
4        return recipes.concat({name: action.name});
5    }
6
7    return recipes;
8  };
9
10 const ingredientsReducer = (ingredients, action) => { ... }
11
12 const rootReducer = (state, action) => {
13   return Object.assign({}, state, {
14     recipes: recipesReducer(state.recipes, action),
15     ingredients: ingredientsReducer(state.ingredients, action)
16   });
17 };
```

There are three main benefits here. First, our root reducer is now very simple. All it does is create a new state object by combining the old state and the results of each of the subreducers. Second, our recipes reducer is much simpler as it only has to handle the recipes part of the state. And best of all, our root, ingredients, and any other reducers that we might create don't need to know or care about the internal structure of the recipes subtree. Thus, changes to that part of the tree will only affect the recipes part. A side effect of this is that we can tell each reducer how to initialize its own subtree, by using default parameters from ES2016:

Reducer for recipes

```
1  const recipesReducer = (recipes = [], action) => { ... };
```

Note the default `[]` set for recipes.

Since combining multiple reducers is a very common pattern, Redux has a special utility function, `combineReducers()`, which does exactly what our root reducer does:

Combining multiple reducers

```
1 export default combineReducers({  
2   recipes: recipesReducer,  
3   ingredients: ingredientsReducer  
4 });
```

Here we created a root reducer that employs two subreducers, one sitting in the *recipes* subtree and the other in the *ingredients* subtree. This is a good time to split our reducers into their own files, *reducers/recipes.js* and *reducers/ingredients.js*.

Handling Typos and Duplicates

Before moving forward, we need to make one last change to our code to fix something that might not be an apparent problem right now. We have been using strings like `'ADD_RECIPE'` in our action creators and reducers, but never bothered to verify that they match. In large applications this often leads to errors that are very hard to debug, as a typo in the action creator will cause a reducer to ignore an action. Or, even worse, two developers might use the same string by mistake, which will lead to very strange side effects as unintended reducers will process the dispatched actions.

To fix these problems we can utilize ES2016's native `const` support, which guarantees that we cannot define the same constant twice in the same file. This will catch duplicate names at compile time, even before our code reaches the browser.

Let's create a new file, *constants/action-types.js*, which will hold all the action type constants in our application:

constants/action-types.js

```
1 export const ADD_RECIPE = 'ADD_RECIPE';  
2 export const ADD_INGREDIENT = 'ADD_INGREDIENT';
```

Now in our reducers and action creators we will use the constants instead of the strings:

Using constants

```

1 import { ADD_RECIPE } from 'constants/action-types';
2
3 const recipesReducer = (recipes = [], action) => {
4   switch (action.type) {
5     case ADD_RECIPE:
6       ...

```

Simple UI

To get a feeling for how a simple UI can be connected to Redux, we will be using a bit of jQuery magic. Note that this example is very simple and should never be used in a real application, although it should give you a general feeling of how “real” applications connect to Redux.

Let’s store our current UI in `ui/jquery/index.js`. The jQuery UI will create a simple view of current recipes in the store:

ui/jquery/index.js

```

1 import $ from 'jquery';
2 import store from 'store/store';
3
4 function updateUI() {
5   const { recipes } = store.getState();
6   const renderRecipe = (recipe) => `<li>${ recipe.name }</li>`;
7
8   $('.recipes > ul').html(recipes.map(renderRecipe));
9 }
10
11 export default function loadUI() {
12   $('#app').append(`
13     <div class="recipes">
14       <h2>Recipes:</h2>
15       <ul></ul>
16     </div>
17   `);
18
19   updateUI();
20 }

```

We are using jQuery’s `append()` method to add a new `div` to our application container and using the `updateUI()` function to pull the recipes list from our state and display them as a list of unordered elements.

To make our UI respond to updates, we can simply register the `updateUI()` function within our store, inside `loadUI()`:

Register `updateUI` with the store

```
1 store.subscribe(updateUI);
```

To support adding recipes, we will add a simple input and button and use our store's `dispatch()` method together with the `addRecipe()` action creator to send actions to the store:

Add support for click events

```
1 import $ from 'jquery';
2 import store from 'store/store';
3 import { addRecipe } from 'actions/recipes';
4
5 function updateUI() {
6   const { recipes } = store.getState();
7   const renderRecipe = (recipe) => `<li>${ recipe.name }</li>`;
8
9   $('.recipes > ul').html(recipes.map(renderRecipe));
10 }
11
12 function handleAdd() {
13   const $recipeName = $('.recipes > input');
14
15   store.dispatch(addRecipe($recipeName.val()));
16
17   $recipeName.val('');
18 }
19
20 export default function loadUI() {
21   $('#app').append(`
22     <div class="recipes">
23       <h2>Recipes:</h2>
24       <ul></ul>
25       <input type="text" />
26       <button>Add</button>
27     </div>
28 `);
29
30   store.subscribe(updateUI);
31
```

```
32  $(document).on('click', '.recipes > button', handleAdd);
33
34  updateUI();
35 }
```

Logging

Now that our UI allows us to add new recipes, we find that it's hard to see what actions are sent to the store. One option is to log received actions from the root reducer—but as we will see shortly, this can be problematic. Another option is to use the *middleware* we discussed in the previous chapter.

The store holds a connection to all the middleware and they get actions before the reducers, which means they have access to any actions dispatched to the store. To test this, let's create a simple logging middleware that will print any action sent to the store:

A simple logging middleware

```
1  const logMiddleware = ({ getState, dispatch }) => (next) => (action) => {
2    console.log(`Action: ${ action.type }`);
3
4    next(action);
5  };
6
7
8  export default logMiddleware;
```

The structure might seem strange at first, as we are creating a function that returns a function that returns a function. While this might be a little confusing, it is required by the way Redux combines middlewares in its core. In practice, in the inner most function we have access to the `dispatch()` and `getState()` methods from the store, the current action being processed, and the `next()` method, which allows us to call the next middleware in line.

Our logger prints the current action and then calls `next(action)` to pass the action on to the next middleware. In some cases, middleware might suppress actions or change them. That is why implementing a logger in a reducer is not a viable solution: some of the actions might not reach it.

To connect the middleware to our store, we need to modify our *store/store.js* file to use Redux's `applyMiddleware()` utility function:

Connecting a middleware to the store

```
1 import { createStore, applyMiddleware } from 'redux';
2 import rootReducers from 'reducers/root';
3 import logMiddleware from 'middleware/log';
4
5 const initialState = { ... };
6
7 export default createStore(
8   rootReducers,
9   initialState,
10  applyMiddleware(logMiddleware)
11 );
```

Getting Data from the Server

Fetching data from a server, like anything with Redux, happens as a result of a dispatched action. In our case, the UI should dispatch an action when it loads to ask Redux to bring data to the store.

For this we will need to add a new constant to *constants/action-types.js* and a new action creator in *actions/recipes.js*. Our action will be called 'FETCH_RECIPES'.

Sadly, we can't handle the action inside a reducer. Since the action requires server access that might take time, our reducer will not be able to handle the response—reducers should return the modified state immediately.

Luckily, we have middleware, which have access to the store and thus the store's `dispatch()` method. This means we can catch the action in a middleware, submit an Ajax request, and then send a new action to the reducers with the data already inside.

Here is a simple API middleware that listens to 'FETCH_RECIPES' and dispatches 'SET_RECIPES' when the data arrives:

API middleware

```
1 import { FETCH_RECIPES } from 'constants/action-types';
2 import { setRecipes } from 'actions/recipes';
3
4 const URL = 'https://s3.amazonaws.com/500tech-shared/db.json';
5
6 function fetchData(url, callback) {
7   fetch(url)
8     .then((response) => {
9       if (response.status !== 200) {
10         console.log(`Error fetching recipes: ${ response.status }`);
```

```
11     } else {
12       response.json().then(callback);
13     }
14   })
15   .catch((err) => console.log(`Error fetching recipes: ${ err }`))
16 }
17
18 const apiMiddleware = ({ dispatch }) => next => action => {
19   if (action.type === FETCH_RECIPES) {
20     fetchData(URL, data => dispatch(setRecipes(data)));
21   }
22
23   next(action);
24 };
25
26 export default apiMiddleware;
```

The main code of our middleware is a simple `if` statement that calls the `fetchData()` function and passes it a callback that dispatches `setRecipes()` with the returned data:

Catching API requests

```
1 if (action.type === FETCH_RECIPES) {
2   fetchData(URL, data => store.dispatch(setRecipes(data)));
3 }
```

The `fetchData()` code itself is a generic use of the `fetch` API.

To make this middleware work, we need to add it to our store:

Adding the API middleware to the store

```
1 import { createStore, applyMiddleware } from 'redux';
2 import rootReducers from 'reducers/root';
3 import logMiddleware from 'middleware/log';
4 import apiMiddleware from 'middleware/api';
5
6 const initialState = { ... };
7
8 export default createStore(
9   rootReducers,
10  initialState,
11  applyMiddleware(logMiddleware, apiMiddleware)
12 );
```

We also need to modify our *reducers/recipes.js* to support the new 'SET_RECIPES' action:

Adding support for SET_RECIPES in the recipes reducer

```
1 import { ADD_RECIPE, SET_RECIPES } from 'constants/action-types';
2
3 const recipesReducer = (recipes = [], action) => {
4   switch (action.type) {
5     case ADD_RECIPE:
6       return recipes.concat({name: action.name});
7
8     case SET_RECIPES:
9       return action.data.recipes;
10  }
11
12  return recipes;
13 };
14
15 export default recipesReducer;
```

The code for the reducer is surprisingly simple. Since we get a new list of recipes from the server, we can just return that list as the new recipes list:

Simple SET_RECIPES implementation

```
1 case SET_RECIPES:
2   return action.data.recipes;
```

Finally, we can remove the `initialState` we passed to our store, since we will be getting data from the server. Each of the reducers has default values for its subtrees (remember the `recipes = []` from above?), and the reducers will be the one to construct the initial state automatically. This magic is explained in the [Reducers Chapter](#).

Here's our new *store/store.js*:

store/store.js

```
1 import { createStore, applyMiddleware } from 'redux';
2 import rootReducers from 'reducers/root';
3 import logMiddleware from 'middleware/log';
4 import apiMiddleware from 'middleware/api';
5
6 export default createStore(
7   rootReducers,
8   applyMiddleware(logMiddleware, apiMiddleware)
9 );
```



In a real application the API middleware will be more generic and robust. We will go into much more detail in the [Middleware Chapter](#).

Summary

In this chapter we built a simple Redux application that supports multiple reducers, middleware, and action creators. We set up access to a server and built a minimal UI using jQuery. In the book's [Git repository](#)¹⁶, you can find the full source code for this example, including the missing parts (like the ingredients UI).

¹⁶<https://github.com/redux-book>

Part 2. Real World Usage

Chapter 3. State Management

One of the main strengths of Redux is the separation of state (data) management from the presentation and logic layers. Due to its division of responsibilities, the design of the state layout can be done separately from the design of the UI and any complex logic flows.

The Concept of Separation

To illustrate the concept, let's consider our recipe book application. The app can manage multiple recipe books, each having multiple recipes. A recipe, in turn, is an object containing a list of ingredients, preparation instructions, images, a favorited flag, etc.:

Simple structure of recipe app state

```
1  const state = {
2    books: [
3      {
4        id: 21,
5        name: 'Breakfast',
6        recipes: [
7          {
8            id: 63,
9            name: 'Omelette',
10           favorite: true,
11           preparation: 'How to prepare...',
12           ingredients: [...]
13         },
14         {...},
15         {...}
16       ]
17     },
18     {...},
19     {...}
20   ]
21 };
```

While this state layout contains all the required information and conforms exactly to the description of our application, it has a couple of issues:

- Reducer nesting and coupling
- Access to multiple nested data entities

Reducer Nesting and Coupling

Let's try to implement a reducer that supports an action that adds a new ingredient to a recipe. There are two main approaches, one where all the reducers in the chain are aware of the action being passed and one where each reducer only passes the information down to its children.

Let's investigate where the problems lie and how we can deal with them. The first approach could be implemented as follows:

Action-aware reducers

```
1  const booksReducer = (state, action) => {
2    switch(action.type) {
3      case ADD_INGREDIENT:
4        return Object.assign({}, state, {
5          books: state.books.map(
6            book => book.id !== action.payload.bookId
7              ? book
8              : recipesReducer(book, action)
9          )
10       });
11   }
12 };
13
14 const recipesReducer = (book, action) => {
15   switch(action.type) {
16     case ADD_INGREDIENT:
17       return Object.assign({}, book, {
18         recipes: book.recipes.map(
19           recipe => recipe.id !== action.payload.recipeId
20             ? recipe
21             : ingredientsReducer(recipe, action)
22         )
23       });
24   }
25 };
26
27 const ingredientsReducer = (recipe, action) => {
28   // Regular reducer
29 };
```

In this implementation, all the “parent” reducers must be aware of any actions used in their children. Any changes or additions will require us to check multiple reducers for code changes, thus breaking the encapsulation benefits of multireducer composition and greatly complicating our code.

The second option is for reducers to pass all actions to their children:

Action-passing reducer

```
1  const booksReducer = (books, action) => {
2    const newBooks = handleBookActions(books, action);
3
4    // Apply recipes reducers
5    return newBooks.map(book => Object.assign({}, book, {
6      recipes: recipesReducer(book.recipes, action)
7    }));
8  };
9
10 const recipesReducer = (recipes, action) => {
11   const newRecipes = handleRecipeActions(book, action);
12
13   // Apply ingredients reducers
14   return newRecipes.map(recipe => Object.assign({}, recipe, {
15     ingredients: ingredientsReducer(recipe.ingredients, action)
16   }));
17  };
```

In this implementation, we separate the reducer logic into two parts: one to allow any child reducers to run and the second to handle the actions for the reducer itself.

While this implementation doesn’t require the parent to know about the actions supported by its children, we are forced to run a very large number of reducers for each recipe. A single call to an action unrelated to recipes, like `UPDATE_PROFILE`, will run `recipesReducer()` for each recipe, and have it in turn run `ingredientsReducer()` for each of the ingredients.

Access to Multiple Nested Data Entities

Another problem with the nested state approach is retrieving data. If we would like to show all of a user’s favorite recipes, we need to scan all the books to find the relevant ones:

Get list of favorite recipes

```
1  const getFavorites = (state) => {
2    const recipes = state.books.map(
3      book => book.filter(recipe => favorite)
4    );
5
6    // Strip all null values
7    return recipes.filter(recipe => recipe);
8  };
```

Also, since this code (or similar) will be used for the UI, any changes to the structure of the state will need to be reflected not just in the reducers but in the UI as well. This approach breaks our separation of concerns model and might require extensive changes to the UI layer(s) on state structure changes.

State as a Database

A recommended approach to solve the various issues raised above is to treat the application state as a database of entities. In our example, we will break down the nesting to make our state as shallow as possible and express connections using IDs:

Normalized state

```
1  const state = {
2    books: {
3      21: {
4        id: 21,
5        name: 'Breakfast',
6        recipes: [63, 78, 221]
7      }
8    },
9
10   recipes: {
11     63: {
12       id: 63,
13       book: 21,
14       name: 'Omelette',
15       favorite: true,
16       preparation: 'How to prepare...',
17       ingredients: [152, 121]
18     },
19     78: {},
```

```

20     221: {}
21   },
22
23   ingredients: {}
24 };

```

In this structure, each object has its own key right in the root of our state. Any connections between objects (e.g., ingredients used in a recipe) can be expressed using a regular ordered array of IDs.

Reducer Nesting and Coupling

Let's examine the implementation of the reducers needed to handle the `ADD_INGREDIENT` action using the new state:

Reducers for adding a new ingredient

```

1  const booksReducer = (books, action) => {
2    // Not related to ingredients any more
3  };
4
5  const recipeReducer = (recipe, action) => {
6    switch (action.type) {
7      case ADD_INGREDIENT:
8        return Object.assign({}, recipe, {
9          ingredients: [...recipe.ingredients, action.payload.id]
10        });
11    }
12
13    return recipe;
14  };
15
16  const recipesReducer = (recipes, action) => {
17    switch (action.type) {
18
19      case ADD_INGREDIENT:
20        return recipes.map(recipe =>
21          recipe.id !== action.payload.recipeId
22            ? recipe
23            : recipesReducer(recipe, action));
24    }
25  };
26

```

```
27 const ingredientsReducer = (ingredients, action) => {  
28   switch (action.type) {  
29     case ADD_INGREDIENT:  
30       return [...ingredients, action.payload]  
31   }  
32 };
```

There are two things to note in this implementation compared to what we saw with the denormalized state:

The books reducer is not even mentioned. Nesting levels only affect the parent and children, never the grandparents. The recipes reducer only adds an ID to the array of ingredients, not the whole ingredient object.

To take this example further, the implementation of `UPDATE_RECIPE` would not even require any change to the recipes reducer, as it can be wholly handled by the ingredients reducer.

Access to Multiple Nested Data Entities

Getting a list of favorite recipes is much simpler in the normalized state, as we only need to scan the recipes “table.” This can be done in the UI using a function called a selector. If you think of the state as a database, you can imagine selectors as database queries:

Favorite recipes selector

```
1 const getFavorites = (state) =>  
2   state.recipes.filter(recipe => favorite);
```

The main improvement is that we do not need to be aware of the structure or nesting of the state to access deeply nested information. Rather, we treat our state as a conventional database from which to extract information for the UI.

Keeping a Normalized State

While normalized state might seem like a great idea, often the data returned from the server is structured in a deeply nested way. A possible example of fetching data from the `/recipes/123` API endpoint might look like this:

Data returned from /recipes/123

```
1 {
2   id: 63,
3   name: 'Omelette',
4   favorite: true,
5   preparation: 'How to prepare...',
6   ingredients: [
7     {
8       id: 5123,
9       name: 'Egg',
10      quantity: 2
11    },
12    {
13      id: 729,
14      name: 'Milk',
15      quantity: '2 cups'
16    }
17  ]
18 };
```

Since the only way to update the Redux store is by sending actions to the reducers, we must build a payload that can be easily handled by our reducers and find a way to extract the payload from the denormalized server-returned data.

Building the Generic Action

Potentially, we would like each of our data reducers to be able to handle a special `UPDATE_DATA` action and extract the relevant parts it needs:

Sample UPDATE_DATA action

```
1 const updateData = ({
2   type: UPDATE_DATA,
3   payload: {
4     recipes: {
5       63: {
6         id: 63,
7         name: 'Omelette',
8         favorite: true,
9         preparation: 'How to prepare...',
10        ingredients: [5123, 729]
11      }
12    }
13  })
```

```
12     },
13     ingredients: {
14       5123: {
15         id: 5123,
16         name: 'Egg',
17         quantity: 2
18       },
19       729: {
20         id: 729,
21         name: 'Milk',
22         quantity: '2 cups'
23       }
24     }
25   }
26 });
```

Using this approach, our recipes reducer's support for `UPDATE_DATA` can be as simple as:

Recipes reducer support for `UPDATE_DATA`

```
1  const recipesReducer = (state, action) => {
2    switch(action.type) {
3      case UPDATE_DATA:
4        if (!('recipes' in action.payload)) return state;
5
6        return Object.assign({}, state, {
7          recipes: Object.assign({},
8            state.recipes,
9            action.payload.recipes
10          )
11        });
12    }
13  };
```

Our reducer checks if the payload contains any recipes and merges the new data with the old recipes object (thus adding to or otherwise modifying it as needed).

Normalizing the Data

With the reducers updated and the action structure defined, we are left with the problem of extracting the payload from the denormalized data we got from the server.

A simple approach might be to have a custom function that knows each API's return data and normalizes the returned nested JSON into a flat structure with custom code.

Since this is quite a common practice, the custom code can be replaced by the [normalizr](https://github.com/paularmstrong/normalizr)¹⁷ library. Using this library, we can define the schema of the data coming from the server and have the `normalizr` code turn our nested JSON into a normalized structure we can pass directly into our new `UPDATE_DATA` action.

Persisting State

In many cases, we will want to keep the current state even across a page refresh or the application's tab being closed. The simplest approach to persisting the state is keeping it in the browser's local storage.

To easily sync our store with local storage (or any other storage engine), we can use the [redux-persist](https://github.com/rt2zz/redux-persist)¹⁸ library. This will automatically serialize and save our state once it has been modified.

To use the library, simply install it with `npm` and modify the store creation file to wrap `createStore` with an enhancer:

Setting up `redux-persist`

```
1 import { createStore } from 'redux';
2 import { persistStore, autoRehydrate } from 'redux-persist';
3 import rootReducer from 'reducers/root';
4
5 const store = createStore(rootReducer, autoRehydrate());
6
7 persistStore(store);
```

Once `persistStore(store)` has been called, our store and the browser's local storage will automatically be in sync and our store will persist across page refresh.

Advanced State Sync

The `redux-persist` library has advanced functionality that will allow us to whitelist only part of the state to persist and to specify special serializers for the part of the state that cannot be serialized with `JSON.stringify()` (functions, symbols, etc.). We recommend you review the library's documentation for details on the more advanced features.

¹⁷<https://github.com/paularmstrong/normalizr>

¹⁸<https://github.com/rt2zz/redux-persist>

Real-World State

In a real-world application, our state will usually contain a number of different entities, including the application data itself (preferably normalized) and auxiliary data (e.g., current access token, pending notifications, etc.).

Structure of a Common State

Unlike the data coming from the server, some information will be used exclusively by our frontend application for its internal needs. A common example would be keeping the total number of active server requests in order to know whether to display a spinner. Or we might have a `currentUser` property where we keep information about the current user, such as the username and access token:

Sample state

```
1  const state = {
2    books: { },
3    recipes: { },
4    ingredients: { },
5    ui: {
6      activeRequests: 0
7    },
8    currentUser: {
9      name: 'Kipi',
10     accessToken: 'topsecrettoken'
11   }
12 };
```

As our application grows, more types of state entities will creep in. Some of these will come from external libraries like `redux-forms`, `react-redux-router`, and others that require their own place in our state. Other entities will come from the application’s business needs.

For example, if we need to support editing of the user’s profile with the option to cancel, our implementation might create a new `temp` key where we will store a copy of the profile while it is being edited. Once the user clicks “confirm” or “cancel,” the temp copy will either be copied over to become the new profile or simply deleted.

Keeping the State Manageable

To make things as simple as possible, it is best to have a reducer for each key in the base state. This will allow for an encapsulation approach where it is immediately clear who can modify which parts of our state.

For a very large project, it might be beneficial to separate the “server data” and the “auxiliary/temp data” under different root keys:

Large nested state

```
1  const state = {
2    db: {
3      books: { },
4      recipes: { },
5      ingredients: { },
6    },
7    local: {
8      ui: {
9        activeRequests: 0
10     },
11     user: {
12       name: 'Kipi',
13       accessToken: 'topsecrettoken'
14     }
15   },
16   vendor: {
17     forms: {},
18     router: {}
19   }
20 };
```

This allows for easier management of the different parts when deciding what needs to be synced to local storage, or when clearing stale data.

In general, the state is the frontend's database and should be treated as such. It is important to periodically check the current layout and do any refactoring to make sure the state's structure is clean, clear, and easy to extend.

What to Put in the State

A common issue when working with Redux is deciding what information goes inside our state and what is left outside, either in React's state, Angular's services, or other storage methods of different UI libraries.

There are a few questions to consider when deciding whether to add something to the state:

- Should this data be persisted across page refresh?
- Should this data be persisted across route changes?
- Is this data used in multiple places in the UI?

If the answer to any of these questions is “yes,” the data should go into the state. If the answer to all of these questions is “no,” it could still go into the state, but it’s not a must.

A few examples of data that can be kept outside of the state:

- Currently selected tab in a tab control on a page
- Hover visibility/invisibility on a control
- Lightbox being open/closed
- Currently displayed errors

We can consider this similar to putting data in a database or keeping it temporarily in memory. Some information can be safely lost without affecting the user’s experience or corrupting his data.

Summary

In this chapter we discussed the structure of our Redux state and how it should be managed for easier integration with reducers and the UI. We also learned that the state should be considered the application’s database and be designed separately from the presentation or logic layers.

In the next chapter we will talk about server communication, the best method of sending and receiving data to and from our server using middleware.

Chapter 4. Server Communication

Server communication is one of the more important parts of any application. And while the basic implementation can be done in a few lines of code, it can quickly grow into a complicated mechanism able to handle authentication, caching, error handling, WebSockets, and a myriad of other functionality and edge cases.

Online tutorials usually devote little time to this topic, and suggest using regular promises and the `redux-thunk` middleware to let action creators `dispatch()` actions when data is fetched. When a project grows, however, it becomes clear that it's best to have a single place to handle authentication (setting custom headers), error handling, and features like caching. Considering this, we need to be able to both access the store and dispatch asynchronous events—which is the perfect job for a middleware.



Before reading this chapter, it is strongly recommended that you read the [Middleware Chapter](#).

Using Promises in Action Creators

Let's start by looking at server communication when implemented using async action creators (using libraries such as `redux-thunk`), to understand the underlying pitfalls of this approach:

Promise in action creator

```
1 const fetchUser = id => (dispatch) =>
2   fetch(`user/${id}`)
3     .then(response => response.json())
4     .then(userData => dispatch(setUserData(userData)))
5     .catch(error => dispatch(apiError(error)));
```

Did you notice we handled the error in `response.json()` instead of the `fetch()` API?

There are a few issues with this code:

1. We can't see an action going out in our logs before the `fetch()` completes, preventing the regular Redux debug flow.
2. Every action creator will need to have the repetitive functionality to handle errors and set headers.
3. Testing gets harder as more async action creators are added.
4. If you want to change the server communication strategy (e.g., replace `fetch()` with WebSockets), you need to change multiple places in the code.

Keeping the code as short and stateless as possible, in keeping with the spirit of Redux, is easier when all the action creators are simple functions. This makes them easier to understand, debug, and test. Keeping the action creators “clean” from async code means moving it into another part of the stack. Luckily, we have the perfect candidate—middleware. As we will see, using this approach we can keep the action creators simple and generate actions that contain all the information needed for a middleware to perform the API request.



Here, we are using the [Fetch API](#)¹⁹ to access the server. Our target URL is built from a constant specifying the root (e.g., `'http://google.com/'`) and the sub-URL we want to access, passed to us in the action object.

API Middleware

Our goal is to create a generic middleware that can serve any API request and requires only the information passed to it in an action. The simplest solution is to define a new action type that is unique to API-related events:

Simple API middleware

```
1  const apiMiddleware = ({ dispatch }) => next => action => {  
2    if (action.type !== 'API') {  
3      return next(action);  
4    }  
5  
6    // Handle API code  
7  };
```

Our middleware will listen to any action with type `'API'` and use the information in its payload to make a request to the server. It will let any other actions flow down the middleware chain.

¹⁹https://developer.mozilla.org/en/docs/Web/API/Fetch_API

Moving Code from Action Creators

The original async example used the following code to communicate with the server:

Promise in action creator

```
1 fetch(`user/${id}`)
2   .then(response => response.json())
3   .then(userData => dispatch(setUserData(userData)))
4   .catch(error => dispatch(apiError(error)));
```

This code has a few hardcoded issues that we will need to address in our generic API:

- How to construct the URL
- What HTTP verb to use (GET/POST/etc)
- What action to dispatch on success or error

Since we plan to pass all this information inside our action object, we can expect the corresponding action creator to pass in all the required parameters.

The URL-building issue is simple to solve, simply by passing the required URL in the action object (we will start with GET-only APIs):

Target URL

```
1 fetch(BASE_URL + action.url)
```



To make things more generic, actions will only hold the relative part of the server's full URL. This will allow us to easily set the `BASE_URL` to be different in production, development, and testing.

Handling the return value from the call is a bit more complex, as our middleware needs to figure out what action to dispatch. A simple solution is to pass the next action to be dispatched inside the API action. In our case we will use the Flux Standard Action (FSA) convention and put the ID of the next action inside the success key (i.e., `action.payload.success`):

Handling the result

```
1 dispatch({ type: action.payload.success, response });
```

Combining these two ideas results in the following basic API middleware:

Basic API middleware

```
1  const apiMiddleware = ({ dispatch }) => next => action => {
2    if (action.type !== 'API') {
3      return next(action);
4    }
5
6    const { payload } = action;
7
8    fetch(BASE_URL + action.url)
9      .then(response => response.json())
10     .then(response => dispatch({ type: payload.success, response }))
11   );
12 };
```

Using the API Middleware

To use our middleware we need to craft a special action object for it:

Sample action creator

```
1  import { API, SET_RECIPES } from 'constants/action-types';
2
3  const fetchRecipes = () => ({
4    type: API,
5    payload: {
6      url: 'recipes.json',
7      success: SET_RECIPES
8    }
9  })
```

Our middleware should call the server and resume the regular application flow. At a later time, once the call from the server completes, it should dispatch a new action to the store:

The resulting action dispatched after a successful call

```
1 {  
2   type: SET_RECIPES,  
3   payload: [ .. array of recipes from server ..]  
4 };
```

Error Handling

Our current example ignores any error handling. To solve this problem, we need to extend our middleware to catch server errors and dispatch events when they happen.

Error handling could be done in a number of ways:

- Dispatch a custom error message (based on data in the action object) on an error event.
- Dispatch a generic API error action to be handled by a special reducer or another middleware.
- Combine both approaches with a fallback for #2 if #1 was not provided.

For example, here we are using FSA-compliant action creators to send a generic `apiError()` message on any failed server request:

Handle API errors with generic callback only

```
1 const handleError = error => dispatch(apiError(error));  
2  
3 fetch(BASE_URL + action.url)  
4   .then(response => {  
5     if (response.status >= 300) {  
6       handleError(response.status);  
7     } else {  
8       response.json()  
9       .then(data => dispatch({ type: action.next, data })))  
10    }  
11  })  
12  .catch(handleError);
```

We leave it to you as an exercise to add support for custom error handling for actions (a way for an action creator to specify it wants a different error flow than the default).

Loading Indicator (Spinner)

A common question when using Redux is how to show a spinner when server requests are in progress. The middleware approach provides an answer using additional `dispatch()` calls. Before a request starts or after it completes, we can dispatch a special action to be caught by reducers responsible for the UI state. Here, we dispatch an `apiStart()` action before starting any server communication and dispatch `apiDone()` on both successful and failed server responses:

Show and hide spinner

```
1 dispatch(apiStart());
2
3 fetch(BASE_URL + action.payload.url)
4   .then(response => {
5     dispatch(apiDone());
6     // ...
7   })
8   .catch(error => {
9     dispatch(apiDone());
10    // ...
11  })
12 }
```

To keep track of pending requests, we can keep a counter in the state under a `serverStatus` or `ui` containers in the state. The counter can be used by the UI to show a spinner if the number of pending requests is greater than zero:

UI reducer to handle the requests counter

```
1 const uiReducer = (state, action) => {
2   switch (action.type) {
3     case API_START:
4       return Object.assign({}, state, {
5         requests: state.requests + 1
6       });
7
8     case API_DONE:
9       return Object.assign({}, state, {
10        requests: state.requests - 1
11      });
12   }
13 };
```

Dynamic Action Types

Building on the loading indicator example, we might want to handle multiple indicators for different parts of our application, by having multiple subtrees in the `ui` state sub-tree. Unfortunately, this does not work with generic success/error actions.

One way to handle multiple pending, success, and error actions is to pass them in the dispatched action:

Action creator with custom pending action

```
1 const fetchRecipes = () => ({
2   type: 'API',
3   payload: {
4     url: 'recipes.json',
5     pending: 'FETCH_RECIPES_PENDING',
6     success: 'FETCH_RECIPES_SUCCESS',
7     error: 'FETCH_RECIPES_FAILURE'
8   }
9 });
```

This method allows us to handle different action types in different reducers. However, this approach is not flexible, encourages code repetition, and forces us to have multiple action types defined for every API action.

Another approach is to store the response status in the dispatched action:

```
1 dispatch({ type: FETCH_RECIPES, status: 'SUCCESS', response });
```

This might look simple, as you can reuse one action in the middleware, but it causes reducers to contain more control flow and logic and it makes logging and debugging more difficult (because we get the same action types in the log and need to accurately verify which one of them had a particular status).

A third approach is to create dynamic action types that will follow a single convention:

constants/action-types.js

```

1  const asyncActionType = (type) => ({
2    PENDING: `${type}_PENDING`,
3    SUCCESS: `${type}_SUCCESS`,
4    ERROR: `${type}_ERROR`,
5  });
6
7  export const LOGIN = asyncActionType('LOGIN');
8  export const FETCH_RECIPES = asyncActionType('FETCH_RECIPES');

```

With this approach we can use the same action type constant to handle three cases for async actions:

reducers/recipes.js

```

1  import { FETCH_RECIPES } from 'constants/action-types';
2
3  const recipesReducer = (state, action) => {
4
5    switch (action.type) {
6      case FETCH_RECIPES.SUCCESS:
7        // Handle success
8
9      case FETCH_RECIPES.ERROR:
10       // Handle failure
11      ...
12    }
13  }

```

Since our API middleware is already checking for success and pending in the `action.payload`, the action creators can simply merge the “async-ready costs” into the resulting payload:

API action creator with custom status handling

```

1  const fetchRecipes = () => ({
2    type: API,
3    payload: Object.assign({ url: 'recipes' }, FETCH_RECIPES)
4  });

```

This action creator will result in the following action being returned:

Action with custom status handling

```
1 {  
2   type: 'API',  
3   payload: {  
4     url: 'recipes',  
5     PENDING: 'RECIPES_PENDING',  
6     SUCCESS: 'RECIPES_SUCCESS',  
7     ERROR: 'RECIPES_ERROR'  
8   }  
9 };
```

Authentication

A common place to store the current user's information (such as the access token) is in the Redux store. As all our API logic is now located in one place and the middleware have full access to the store using the `getState()` method, we can extract the `accessToken` from the state and set it as a header for our server requests:

Setting access token

```
1 const { accessToken } = getState().currentUser;  
2  
3 if (accessToken) {  
4   // Set headers  
5 }
```

All our server calls will now automatically get the correct headers without us having to worry about this in any other parts of our application.

More Extensions

There are still quite a few things missing from our API middleware to make it usable in the real world. We need support for more verbs (not just GET), setting of custom headers, timeouts, caching, and more. Much of this can be done by taking data from the action object or from the store itself. A robust API middleware solution is already available as (`redux-api-middleware`)[<https://github.com/agraboso/redux-api-middleware>].

Chaining APIs

Sometimes fetching data from a server requires a number of different calls—for instance, when the returned data from one is needed to issue additional calls. A simple example might be fetching the current user and then the user’s profile. If we were to use promises in an action creator, the solution would appear to be quite straightforward:

Chaining promises

```
1  const fetchCurrentUser = () => (dispatch) => fetch(`user`)
2    .then(response => response.json())
3    .then(userData => {
4      dispatch(setUserData(userData));
5
6      // Get user's profile
7      fetch(`profile/${userData.profileId}`)
8        .then(response => response.json())
9        .then(profileData => dispatch(setProfileData(profileData)));
10   }
11   );
12  };
```

Scary stuff there. There are a few issues with this code:

- Error handling – Exact branching and catching of errors is not obvious and can become complex as the chain grows.
- Debugging – It is hard to debug and understand what stage in the chain we are at.
- Cancellation and recovery – It is nearly impossible to cancel or abort the chain if the user navigates to a different part of the UI and the current request chain is no longer needed.

As we can see, chaining promises is not an ideal solution. When working with Redux we have two other alternatives to use, middleware and sagas.

Using Middleware for Flow

In the middleware approach, we split the code handling server access and logic flow. Our API middleware stays the same, and we only need to find another place to put the logic flow. One approach, discussed in the [Middleware Chapter](#), is to create additional middleware to handle flow management:

Sample middleware to handle user flow

```

1  const userFlowMiddleware = ({ dispatch }) => next => action => {
2    switch (action.type) {
3      case FETCH_CURRENT_USER:
4        dispatch(fetchCurrentUser());
5        break;
6      case SET_CURRENT_USER:
7        dispatch(fetchProfile(action.payload.userId));
8        break;
9    };
10
11    next(action);
12  }

```

Unfortunately, this approach has its problems too. This setup will cause the `fetchProfile()` action to be dispatched every time someone dispatches `SET_CURRENT_USER`. There might be a flow where we don't need the profile fetch but can't prevent the middleware from scheduling it.

We can solve this problem by creating a special action flow that has similar behavior to `fetchCurrentUser()` but also triggers the `fetchProfile()` action. This can be done by creating a new action creator and action:

Handle flow with custom action

```

1  const fetchCurrentUser = (next = SET_CURRENT_USER) => ({
2    type: API,
3    url: 'user',
4    next
5  });
6
7  const userFlowMiddleware = ({ dispatch }) => next => action => {
8    switch (action.type) {
9      case FETCH_CURRENT_USER:
10       dispatch(fetchCurrentUser(SPECIAL_SET_CURRENT_USER));
11       break;
12
13     case SPECIAL_SET_CURRENT_USER:
14       dispatch(setCurrentUser(action.payload));
15       dispatch(fetchProfile(action.payload.userId));
16       break;
17     };
18

```

```
19   next(action);
20 }
```

This approach requires changing our action creators in a somewhat unclear way. While it will work, it might cause bugs if we forget to issue the regular `setCurrentUser()` call from our special action handler. On the positive side, it will be much easier to debug as it's clear exactly what type of fetch we are performing.

A cleaner approach would be to allow our async action creators to pass an array of actions that the API middleware needs to `dispatch()` when a request completes successfully:

Action creator that allows multiple success callbacks

```
1  const fetchCurrentUser = (extraActions = []) => ({
2    type: API,
3    payload: {
4      url: 'user',
5      success: extraActions.concat(SET_CURRENT_USER)
6    }
7  });
```

API middleware with support for multiple success callbacks

```
1  const notify = (data) => {
2    action.next.each(type => dispatch({ type, data }));
3  };
4
5  fetch(`user/${id}`)
6    .then(response => response.json())
7    .then(notify)
8    .catch(error => dispatch(apiError(error)));
```

This new feature will allow us to clean up the flow middleware:

Handle flow with multiple actions

```
1  const userFlowMiddleware = ({ dispatch }) => next => action => {
2    switch (action.type) {
3      case FETCH_CURRENT_USER:
4        dispatch(fetchCurrentUser(FETCH_PROFILE));
5        break;
6
7      case FETCH_PROFILE:
8        dispatch(fetchProfile(action.payload.userId));
9        break;
10   };
11
12   next(action);
13 }
```

This approach allows us to fetch the current user with or without a profile update:

Fetch current user with and without a profile update

```
1  // Regular current user fetch
2  dispatch(fetchCurrentUser());
3
4  // With profile update
5  dispatch(fetchCurrentUser(FETCH_PROFILE));
```

There are a number of suggestions on flow handling in the [Middleware Chapter](#) that might make this flow even simpler to manage—for example, using sagas.

Using Sagas for Flow

A cleaner approach for flow management is using [redux-saga](#)²⁰. This library allows us to build complex asynchronous flow management solutions using sagas and effects. In essence, it uses a special middleware to add a new actor to the Redux world.

While Redux sagas are not covered in detail in this book, a simple example of using sagas to control the flow can be seen here:

²⁰<https://github.com/redux-saga/redux-saga>

Using redux saga for flow control

```
1 import { call, put } from 'redux-saga/effects'
2
3 export function *fetchCurrentUser() {
4   while (true) {
5     yield take(FETCH_CURRENT_USER);
6
7     const action = yield take(SET_CURRENT_USER);
8
9     yield put(fetchProfile(action.payload.userId));
10  }
11  };
```

In this example we have an endless loop that waits for the `FETCH_CURRENT_USER` action to be dispatched. When this occurs, the code starts waiting for the corresponding `SET_CURRENT_USER` action. The payload can be used to dispatch a `fetchProfile()` action to get the corresponding profile from the server.

This is a very basic example of saga usage and does not handle error or allows to cancel requests of flows. For more information on sagas, consult the extensive documentation at [the official redux-saga documentation site](http://redux-saga.github.io/redux-saga/index.html)²¹.

Canceling API Requests

During the app's flow we might issue a number of long requests that we need to cancel (e.g., when the user navigates to a different page of the app). Some promise implementations support this feature, but it is also quite doable with the API middleware approach.

To allow canceling we need to give a unique ID to each request being sent and keep it for the cancellation phase. This will require us to add ID support to our action creators:

²¹<http://redux-saga.github.io/redux-saga/index.html>

Action creator with ID support

```
1  const fetchUser = (id, cancelable) => ({
2    type: API,
3    url: `user/${id}`,
4    next: SET_USER,
5    cancelable
6  });
7
8  const actionId = uuid.generate();
9  dispatch(fetchUser(100, actionId));
```

In this code we used a fake `uuid.generate()` function; there are a number of different implementations of such a function, with a simple one being a global counter.

If at a later stage we want to cancel a particular API request, we will need to dispatch a special action to our middleware with the ID generated for the original action being canceled:

Action to cancel an API request

```
1  const cancelAPI = (id) => ({
2    type: CANCEL_API,
3    id
4  });
```

To handle this in our API middleware, we must either cancel the promise (when using implementations that support this feature) or let the request finish and ignore the response (simply dispatch nothing):

API middleware with cancellation support

```
1  const canceled = {};
2
3  const apiMiddleware = ({ dispatch }) => next => action => {
4
5    const handleResponse = (data) => {
6      if (action.cancelable && canceled[action.cancelable]) {
7        return;
8      }
9
10     dispatch({ type: action.next, data });
11   };
12
```

```
13  switch (action.type) {
14    case API:
15      fetch(BASE_URL + action.url)
16        .then(response => response.json())
17        .then(handleResponse)
18      );
19    return;
20
21    case CANCEL_API:
22      canceled[action.id] = true;
23      setTimeout(() => delete canceled[action.id], 5000);
24  }
25
26  return next(action);
27  };
```

To implement this functionality, we simply added an object with keys corresponding to canceled requests. The `setTimeout()` function is used to clear canceled requests after 5 seconds to prevent the object from filling up needlessly.

With this functionality we can cancel requests at any time and not have to worry about request completion happening long after the user has navigated away from the original location in the app or after a later request has completed (for example, two consecutive filter requests for data being sent and the first one returning after the latter one).

Summary

In this chapter we have learned how to set up a comprehensive mechanism for server communication. We have used Redux's concept of middleware to move most of the complicated and asynchronous logic away from our action creators and created a single place where error handling, caching, and other aspects of server requests can be concentrated.

In the next chapter we will cover WebSocket based communication and how well it can work with the Redux architecture.

Chapter 5. WebSockets

WebSockets have brought a robust socket communication method directly into our browsers. What started as a solution for polling data changes on the server is slowly taking over more and more responsibilities from traditional REST endpoints. The action-based architecture of Redux makes working with WebSockets exceptionally easy and natural, as it involves using WebSockets as a pipe to pass actions to and from the server.

Basic Architecture

WebSockets allow us to open a connection to a server and send or receive messages in a fully asynchronous way. The native implementation in browsers has only four callback methods that are required to fully support WebSockets:

- `onopen` – A connection has become active.
- `onclose` – A connection has been closed.
- `onerror` – An error related to WebSocket communication has been raised.
- `onmessage` – A new message has been received.

While multiple WebSockets might be used, most applications will require a single one or at most a few connections for different servers based on function (chat server, notifications server, etc.).

To start, we will build a system to communicate with a single WebSocket, which can later be extended for multi-WebSocket support.

Redux Link

The general Redux architecture is all about sending well-defined messages to the store. This same scheme can work perfectly for server communication over WebSockets. The same structure of plain objects with the `type` property can be sent to the server, and we can receive a similarly structured response back:

Sample communication flow

```
1 > TO-SERVER: { type: 'GET_USER', id: 100 }
2 < FROM-SERVER: { type: 'USER_INFO', data: { ... } }
```

A more robust example might be a chat server, where we can dispatch to the store a message similar to: `{ id: 'XXX', type: 'ADD_MESSAGE', msg: 'Hello' }`. Our store can handle this immediately by adding the message to the current messages array and send it “as is” over a WebSocket to the server. The server, in turn, can broadcast the message to all other clients. Each will get a perfectly standard Redux action that can be passed directly to their stores.

This way our frontend can use Redux actions to pass information between browser windows and machines, using the server as a generic dispatcher. Our server might do some additional work, like authentication and validation to prevent abuse, but in essence can serve as a message passer.

An ideal WebSocket implementation for Redux would allow us to `dispatch()` actions and have them smartly routed to the server when needed, and have any actions coming from the WebSocket be dispatched directly to the store.

Code Implementation

As with any infrastructure-related code, middleware is the perfect place for our WebSocket implementation. It will allow us to catch any actions that are required to be sent over the WebSocket and `dispatch()` anything coming from the server.

Basic structure of a WebSocket setup

```
1 const WS_ROOT = "ws://echo.websocket.org/";
2
3 const websocket = new WebSocket(WS_ROOT);
4
5 websocket.onopen    = () => {};
6 websocket.onclose   = () => {};
7 websocket.onerror   = event => {};
8 websocket.onmessage = event => {};
```

To make the code more readable, we can replace the four different assignments with a single use of `Object.assign()` and use code similar to this:

Using Object.assign

```
1 Object.assign(websocket, {  
2   onopen()    { },  
3   onclose()   { },  
4   onerror(e)  { },  
5   onmessage(e) { }  
6 });
```

In our middleware, we want to make sure a WebSocket is created only once. Thus, we cannot put the setup code inside the action handler:

The wrong way to initialize in middleware

```
1 const wsMiddleware = ({ dispatch, getState }) => next => action => {  
2   // Initialization not allowed  
3 };
```

The code in the innermost block gets called every time an action is dispatched, so this would cause our setup and WebSocket creation code to be called multiple times. To prevent this, we can do the initialization outside the action callback block:

Correct way to initialize in middleware

```
1 const wsMiddleware = ({ dispatch, getState }) => next => {  
2  
3   // TODO: Initialization  
4  
5   return action => {  
6     // TODO: Middleware code  
7   };  
8 };
```

Let's get back to the initialization code and consider how to handle each of the four callbacks: `onopen`, `onclose`, `onerror`, and `onmessage`.

onopen

This is mainly an informative stage; we need to indicate to ourselves that the socket is ready to send and receive data and might choose to notify the rest of the Redux application that the socket is ready (perhaps to show some indication in the UI).

Once the socket is open, we dispatch a simple `{ type: 'WS_CONNECTED' }` action to notify the rest of Redux:

Handling onopen

```
1 websocket.onopen = () => dispatch(wsConnected());
```

The `wsConnected()` function is a simple action creator that should be implemented in one of the action creator files:

`app/actions/ui.js`

```
1 import { WS_CONNECTED } from 'consts/action-types';  
2  
3 const wsConnected = () => ({ type: WS_CONNECTED });
```

onclose

The close or disconnect event is very similar to `onopen` and can be handled in the exact same way:

Handling onclose

```
1 websocket.onclose = () => dispatch(wsDisconnected());
```

onerror

The WebSocket implementation in a browser can provide information on various failures in the underlying socket communication. Handling these errors is similar to handling regular REST API errors, and might involve dispatching an action to update the UI or closing the socket if needed.

In this example we will stop at a generic `console.log()` and leave it to the reader to consider more advanced error handling methods:

Handling onerror

```
1 Websocket.onerror = (error) =>  
2   console.log("WS Error", error.data);
```

onmessage

This callback is called every time a new message is received over a WebSocket. If we have built our server to be fully compatible with Redux actions, the message can simply be dispatched to the store:

Handling onmessage

```
1 websocket.onmessage = (event) => dispatch(JSON.parse(event.data));
```

Handling Outgoing Messages and Actions

With all the WebSocket callbacks handled, we need to consider how and when to pass actions from Redux to the server:

```
1 return action => {  
2   // TODO: Pass action to server  
3  
4   next(action);  
5 };
```

Before sending any actions, we need to make sure that the WebSocket is open and ready for transmissions. WebSockets have a `readyState` property that returns the current socket status.

Check if the socket is open

```
1 const SOCKET_STATES = {  
2   CONNECTING: 0,  
3   OPEN: 1,  
4   CLOSING: 2,  
5   CLOSED: 3  
6 };  
7  
8 if (websocket.readyState === SOCKET_STATES.OPEN) {  
9   // Send  
10 }
```

Even when the socket is open, not all actions need to be sent (for example, the `TAB_SELECTED` or `REST_API_COMPLETE` actions), it is best to leave the decision of what to send to our action creators. The standard way to provide special information about actions to middleware is to use the meta key inside an action. Thus, instead of using a regular action creator:

A regular action creator

```
1 export const localAction = (data) => ({
2   type: TEST,
3   data
4 });
```

we can add special information to the metadata part of the action:

An action creator for an action to be sent to the server

```
1 export const serverAction = (data) => ({
2   type: TEST,
3   data,
4   meta: { websocket: true }
5 });
```

This way our middleware can use the `meta.websocket` field to decide whether to pass the action on or not:

Sending actions to the server

```
1 return action => {
2   if (websocket.readyState === SOCKET_STATES.OPEN &&
3     action.meta &&
4     action.meta.websocket) {
5     websocket.send(JSON.stringify(action));
6   }
7   next(action);
8 };
9
```

Note, however, that this code might cause a surprising bug. Since we are sending the whole action to the server, it might in turn broadcast it to all other clients (even ourselves). And because we didn't remove the action's meta information, the other clients' WebSocket middleware might rebroadcast it again and again.

A Redux-aware server should consider stripping all meta information for any action it receives. In our implementation we will remove this on the client side, though the server should still do the check:

Sending actions to the server (without metadata)

```
1 return next => action => {
2   if (websocket.readyState === SOCKET_STATES.OPEN &&
3     action.meta &&
4     action.meta.websocket) {
5
6     // Remove action metadata before sending
7     const cleanAction = Object.assign({}, action, { meta: undefined });
8     websocket.send(JSON.stringify(cleanAction));
9   }
10
11   next(action);
12 };
```

Using this approach, sending actions to our server via a WebSocket becomes as simple as setting the `meta.websocket` field to `true`.

Complete WebSocket Middleware Code

middleware/ws.js

```
1 import { wsConnected, wsDisconnected } from 'actions';
2 import { WS_ROOT } from 'const/global';
3
4 const SOCKET_STATES = {
5   CONNECTING: 0,
6   OPEN: 1,
7   CLOSING: 2,
8   CLOSED: 3
9 };
10
11 const wsMiddleware = ({ dispatch }) => next => {
12
13   const websocket = new WebSocket(WS_ROOT);
14
15   Object.assign(websocket, {
16     onopen() {
17       active = true;
18       dispatch(wsConnected())
19     },
```

```
20
21   onclose() {
22     active = false;
23     dispatch(wsDisconnected())
24   },
25
26   onerror(error) {
27     console.log(`WS Error: ${ error.data }`);
28   },
29
30   onmessage(event) {
31     dispatch(JSON.parse(event.data));
32   }
33 });
34
35 return action => {
36   if (websocket.readyState === SOCKET_STATES.OPEN &&
37       action.meta &&
38       action.meta.websocket) {
39
40     // Remove action metadata before sending
41     const cleanAction = Object.assign({}, action, {
42       meta: undefined
43     });
44     websocket.send(JSON.stringify(cleanAction));
45   }
46
47   next(action);
48 };
49
50 export default wsMiddleware;
```

Authentication

Handling authentication with WebSockets might be a little tricky as in many applications, WebSockets are used alongside regular HTTP requests. The authentication will usually be done via regular REST or OATH calls and the frontend granted a token - either set in cookies or to be saved in LocalStorage.

To allow the server to authenticate a WebSocket, a special - agreed upon action - needs to be sent by the client. In the case of Redux, a special action object can be serialized and sent before doing any other work over WebSockets.

Sample Flow

A simple way to implement authentication might be to send an API action to our server containing an email and a password:

Sample action to authenticate with the server

```
1 dispatch({
2   type: API,
3   payload: {
4     url: 'login',
5     method: 'POST',
6     success: LOGIN_SUCCEESS,
7     data: {
8       email: 'info@redux-book.com',
9       password: 'top secret'
10    }
11  }
12 });
```

If successful, our API Middleware will dispatch the LOGIN_SUCCESS action containing the information returned from the server:

Action dispatched on successful login

```
1 {
2   type: LOGIN_SUCCEESS,
3   payload: {
4     token: 'xxxYYYzzzz'
5   }
6 }
```

Our user's reducer will probably act on this action to add the token to the state - to be passed in headers of future API requests to the server.

To make WebSockets authenticate using this token, we can add special code to our WebSocket API that will check for LOGIN_SUCCESS (and LOGOUT_SUCCESS)

Authentication code in the WebSocket middleware

```
1  if (action.type === LOGIN_SUCCESS) {
2    dispatch({
3      type: WEBSOCKET_AUTH,
4      payload: action.payload.token,
5      meta: { websocket: true }
6    });
7  }
8
9  if (action.type === LOGOUT_SUCCESS) {
10   dispatch({
11     type: WEBSOCKET_LOGOUT,
12     meta: { websocket: true }
13   });
14 }
```

Now the passage of `LOGIN_SUCCESS` will cause a new WebSocket enabled action to be dispatched and processed by our middleware to authenticate with the server.

The flow of actions

```
1  > Store:
2  { type: API, payload: ... }
3
4  > Server:
5  POST http://.../login
6
7  > Store:
8  { type: LOGIN_SUCCESS, payload: token }
9
10 > Store:
11 { type: WEBSOCKET_AUTH, payload: token, meta: { websocket: true }}
12
13 > WebSocket:
14 { type: WEBSOCKET_AUTH, payload: token }
```

Notes

For a full flow of the WebSocket middleware, it would be best to keep track of the authentication state of the WebSocket and prevent actions from being sent or received before the WebSocket has been authenticated or after it has been logged out from.

When the token is already present in cookie it will be passed to WebSocket as soon as the socket is opened. This might cause problems if the login process happens after the application loads. Or even worse, when the user logs out our WebSocket might still stay authenticated. It is better to use the action based authentication approach described above to avoid these and similar issues.

Summary

This chapter has illustrated how well WebSockets work with Redux and the practical steps needed to set up WebSocket-based communication.

In the next chapter we will cover the subject of testing and how each part of our Redux application can be tested separately and together.

Chapter 6. Tests

One of the key strengths of Redux is its ease of testability. To fully automate the testing suite, we can create unit tests for each of the different actors (reducers, action creators, and middleware) and combine them together for comprehensive integration tests.

There are a large number of testing tools available, but the exact tooling is less important as most parts of our Redux application will rely on plain JavaScript functions and objects with no complicated libraries or async flows to test.

As our testing framework we will be using the excellent [Jest](https://facebook.github.io/jest/)²² library from Facebook, the latest version of which proves to be an excellent choice for testing Redux. Using other frameworks and tools such as Karma, Mocha, and so on should look very similar to the examples in this chapter.

To find the best way to add Jest to your project and operating system, please follow [Jest's getting started guide](https://facebook.github.io/jest/#getting-started)²³.

Test Files and Directories

To start off we need a way to organize our tests. There are two main approaches: putting the tests together in the same directory with the implementation files, or putting them in a separate directory. In this guide we will use the latter. The choice is a matter of convenience and personal preference, with the only side effects being different test runner configurations.

We will create a separate test file for each implementation file in our project. In the case of `app/actions/recipes.js`, our test file will be `tests/actions/recipes.test.js`.

Test File Structure

In our test files we will use a `describe()` function to wrap all our tests. The first string parameter in this function will allow us to easily determine which group of tests are failing or succeeding:

²²<https://facebook.github.io/jest/>

²³<https://facebook.github.io/jest/#getting-started>

Sample test file structure

```
1 describe('actions', () => {  
2   // TODO: Add tests  
3 });
```

Inside this function other nested `describe()` functions can be used, to further distinguish between different sets of states (for example, testing failing or succeeding API calls).

Each test in Jest is wrapped within an `it()` block describing what the test does. To keep the tests readable and easy to understand, it is generally recommended to create as many short tests as possible (each within its own `it()` block) rather than creating very large single test functions:

Sample test file with test placeholders

```
1 describe('actions', () => {  
2   it('should create an action to add a todo', () => {  
3     // TODO: Implement test  
4   });  
5  
6   it('should create an action to delete a todo', () => {  
7     // TODO: Implement test  
8   });  
9 });
```

Testing Action Creators

Throughout this book we have tried to keep asynchronous flows out of action creators by moving them into middleware and utility functions. This approach allows for very easy testing of action creators, as they are functions that simply return plain JavaScript objects:

Simple action creator

```
1 import * as actions from 'constants/action-types';  
2  
3 export const setRecipes = (recipes) => ({  
4   type: actions.SET_RECIPES,  
5   payload: recipes  
6 });
```

Our `setRecipes()` action creator receives a single parameter and creates a plain JavaScript object in return. Since there is no control flow logic or side effects, any call to this function will always return the same value, making it very easy to test:

Simple test for setRecipes

```
1 import * as actions from 'actions'
2
3 describe('actions', () => {
4   it('should create an action to add a todo', () => {
5     const expected = { type: 'ADD_RECIPE', payload: 'test' };
6     const actual = actions.addRecipe('test');
7
8     expect(actual).toEqual(expected);
9   });
10 });
```

This test is built in three parts. First, we calculate what our action creator should return when called with 'test' as an argument—in this case a JavaScript object containing two keys, type and payload:

Calculate expected result

```
1 const expected = { type: 'ADD_RECIPE', payload: 'test' };
```

The second stage is running the action creator `actions.addRecipe('test')` to get the value built by our action creator's implementation:

Calculate actual result

```
1 const actual = actions.addRecipe('test');
```

And the final stage is using Jest's `expect()` and `toEqual()` functions to verify that the actual and expected results are the same:

Verify results match

```
1 expect(actual).toEqual(expected);
```

If the `expected` and `actual` objects differ, Jest will throw an error and provide information describing the differences, allowing us to catch incorrect implementations.

Improving the Code

Due to the simplicity of this code, it is common to combine multiple stages into a single call and rewrite the test as follows:

Shorter version of the test

```
1 it('should create an action to add a recipe', () => {  
2   const expected = { type: 'ADD_RECIPE', payload: 'test' };  
3  
4   expect(actions.addRecipe('test')).toEqual(expected);  
5 });
```

Using Snapshots

The approach of calculating the expected value and then comparing it to dynamically calculated values is very common in Redux tests. To save typing time and make the code cleaner to read, we can use one of Jest's greatest features, [snapshots](https://facebook.github.io/jest/docs/tutorial-react.html#snapshot-testing)²⁴.

Instead of building the expected result, we can ask Jest to run the `expect()` block and save the result in a special `.snap` file, generating our expected object automatically and managing it for us:

Test with snapshot

```
1 it('should create an action to add a recipe', () => {  
2   expect(actions.addRecipe('test')).toMatchSnapshot();  
3 });
```

The expected calculation is gone, and instead of using `isEqual()`, Jest will now compare the result of the expression inside `expect()` to a version it has saved on disk. The actual snapshot is placed in a `__snapshots__` directory in a file with the same name as the test file plus the `.snap` extension:

snapshots/action.test.js.snap

```
1 exports[`actions should create an action to add a recipe 1`] = `  
2 Object {  
3   "payload": "test",  
4   "type": "ADD_RECIPE",  
5 }  
6 `;
```

²⁴<https://facebook.github.io/jest/docs/tutorial-react.html#snapshot-testing>

The structure is more complicated than that of a regular JavaScript object, but the result is exactly the same as our original expected calculation:

Calculate expected result

```
1 const expected = { type: 'ADD_RECIPE', payload: 'test' };
```

What happens when our code changes? In some cases we want to intentionally change the structure of our action object. In these cases, Jest will detect that the returned value does not match what is saved inside its snapshot file and throw an error. But if we determine that the new result is the correct one and the cached snapshot is no longer valid, we can easily tell Jest to update its snapshot version to the new one.

Dynamic Action Creators

In some cases, action creators might contain logic that emits different action objects based on its input parameters. As long as no asynchronous code or other external entities (like `localStorage`) are touched, we can easily test the logic by providing different input parameters to the action creator and verifying it creates the correct object every time:

An action creator that modifies the input

```
1 export const addRecipe = (title) => ({  
2   type: actions.ADD_RECIPE,  
3   payload: title || "Default"  
4 });
```

The modified `addRecipe()` action creator will set payload to "Default" if the user does not provide a title. To test this behavior we can create two tests, one that provides a parameter (as we already did) and one that provides an empty string. A fully comprehensive test might contain multiple “empty string” cases, for `null`, `undefined`, and `''`:

Combined test of multiple emptystring input values

```
1 it('should add recipe with default parameter', () => {  
2   expect(actions.addRecipe(undefined)).toMatchSnapshot();  
3   expect(actions.addRecipe(null)).toMatchSnapshot();  
4   expect(actions.addRecipe('')).toMatchSnapshot();  
5 });
```

In contrast to what we discussed earlier, here we tried putting multiple `expect()` functions into the same test. While this approach will work, it will be harder to identify which of the test cases failed in the event of an error.

Since we are using JavaScript to write our tests, we can easily create test cases for each input value without increasing our code size significantly (by creating an `it()` clause for each). We can do that by adding all the possible inputs into an array and automatically creating corresponding `it()` blocks:

Automatically create tests for each test case

```
1 [undefined, null, ''].forEach((param) =>
2   it(`should add recipe with default parameter ${param}`, () => {
3     expect(actions.addRecipe(param)).toMatchSnapshot()
4   }));
```

Using this approach we get three different `it()` blocks automatically generated by JavaScript, keeping our tests clear and the code short.

Async Action Creators

Throughout this book we have tried to discourage the use of asynchronous action creators and functions that have side effects and have used various libraries like `redux-thunk`²⁵ to allow action creators to schedule async work and be non-idempotent. One of the main benefits is the ease of testing regular action creators offer—more information on this can be found in the [Action Creators Chapter](#).

For our example we will create a simple async action creator that uses `redux-thunk` and the `fetch()` API to get recipe data from a server and dispatches the result with a `SET_RECIPE` action:

Async action creator

```
1 export const setRecipe = (id, data) => ({
2   type: actions.SET_RECIPE,
3   payload: { id, data }
4 });
5
6 export const fetchRecipe = id => dispatch => {
7   return fetch('recipe/' + id)
8     .then(response => response.json())
9     .then(json => dispatch(setRecipe(id, json)))
10  };
```

With `redux-thunk`, our action creators can return a function instead of a plain JavaScript object. The thunk middleware will call such a function and pass it the store's `dispatch()` and `getState()` methods. This allows the action creator to use the async `fetch()` API to get data from the server and dispatch an action when it's done using `dispatch()`.

²⁵<https://github.com/gaearon/redux-thunk>

Stubbing fetch()

Before we move on to the actual tests, we need to lay out some infrastructure for stubbing the `fetch()` API. We are going to create a mock response object and then stub the `fetch()` API on our window object:

Create a fake response object

```
1 export const mockResponse = (status, statusText, response) => {
2   return new window.Response(response, {
3     status: status,
4     statusText: statusText,
5     headers: {
6       'Content-type': 'application/json'
7     }
8   });
9 };
```

Stub a successful fetch

```
1 export const mockFetch = (status, data) => {
2   window.fetch = jest.fn().mockImplementation(
3     () => Promise.resolve(mockResponse(status, null, data));
4 };
```

Stub a failing fetch

```
1 export const mockFetchError = (state, error) => {
2   window.fetch = jest.fn().mockImplementation(
3     () => Promise.reject(mockResponse(state, error, '{}'));
4   );
5 };
```

The mock `fetch()` call will return a resolved promise that is similar to the real result from a `fetch()` call:

Sample mocked fetch code

```
1 mockFetch(200, '{"key": "value"}');
2 fetch('test.json')
```

This code will allow us to call `mockFetch()` or `mockFetchError()`, causing the next call to `fetch()` to return with our mocked response. The only issue with this implementation is that it stubs all the `fetch()` calls in the system, regardless of the URL.

Since the first parameter to `fetch()` is the URL, we can use the common `handleResponse()` function to first verify that the URL passed to `fetch()` is the URL we have stubbed:

Stubbing with URL verification

```

1  const handleResponse = (mockedUrl, response) =>
2    window.fetch = jest.fn().mockImplementation(url => {
3      if (url === mockedUrl) {
4        return response;
5      }
6      throw('Unknown URL: ' + url);
7    });
8
9  export const mockFetch = (mockedUrl, status, data) =>
10    handleResponse(
11      mockedUrl,
12      Promise.resolve(mockResponse(status, null, data)));
13
14  export const mockFetchError = (mockedUrl, state, error) =>
15    handleResponse(
16      mockedUrl,
17      Promise.reject(mockResponse(state, error, '{}')));

```

Creating a Mock Store

Unlike simple action creators, our code now relies on `dispatch()` being used, which forces us to create a mock instance of a store. To do so, we will use the [redux-mock-store](https://github.com/arnaudbenard/redux-mock-store)²⁶ library:

Create a mock store

```

1  import configureStore from 'redux-mock-store';
2  import thunk from 'redux-thunk';
3
4  const mockStore = configureStore([ thunk ]);

```

Here we create a mock store object with a single `thunk` middleware. This store object can be used as a regular Redux store; it supports dispatching of actions and will later allow us to assert that the correct set of actions was sent to our store.

Async Action Creator Test Structure

Since async action creators might contain different flows based on the result of the async action, it is best to put them into their own `describe()` blocks in the tests. This will also allow us to easily create a fresh “mock store” for each of the test cases using Jest’s `beforeEach()` method:

²⁶<https://github.com/arnaudbenard/redux-mock-store>

Structure of an async test block

```
1 describe('fetch recipe', () => {  
2   let store;  
3  
4   beforeEach(() => store = mockStore({}));  
5  
6   it('should fetch recipe if it exists');  
7  
8   ...  
9 });
```

Our mock store gets automatically re-created before each iteration of the tests, clearing any actions cached from the previous run.

Basic Async Action Creator Test

Jest handles async tests by allowing us to return a promise as the test's result. If a promise is returned, the test runner will wait for the promise to resolve and only then continue to the next test:

Async test

```
1 it('should fetch recipe if it exists', () => {  
2   return store.dispatch(actions.fetchRecipe(100));  
3 });
```

Since `store.dispatch()` in this case returns a promise (remember our `fetchRecipe()` action creator returns a call to the `fetch()` API), we can use it to create an async test.

To add an `expect()` clause to the code, we can use the same promise and run our tests as soon as it is resolved:

Adding expect calls to async tests

```
1 it('should fetch recipe if it exists', () => {  
2   return store.dispatch(actions.fetchRecipe(100))  
3     .then(() => expect(store.getActions()).toEqual([]))  
4 });
```

The `expect()` clause is similar to what we used in our previous tests. We are using the mocked store's `getActions()` method to get an array of all the actions dispatched to the store. In our implementation we expect a successful call to `fetch()` to dispatch the result of the `setRecipe()` action creator.

Running this test now will fail, since we didn't mock the `fetch()` API. Using the small utility library we created previously, we can create the mock that will result in the correct action sequence:

Full async test

```
1 it('should fetch recipe if it exists', () => {  
2   mockFetch('recipe/100', 200, '{"title":"hello"}');  
3  
4   return store.dispatch(actions.fetchRecipe(100))  
5     .then(() => expect(store.getActions()).toMatchSnapshot())  
6 });
```

Here we mock a 200 successful response from the `fetch()` API and expect that dispatching the async action created by `fetchRecipe(100)` results in a later dispatch of the action created by `setRecipe()`.

Async Tests Summary

As can be seen from this minimal example, testing async action creators is much more complicated than testing regular action creators. If we add proper error handling and branching, the tests quickly become very hard to reason out and build.

The [Middleware Chapter](#) offers an alternative to async action creators by moving the asynchronous logic into middleware. This allows us to test and concentrate all the async code of an application in a single place.

Reducer Tests

Testing reducers is very similar to testing action creators, as reducers by definition are idempotent (given a state and an action, the same new state will be returned every time).

This makes reducer tests very easy to write, as we simply need to call the reducer with different combinations of input to verify the correctness of the output.

Basic Reducer Test

For our test, we can create a very crude reducer that handles a single `ADD_RECIPE` action and whose state is simply an array of recipes:

Simple recipes reducer

```
1 import { ADD_RECIPE } from 'consts.js';
2
3 const reducer = (state = initialState, action) => {
4   switch(action.type) {
5     case ADD_RECIPE:
6       return state.concat({ title: action.payload });
7   }
8
9   return state;
10 };
11
12 export default reducer;
```

There are two main test cases to consider, adding a recipe to an empty list and a non-empty one. We can test the first case as follows:

Simple recipes reducer test

```
1 import reducer from 'reducers/recipes';
2
3 import { ADD_RECIPE } from 'consts';
4
5 describe("recipes reducer", () => {
6   it('should add recipe to empty list', () => {
7     const initialState = [];
8     const action       = { type: ADD_RECIPE, payload: 'test' };
9     const expected      = [{ title: "test" }];
10    const actual         = reducer(initialState, action);
11
12    expect(actual).toEqual(expected);
13  });
14 };
```

The steps taken here should already be familiar:

1. Calculate the initial state (an empty array in our case).
2. Build the action to send.
3. Set the expected state the reducer should return.
4. Call `reducer()` to calculate the state based on the empty array and our action.
5. Verify that the actual and expected states match.
6. Calculating the initial state

Before we simplify the code, let's consider the second test case, adding a recipe to a non-empty list:

Test of adding a recipe to a non-empty list

```
1 it('should add recipe to non-empty list', () => {
2   const initialState = [{ title: "first" }];
3   const action       = { type: ADD_RECIPE, payload: 'test' };
4   const expected     = [{ title: "first" }, { title: "test" }];
5   const actual       = reducer(initialState, action);
6
7   expect(actual).toEqual(expected);
8 });
```

In this test we start with a list containing a single item and update our expected result to match. While this works, it has a maintenance problem. What will happen if our recipes contain more fields in the future?

Using this method of writing tests, we will need to find each test definition's initial state and add more properties to it. This complicates the test writer's job without providing any benefits. Luckily, we already have a way to create non-empty states: the reducer! Since we already tested adding to an empty list in the first test, we can rely on our reducer to create a non-empty list with all the required recipe information:

Build initial state using the reducer

```
1 const initialState = reducer([], { type: ADD_RECIPE, payload: 'first' });
```

This only partially solves the problem, though, as we are still treating the initial state as an empty array (`[]`). While this is true in our test case, other reducers might have more complicated structures to deal with. A simple solution would be to create a `const initialState = {}` at the root of the tests and rely on it when needed:

Set initial state for all tests

```

1 describe("recipes reducer", () => {
2   const initialState = [];
3
4   it('should add recipe to empty list', () => {
5     const action      = { type: ADD_RECIPE, payload: 'test' };
6     const expected    = [{ title: "test" }];
7     const actual      = reducer(initialState, action);
8
9     expect(actual).toEqual(expected);
10  });
11
12  it('should add recipe to non-empty list', () => {
13    const testState    = reducer(initialState, { type: ADD_RECIPE, payload: 'first' });
14    const action      = { type: ADD_RECIPE, payload: 'test' };
15    const expected    = [{ title: "first" }, { title: "test" }];
16    const actual      = reducer(testState, action);
17
18    expect(actual).toEqual(expected);
19  });
20 }
21 
```

The same `initialState` is used in all the tests, but it is still hardcoded in our test file. If our reducer changes the way state is built, we will be forced to update the test files accordingly. To remove this dependency we can rely on a feature that is forced by Redux's `combineReducers()`. It mandates that any reducer called with an undefined state must return its part of the initial state structure:

Excerpt from our reducer

```

1 const initialState = [];
2
3 const reducer = (state = initialState, action) => {
4   ...
5 }

```

This means we can use the reducer to get the initial state to use for all of our tests, simply by calling it with `undefined` and any action:

Generate the initial state using our reducer

```
1  const initialState = reducer(undefined, { type: 'INIT' });
```

The result will put the same `[]` in the initial state, but now any changes to what the reducer considers to be the initial state will be automatically picked up by the tests as well.

Making the Tests Pretty

Now that we've solved all the functionality issues, we can use the same tricks we used in the action creator tests to simplify our reducer tests. Here are the original tests:

Original tests

```
1  it('should add recipe to empty list', () => {
2    const action = { type: ADD_RECIPE, payload: 'test' };
3    const expected = [{ title: "test" }];
4
5    expect(reducer(initialState, action)).toEqual(expected);
6  });
7
8  it('should add recipe to empty list', () => {
9    const baseState = reducer(initialState,
10     { type: ADD_RECIPE, payload: 'first' });
11    const action      = { type: ADD_RECIPE, payload: 'test' };
12    const expected    = [{ title: "first" }, { title: "test" }];
13    const actual      = reducer(baseState, action);
14
15    expect(actual).toEqual(expected);
16  });
```

The first step will be to combine `action`, `actual`, and `expect()` into a single line:

Simplified tests

```
1 it('should add recipe to empty list', () => {
2   const expected = [{ title: "test" }];
3
4   expect(reducer(initialState, { type: ADD_RECIPE, payload: 'test' }))
5     .toEqual(expected);
6 });
7
8 it('should add recipe to empty list', () => {
9   const baseState = reducer(initialState, { type: ADD_RECIPE, payload: 'first' })\
10 );
11   const expected = [{ title: "first" }, { title: "test" }];
12
13   expect(reducer(baseState, { type: ADD_RECIPE, payload: 'test' }))
14     .toEqual(expected);
15 });
```

The second step is to use Jest's snapshots instead of manually calculated expected values:

Simplified tests, stage 2

```
1 it('should add recipe to empty list', () => {
2   expect(reducer(initialState, { type: ADD_RECIPE, payload: 'test' }))
3     .toMatchSnapshot()
4 });
5
6 it('should add recipe to empty list', () => {
7   const baseState = reducer(initialState, { type: ADD_RECIPE, payload: 'first' })\
8 );
9
10   expect(reducer(baseState, { type: ADD_RECIPE, payload: 'test' }))
11     .toMatchSnapshot();
12 });
```

Avoiding Mutations

One key requirement is that our reducers never modify the state, but only create a new one. Our current tests do not catch these issues (try changing `.concat()` to `.push()` in the reducer implementation).

While we can try to catch these mistakes by manually verifying that the initial state did not change, a simpler approach would be to “freeze” the initial state and have any changes to it automatically stop the tests. To achieve this we can use the excellent [deep-freeze²⁷](#) library, installed as follows:

Installing deep-freeze

```
1 npm install deep-freeze --save
```

To use deep-freeze, we wrap our initial state with a call to `deepFreeze()`:

Using deep-freeze

```
1 import deepFreeze from 'deep-freeze';
2
3 const initialState = deepFreeze(reducer(undefined, { type: 'INIT' }));
```

Any attempt by any parts of our code to modify `initialState` will now automatically throw an error:

Automatically catch change attempts

```
1 initialState.push('test');
2 > TypeError: Can't add property 0, object is not extensible
```

To ensure that our reducers never change the original state, we can always call `deepFreeze()` on the state passed as the first parameter to a reducer:

Updated add to non-empty list test

```
1 it('should add recipe to empty list', () => {
2   const baseState = reducer(initialState, { type: ADD_RECIPE, payload: 'first' })\
3   );
4
5   expect(reducer(
6     deepFreeze(baseState),
7     { type: ADD_RECIPE, payload: 'test' }
8   )
9   ).toMatchSnapshot();
10 });
```

²⁷<https://github.com/substack/deep-freeze>

Action Creators and Reducers

Usually when writing unit tests it is recommended to test each part of the system separately and only test connections and interfaces in the integration tests. In the case of Redux, though, it is worth considering the connection between action creators and reducers.

In the current way we've built our tests, the `ADD_RECIPE` action object is defined in three different places: the recipe's action creators, the recipe's tests, and the reducer's tests.

If, in the future, we decide to change the structure of the `ADD_RECIPE` action, our action creator tests will catch the change and remind us to update the test code. But the reducer's tests will continue to pass unless we remember to change the hardcoded `ADD_RECIPE` action objects used in those tests as well.

This can lead to painful edge cases where all the tests pass, but the system doesn't work. To avoid this, we can stop using hardcoded action objects in reducers and rely on action creators directly:

Reducer tests modified to use action creators directly

```
1 it('should add recipe to empty list', () => {
2   expect(reducer(initialState, addRecipe('test'))).toMatchSnapshot()
3 });
4
5 it('should add recipe to empty list', () => {
6   const baseState = deepFreeze(reducer(initialState, addRecipe('first')));
7
8   expect(reducer(baseState, addRecipe('test'))).toMatchSnapshot();
9 });
```

While somewhat breaking the unit test principle, combining the reducers with action creators results in cleaner code, fewer bugs, and less duplication.

Unknown Actions

One last issue to test with reducers is that they gracefully handle unknown actions and return the original state passed to them without modifications.

Since every action can propagate to the whole reducer tree, it is important for the reducer to return the original state and not a modified copy. This will allow UI libraries to identify changes in the tree using reference comparison.

We can do this as follows:

Unknown actions test

```
1 it('should handle unknown actions', () => {  
2   expect(reducer(initialState, { type: 'FAKE' })).toBe(initialState);  
3 });
```

An important thing to note about this test is the use of `.toBe()` instead of `.toEqual()` or `.toMatchSnapshot()`. Unlike the other methods, `.toBe()` expects the result of the reducer to be the exact same object, not a similar object with the same data:

Example use of toBe

```
1 const a = { name: 'Kipi' };  
2 const b = { name: 'Kipi' };  
3  
4 it('passing test', () => {  
5   expect(a).toEqual(b);  
6 });  
7  
8 it('failing test', () => {  
9   expect(a).toBe(b);  
10  });
```

The main goal of this test is to verify that our reducer returns the original state if the action sent was not intended for it:

Correct reducer code

```
1 const reducer = (state = initialState, action) => {  
2   switch(action.type) {  
3     case ADD_RECIPE: return state.concat({ title: action.payload })  
4   }  
5  
6   return state;  
7 };
```

Testing Middleware

Middleware are where most of the complex logic of our application will reside. Since they have full access to the store's `dispatch()` and `getState()` methods as well as control over the actions' flow via `next()`, middleware can become quite complex with nontrivial asynchronous flows.

Middleware Test Structure

At their core middleware are functions that receive actions to process, albeit with a complicated signature (a function, returning a function, returning a function). The first two function calls are made by Redux during startup. Only the last call is made dynamically, when new actions need to be processed. The basic signature looks like this:

Middleware signature

```

1  function sampleMiddleware({ dispatch, getState }) {
2    return function nextWrapper(next) {
3      return function innerCode(action) {
4        // TODO: Implement the middleware
5
6        next(action);
7      }
8    }
9  }

```

To test middleware we will need to mock `dispatch()`, `getState()`, and `mock()` and call `sampleMiddleware()` and `nextWrapper()` to get our test target, the `innerCode()` function:

Setting up middleware for tests

```

1  const next          = jest.fn();
2  const dispatch      = jest.fn();
3  const getState      = jest.fn();
4  const middleware    = apiMiddleware({ dispatch, getState })(next);

```

We can now use the regular Jest tests to test the `middleware()` function we built by calling it with action objects:

Simple middleware test call

```

1  it('should process action', () => {
2    const next          = jest.fn();
3    const dispatch      = jest.fn();
4    const getState      = jest.fn();
5    const middleware    = sampleMiddleware({ dispatch, getState })(next);
6
7    const sampleAction = { type: 'SAMPLE_ACTION' };
8
9    middleware(sampleAction);
10

```

```

11  // TODO: Add expects
12  });

```

In the case of our simple middleware, we only want to verify that it passed the action correctly down the chain by calling `next(action)`. Since we used Jest's function mocking, we can get a full history of calls to each mock by accessing `next.mock.calls`:

Verify correct calls to next

```

1  expect(next.mock.calls.length).toBe(1);
2  expect(next.mock.calls[0].length).toBe(1);
3  expect(next.mock.calls[0][0]).toEqual(sampleAction);

```

Our test verified that there was only one call to `next()`. In that call there was only one parameter passed, and that parameter was the sample action.

We could do all the three tests in one go by using:

Combine the test cases

```

1  expect(next.mock.calls).toEqual([[sampleAction]]);

```

Simplifying the Test Structure

To avoid having to duplicate the test setup code before every `it()` clause, we can use Jest's `beforeEach()` method to combine the setup in one place:

Generic setup

```

1  describe('sample middleware', () => {
2    let next, dispatch, getState, middleware;
3
4    beforeEach(() => {
5      next      = jest.fn();
6      dispatch  = jest.fn();
7      getState  = jest.fn();
8      middleware = sampleMiddleware({ dispatch, getState })(next);
9    });
10
11    it('should process action', () => {
12      const sampleAction = { type: 'SAMPLE_ACTION' };
13
14      middleware(sampleAction);

```

```

15
16     expect(next.mock.calls).toEqual([[sampleAction]]);
17   };
18 };

```

Using this structure, our middleware will be rebuilt before each test and all the mocked functions will be reset, keeping the testing code itself as short as possible.

Testing Async Middleware

For a more complete example, let's use an API middleware similar to the one discussed in the [Server Communication Chapter](#):

API middleware

```

1  import 'whatwg-fetch';
2  import { API } from 'consts';
3  import { apiStarted, apiFinished, apiError } from 'actions/ui';
4
5  const apiMiddleware = ({ dispatch }) => next => action => {
6    if (action.type !== API) {
7      return next(action);
8    }
9
10   const { url, success } = action.payload;
11
12   dispatch(apiStarted());
13
14   return fetch(url)
15     .then(response => response.json())
16     .then(response => {
17       dispatch(apiFinished());
18       dispatch(success(response));
19     })
20     .catch(({ status, statusText }) =>
21       dispatch(apiError(new Error({ status, statusText }))))
22   };
23
24  export default apiMiddleware;

```

Our middleware catches any actions of the type 'API', which must contain a payload key with a url to make a request to and a success parameter that holds an action creator to call with the returned data:

Sample API action

```
1  const setData = data => ({
2    type: 'SET_DATA',
3    payload: data
4  });
5
6  const apiAction = () => ({
7    type: API,
8    payload: {
9      success: setData,
10     url: 'fake.json'
11   }
12 });
```

In our Redux call, calling `dispatch(apiAction())` will result in our API middleware doing a GET request for `server/fake.json` and (if successful) dispatching the `SET_DATA` action with payload set to the response. When there is an error, an action created by `apiError()` will be dispatched containing `status` and `statusText`.

Another important feature of the API middleware is that it will dispatch `apiStarted()` before contacting the server and `apiFinished()` on success (or `apiError()` on failure). This allows the application to keep track of the number of active requests to the server and display a spinner or some other user indication.

To fully test this middleware we can split the tests into three groups: general tests, success tests, and failure tests.

Setup

To make our tests cleaner we will be using the structure discussed previously and mocking the `fetch()` API as discussed in the “Async Action Creators” section of this chapter.

We will also use the sample API action creators from earlier to drive the tests and a fake data response from the server:

Base of the API middleware tests

```
1 import apiMiddleware from 'middleware/api';
2 import { mockFetch, mockFetchError } from 'test-utils';
3 import { API_STARTED, API_FINISHED, API, API_ERROR } from 'consts';
4
5 const data = { title: 'hello' };
6
7 const setData = data => ({
8   type: 'SET_DATA',
9   payload: data
10 });
11
12 const apiAction = () => ({
13   type: API,
14   payload: {
15     success: setData,
16     url: 'fake.json'
17   }
18 });
19
20 describe("api middleware", () => {
21   let next, dispatch, middleware;
22
23   beforeEach(() => {
24     next = jest.fn();
25     dispatch = jest.fn();
26     middleware = apiMiddleware({ dispatch })(next);
27   });
28
29   describe('general', () => {
30     // TODO
31   });
32
33   describe('success', () => {
34     // TODO
35   });
36
37   describe('error', () => {
38     // TODO
39   });
40 });
```

General tests

The first test for any middleware is to ensure that it passes unknown actions down the chain. If we forget to use `next(action)`, no actions will reach the reducers:

Verify unknown actions are handled correctly

```
1 it('should ignore non-API actions', () => {
2   const sampleAction = { type: 'SAMPLE_ACTION' };
3
4   middleware(sampleAction);
5
6   expect(dispatch.mock.calls.length).toBe(0);
7   expect(next.mock.calls).toEqual([[sampleAction]]);
8 });
```

Here we verify that `dispatch()` is never called and `next()` is called exactly once with our `sampleAction`. Since we will be using `dispatch.mock.calls` and `next.mock.calls` very often in our tests, we can shorten them a little by adding the following to our setup code:

Improve the setup code

```
1 let next, dispatch, middleware, dispatchCalls, nextCalls;
2
3 beforeEach(() => {
4   next      = jest.fn();
5   dispatch  = jest.fn();
6
7   dispatchCalls = dispatch.mock.calls;
8   nextCalls    = next.mock.calls;
9
10  middleware    = apiMiddleware({ dispatch })(next);
11 });
```

Now instead of `expect(next.mock.calls)` we can use `expect(nextCalls)`.

Another general test could be to verify that the `API_STARTED` action is dispatched every time the middleware is about to access the server:

Test that API_STARTED is dispatched

```
1 it('should dispatch API_STARTED', () => {  
2   middleware(apiAction());  
3   expect(dispatchCalls[0]).toEqual([{ type: API_STARTED }]);  
4 });
```

Our `expect()` call only checks that the first `dispatch()` action is `API_STARTED` because the middleware might call additional actions later on.

Successful server access

In the success scenario, we need to mock our `fetch()` API to return a successful response. We will be using the same `mockFetch()` utility created in the “Async Action Creators” section of this chapter.

Our basic success tests need to check that `API_FINISHED` is dispatched once the API is done and that our `success()` action creator is called, passed the response, and dispatched to the store:

Success tests framework

```
1 describe('success', () => {  
2   beforeEach(() => mockFetch('recipes.json', 200, JSON.stringify(data)));  
3  
4   it('should dispatch API_FINISHED');  
5  
6   it('should dispatch SET_DATA');  
7 });
```

A first attempt at testing the first case might look similar to the `API_STARTED` test:

Test that API_FINISHED is dispatched

```
1 it('should dispatch API_FINISHED', () => {  
2   middleware(apiAction());  
3   expect(dispatchCalls[2]).toEqual([{ type: API_FINISHED }]);  
4 });
```

Unfortunately, this code will not work. Since `API_FINISHED` is only dispatched after the `fetch()` promise is resolved, we need to wait for that to happen before calling `expect()`.

As discussed in the “Async Action Creators” section of this chapter, we rely on our call to the middleware to return a promise that gets resolved once the `fetch()` call completes. Only then can we run assertions and verify that everything behaved according to our expectations:

The correct API_FINISHED test

```
1 it('should dispatch API_FINISHED', () => {  
2   return middleware(apiAction())  
3     .then(() => {  
4       expect(dispatchCalls[2]).toEqual([{ type: API_FINISHED }]);  
5     });  
6 });
```

In this version of the test, only once the promise returned by the call to `middleware()` is resolved do we check the array of calls to `dispatch()`. Since our new test is a one-liner, we can use some ES2016 magic and Jest's `toMatchSnapshot()` method to shorten the code:

Short API_FINISHED test

```
1 it('should dispatch API_FINISHED', () =>  
2   middleware(apiAction()).then(() =>  
3     expect(dispatchCalls[2]).toMatchSnapshot()));
```

Testing that the API middleware correctly sends the response from the server via the action creator provided in `action.payload.success` is very similar:

Test that SET_DATA was dispatched

```
1 it('should dispatch SET_DATA', () =>  
2   middleware(apiAction()).then(() =>  
3     expect(dispatchCalls[1]).toEqual([setData(data)])));
```

After the `fetch()` method is done, we check that the third call to `dispatch()` sent us the same action object as a direct call to the `setData(data)` action creator.



Remember that we mocked the server response for `fetch()` with `mockFetch()`, passing it the stringified version of `data`.

Failed server access

The failing case is similar to the success one, except that we mock `fetch()` to fail. There are two tests in this scenario, verifying that `API_FINISHED` was not dispatched and that `API_ERROR` was dispatched instead:

The failure case scenario tests

```
1 describe('error', () => {
2   beforeEach(() => mockFetchError('recipes.json', 404, 'Not found'));
3
4   it('should NOT dispatch API_FINISHED', () =>
5     middleware(apiAction()).then(() =>
6       expect(dispatchCalls[1][0].type).not.toBe(API_FINISHED)));
7
8   it('should dispatch error', () =>
9     middleware(apiAction()).then(() =>
10       expect(dispatchCalls[1]).toMatchSnapshot()));
11 });
```

Here we have used all the methods discussed previously to test both cases.

Middleware Tests Summary

As our application grows, more complex and asynchronous code will be moved to middleware. While this will cause the tests for the middleware to become complex, it will keep the complexity from spreading to other parts of our Redux application.

The basic structure discussed here for the API middleware should be enough to cover most implementations.

We have left mocking `getState()` as an exercise for the reader. It is suggested that you take the sample project and modify the API middleware to read something from the state before the code that performs the API request (e.g., get an access token), and that you correctly update the tests to check that the store is accessed and correct values are used in the middleware.

Integration Tests

The role of the integration tests is to verify that all the parts of the application work correctly together. A comprehensive unit test suite will ensure all the reducers, action creators, middleware, and libraries are correct. With integration tests, we will try to run them together in a single test to check system-wide behavior.

As an example of an integration test, we will verify that when the `fetchRecipes()` action creator is dispatched, data is correctly fetched from the server and the state is updated. In this flow we will check that the API middleware is correctly set up, all the required action creators are correct, and the recipes reducer updates the state as needed.

Basic Setup

Since the integration tests will be using the real store, we can simply require and initialize it as in our regular application:

Integration test skeleton

```
1 import store from 'store';
2
3 describe('integration', () => {
4   it('should fetch recipes from server', () => {
5     // TODO
6   });
7 });
```

Basic Integration Test

Our test will include four steps:

1. Verify the initial state.
2. Mock the data returned from the server.
3. Dispatch the action created by `fetchRecipes()`.
4. Verify that our state's `recipes` key holds the data returned from the server.

The full test looks like this:

Full integration test

```
1 import store from 'store';
2 import { fetchRecipes } from 'actions/recipes';
3 import { mockFetch } from 'test-utils';
4
5 describe('integration', () => {
6   it('should fetch recipes from server', () => {
7     const data = [{ title: 'test' }];
8
9     expect(store.getState().recipes).toEqual([]);
10
11     mockFetch('recipes.json', 200, JSON.stringify(data));
12
13     return store.dispatch(fetchRecipes())
14       .then(() => expect(store.getState().recipes).toEqual(data));
15   });
16 });
```

To make sure our reducer updates the state, we first verify that our initial `recipes` list is empty and check that it was changed to contain the server-returned data after the `fetchRecipes()` action completed.

Integration Tests Summary

As can be seen from this simple test, doing integration tests in Redux is usually fairly straightforward. Since everything is driven by actions, in most cases our integration tests will follow the four steps outlined above: we verify the initial state of the system, mock any external dependencies, dispatch an action, and verify that the state has changed and any external APIs were called as expected.

Summary

In this chapter we have discussed in detail various methods of testing Redux using the Jest library. Given the clear division of responsibilities in Redux and in keeping with its plain JavaScript objects and idempotent functions, most unit tests (and integration tests) are short and simple to write.

This in turn means that we, as developers, can minimize the time we spend writing tests and still have a comprehensive and understandable testing suite.

This is the last chapter in the “Real World” part of this book. In the next part, “Advanced Redux,” we will delve deeper into each of Redux’s actors and learn advanced methods for organizing and managing our code.

Part 3. Advanced Concepts

Chapter 7. The Store

In contrast to most other Flux implementations, in Redux there is a single store that holds all of the application state in one object. The store is also responsible for changing the state when something happens in our application. In fact, we could say that Redux is the store. When we talk about accessing the state, dispatching an action, or listening to state changes, it is the store that is responsible for all of it.



Sometimes the concern is raised that storing the whole state in one huge JavaScript object might be wasteful. But since objects are reference-type values and the state is just an object holding a reference to other objects, it doesn't have any memory implications; it is the same as storing many objects in different variables.

Creating a Store

To create the store we use the `createStore()` factory function exported by Redux. It accepts three arguments: a mandatory reducer function, an optional initial state, and an optional store enhancer. We will cover store enhancers later in this chapter and start by creating a basic store with a dummy reducer that ignores actions and simply returns the state as it is:

Sample store

```
1 import { createStore } from 'redux';
2
3 const initialState = {
4   recipes: [],
5   ingredients: []
6 }
7 const reducer = (state, action) => state;
8
9 const store = createStore(reducer, initialState);
```



The `initialState` parameter is optional, and usually we delegate the task of building an initial state to reducers, as described in the [Reducers Chapter](#). However, it is still useful when you want to load the initial state from the server to speed up page load times. State management is covered extensively in the [State Management Chapter](#).

The simple store that we have just created has five methods that allow us to access, change, and observe the state. Let's examine each of them.

Accessing the State

The `getState()` method returns the reference to the current state:

Get current state from store

```
1 store.getState();
2 // => { recipes: [], ingredients: [] }
```

Changing the State

Redux does not allow external changes to the state. Using the state object received from `getState()` and changing values directly is prohibited. The only way to cause a change of the state is by passing actions to the reducer function. Actions sent to the store are passed to the reducer and the result is used as the new global state.

Sending action objects to reducers is done via the store using the store's `dispatch()` method, which accepts a single argument, the action object:

Dispatch action to store

```
1 const action = { type: 'ADD_RECIPE', ... }
2 store.dispatch(action);
```

Now we can rewrite our reducer to make it able to create an updated state for actions of type 'ADD_RECIPE' and return the current state otherwise:

Sample reducer code

```
1 const reducer(state, action) => {
2   switch (action.type) {
3     case 'ADD_RECIPE':
4       return Object.assign(...);
5     default:
6       return state;
7   }
8   };
```

Listening to Updates

Now that we know how the store updates the state, we need a way to update the UI or other parts of our application when the state changes. The store allows us to subscribe to state changes using the `subscribe()` method. It accepts a callback function, which will be executed after every action has been dispatched:

The subscribe method

```
1 const store = createStore((state) => state);
2
3 const onStoreChange = () => console.log(store.getState());
4
5 store.subscribe(onStoreChange);
```



The subscribed callback does not get passed any arguments, and we need to access the state. So, we must call `store.getState()` ourselves.

The return value of the `subscribe()` method is a function that can be used to unsubscribe from the store. It is important to remember to call `unsubscribe()` for all subscriptions to prevent memory leaks:

Unsubscribing from store updates

```
1 const unsubscribe = store.subscribe(onStoreChange);
2
3 // When the subscription is no longer needed
4 unsubscribe();
```

Replacing the Reducer

When creating the Redux store, a reducer function (often referred to as the root reducer) is passed as the first parameter to `createStore()`. During runtime we can use the store's `replaceReducer()` method to replace this reducer function. Usually this method is used in development to allow hot replacement of reducers. In complex applications it might be used to dynamically decorate or replace the root reducer to allow code splitting.



If your application is too large to bundle into a single file or if you want to gain extra performance, you usually use a technique called code splitting—separating the production bundle into multiple files and loading them on demand when the user performs some interaction or takes a specific route. Implementing lazy loading is outside the scope of this book, but you might want to know that code splitting also can be applied to the Redux store, thanks to the `replaceReducer()` method.

Let's look at a simple example with some functionality available only for authenticated users. At initial load, our store will only handle the `currentUser` substate—just enough for the authentication:

Basic reducer setup

```
1 import { combineReducers } from 'redux';
2 import { currentUser } from 'reducers/current-user';
3
4 const reducer = (state, action) => combineReducers({ currentUser });
5
6 const store = createStore(reducer);
```

If `combineReducers()` looks unfamiliar to you, take a look at [Chapter 9](#) to learn about this technique. For now, let's just assume the functions inside are going to handle a `currentUser` substate. After the user signs in, we load the new functionality. Now we need to make our store aware of the new subset of our application state and the function that should handle it. Here is where the `replaceReducer()` method comes in handy:

Replacing the root reducer

```
1 const newReducer = (state, action) => combineReducers({ currentUser, recipes });
2
3 store.replaceReducer(newReducer);
```

Keep in mind that when you call `replaceReducer()`, Redux automatically calls the same initial action it calls when you first create the store, so your new reducer automatically gets executed and the new state is immediately available via the `store.getState()` method. For more on the initial action, see [Chapter 9](#).

The same technique can be used by development tools to implement the hot reloading mechanism for a better developer experience. Hot reloading is a concept where source code changes don't cause a full page reload, but rather the affected code is swapped in place by special software and the application as a whole is kept in the same state that it was in before the code change. Hot reloading tools are outside the scope of this book, but you can easily find more information online.

Store as Observable

Starting from version 3.5.0, Redux store can also act as an Observable. This allows libraries like RxJS to subscribe to the store's state changes. This subscription method is different from the regular `subscribe()` method of the store: when subscribing to the store as an observable, the latest state is passed without the need to call `store.getState()`.

To support older browsers, Redux uses the [symbol-observable²⁸](#) polyfill when `Symbol.observable` is not natively supported.

²⁸<https://github.com/blesh/symbol-observable>

Integration with RxJS

```
1 import store from "store";
2 import { Observable } from "rxjs";
3
4 const store$ = Observable.from(store);
5
6 store$.forEach((state) => console.log(state))
```

This basic API is interoperable with most common reactive libraries (e.g. RxJS). Any library that exports the `next()` method can be subscribed and receive updates. This implementation also conforms to the [tc39/proposal-observable](https://github.com/tc39/proposal-observable)²⁹.

If you don't use reactive libraries, you can still subscribe to the store by accessing the `Symbol.observable` property (or using `symbol-observable` polyfill like Redux does):

Getting the Redux store observable

```
1 const observable = store[Symbol.observable]();
```

Subscribing with a generic observer will cause the observer's `next()` be called on every state change and be passed the current store state.

Subscribing to changes

```
1 const observer = {
2   next(state) {
3     console.log("State change", state);
4   }
5 };
6
7 const observable = store.$$observable();
8
9 const unsubscribe = observable.subscribe(observer);
```

To unsubscribe, we simply call the function returned from the call to `subscribe()`

²⁹<https://github.com/tc39/proposal-observable>

Unsubscribing from changes

```
1 const observable = store[Symbol.observable]();  
2 const unsubscribe = observable.subscribe(observer);  
3  
4 unsubscribe();
```

Full Store API

The five methods of the store—`getState()`, `dispatch()`, `subscribe()`, `replaceReducer()`, and the observable symbol—make up the whole of the store’s API and most of the API Redux exports. In the first chapter of this book we learned how the first three are enough to build a fully functional application. This low API footprint, coupled with strong versatility, is what makes Redux so compelling and easy to understand.

Decorating the Store

The basic store functionality in Redux is very simple and sufficient for most use cases. Yet sometimes it is useful to slightly change one of the methods, or even add new ones to support more advanced use cases. This can be done by decorating the store. In previous versions of Redux (prior to 3.1.0) higher-order functions were used to decorate the store, but because of complicated syntax, the `createStore()` API has changed and it now supports an optional parameter for a store decorator.

Higher-Order Functions

Before we proceed, let’s do a quick overview of what higher-order functions are. We can define the term as referring to a function that either takes one or more functions as arguments, returns a function as its result, or does both. Here’s an example:

Sample higher-order function

```
1 function output(message) {  
2   console.log(message);  
3 }  
4  
5 function addTimeStamp(fn) {  
6   return function(...args) {  
7     console.log(`Executed at: ${Date.now()}`);  
8     fn(...args);  
9   }  
10 }
```

```
11
12 const timedOutput = addTimeStamp(output);
13
14 timedOutput('Hello World!');
15
16 > Executed at: 1464900000001
17 > Hello World!
```

Here, the `output()` function prints our message to the console. The `addTimeStamp()` function is a higher-order function that can take any other function and log the time of execution. Calling `addTimeStamp()` with `output()` as the parameter creates a new “wrapped” function that has enhanced functionality. It still has the signature of the original `output()` function but now also prints the timestamp.

The `compose()` Function

The use of higher-order functions is very common in Redux applications, as it allows us to easily extend the behavior of other parts of the code. Take a look at an imaginary example where we have to wrap our original function in three wrappers:

Multiple decoration

```
1 const wrapped = third(second(first(originalFn)));
2
3 wrapped();
```

Using multiple decorators is a valid and practical approach, but the resulting code can be hard to read and appear somewhat cumbersome. Instead, Redux provides the `compose()` function to handle multiple wrappers in a cleaner manner:

Multiple wrappers with `compose`

```
1 import { compose } from 'redux';
2
3 const wrapped = compose(third, second, first)(originalFn);
4
5 wrapped();
```

The simplest implementation of that function is very neat. Notice the use of the `reduceRight()` method on the array of functions, which ensures that wrapping of higher-order functions happens from right to left:

Implementation of compose

```
1 function compose(...funcs) {
2   return (...args) => {
3     const last = funcs[funcs.length - 1]
4     const rest = funcs.slice(0, -1)
5
6     return rest.reduceRight(
7       (composed, f) => f(composed),
8       last(...args)
9     )
10  }
11 }
```

Store Enhancers

Store enhancers are higher-order functions used to enhance the default behavior of the Redux store. In contrast to middleware and reducers, they have access to all internal store methods (even those not available to middleware, such as `subscribe()`).

To give a few examples, there are store enhancers for:

- Store synchronization (between browser tabs or even network clients)
- State persistence
- Integration with developer tools

Let's build an example store enhancer that will persist state changes and load initial state from `localStorage`. To enhance or decorate a store, we need to write a higher-order function that receives the original store factory function as a parameter and returns a function similar in signature to `createStore()`:

Implementation of store enhancer

```
1 import { createStore } from 'redux';
2 import { rootReducer } from 'reducers/root';
3
4 const persistStore = () => (next) =>
5   (reducer, initialState, enhancer) => {
6     let store;
7
8     if (typeof initialState !== 'function') {
9       store = next(reducer, initialState, enhancer);
10    } else {
```

```
11     const preloadedState = initialState ||
12       JSON.parse(localStorage.getItem('@@PersistedState')) || {}
13
14     store = next(reducer, preloadedState, enhancer);
15   }
16
17   store.subscribe(() => localStorage.setItem(
18     '@@PersistedState',
19     JSON.stringify(store.getState())
20   ));
21
22   return store;
23 }
```

We start by creating a store. We first check if an `initialState` was originally passed. If it was, we create the store with it. Otherwise, we read the initial state from `localStorage`:

Check if `initialState` was provided

```
1  let store;
2
3  if (typeof initialState !== 'function') {
4    store = next(reducer, initialState, enhancer);
5  } else {
6    const preloadedState = initialState ||
7      JSON.parse(localStorage.getItem('@@PersistedState')) || {}
8
9    store = next(reducer, preloadedState, enhancer);
10 }
```

Right after our store is initiated, we subscribe to state updates and save the state to `localStorage` on every change. This will ensure our state and the local storage are always in sync. Finally, we return the decorated store:

Sync local storage with latest state

```
1 store.subscribe(() => $localStorage.setItem(  
2   '@@PersistedState',  
3   JSON.stringify(store.getState())  
4 ));  
5  
6 return store;
```

This example doesn't handle errors or edge cases, but it showcases the base of a store enhancer.

To simplify the syntax, Redux allows us to pass the store enhancer as a parameter to `createStore()`:

Passing store enhancer as an argument

```
1 import { createStore } from 'redux';  
2  
3 const store = createStore(rootReducer, persistStore());
```

If you've been following along carefully, you may have noticed that in the sample code at the beginning of the chapter the second parameter to the `createStore()` function was `initialState`. Both parameters are optional, and Redux is smart enough to distinguish between the state object and the store enhancer when you pass only two arguments. However, if you also need an initial state, the parameters of `createStore()` should come in the following order:

Passing initial state before store enhancer

```
1 createStore(rootReducer, initialState, persistStore());
```

We can use multiple store enhancers to create the final store for our application, and the same `compose()` method we saw earlier can be used for store composition as well:

Using `compose` to combine store enhancers

```
1 const storeEnhancers = compose(  
2   // ...other decorators  
3   decorateStore  
4 );  
5  
6 const store = createStore(rootReducer, storeEnhancers);  
7  
8 store.createdAt // -> timestamp
```

applyMiddleware()

One of the best-known store enhancers is called `applyMiddleware()`. This is currently the only store enhancer provided by Redux (if you aren't familiar with middleware, head to [Chapter 10](#) for an in-depth explanation).

Implementation of `applyMiddleware`

```
1 export default function applyMiddleware(...middlewares) {
2   return (createStore) => (reducer, preloadedState, enhancer) => {
3     var store = createStore(reducer, preloadedState, enhancer)
4     var dispatch = store.dispatch
5     var chain = []
6
7     var middlewareAPI = {
8       getState: store.getState,
9       dispatch: (action) => dispatch(action)
10    }
11    chain = middlewares.map(middleware => middleware(middlewareAPI))
12    dispatch = compose(...chain)(store.dispatch)
13
14    return { ...store, dispatch }
15  }
16 }
```



In this example, the word `middlewares` is used as plural form to distinguish between singular form in the `'map'` function. It is the actual source code of `applyMiddleware()`.

At its core, `applyMiddleware()` changes the store's default `dispatch()` method to pass the action through the chain of middleware provided:

Setup of store

```
1 var store = createStore(reducer, preloadedState, enhancer)
2 var dispatch = store.dispatch
3 var chain = []
4
5 var middlewareAPI = {
6   getState: store.getState,
7   dispatch: (action) => dispatch(action)
8 }
```

First a store is created and the core `getState()` and `dispatch()` methods are wrapped into something called `middlewareAPI`. This is the object our middleware receives as the first parameter (commonly confused with `store`):

Building the middleware chain

```
1 chain = middlewarees.map(middleware => middleware(middlewareAPI))
```

The array of `middleware` is transformed into the result of calling `middleware()` with `middlewareAPI` as its argument. Since the structure of a `middleware` is `api => next => action => {}`, after the transformation, `chain` holds an array of functions of type `next => action => {}`.

The last stage is to use the `compose()` function to decorate the middleware one after another:

Building the dispatch chain

```
1 dispatch = compose(...chain)(store.dispatch)
```

This line causes each middleware to decorate the chain of previous ones in a fashion similar to this:

Composing middleware without `compose`

```
1 middlewareA(middlewareB(middlewareC(store.dispatch)));
```

The original `store.dispatch()` is passed as a parameter to the first wrapper in the chain.



This implementation explains the strange syntax of the Redux middleware (the 3-function structure):

```
1 const myMiddleware =
2   ({ getState, dispatch }) => (next) => (action) => { ... }
```

Other Uses

Store enhancers are powerful tools that allow us to debug stores, rehydrate state on application load, persist state to `localStorage` on every action, sync stores across multiple tabs or even network connections, add debugging features, and more. If you'd like an idea of what's available, Mark Erikson has composed a list of [third-party store enhancers](https://github.com/mark Erikson/redux-ecosystem-links/blob/master/store.md)³⁰ in his awesome [redux-ecosystem-links](https://github.com/mark Erikson/redux-ecosystem-links)³¹ repository.

³⁰<https://github.com/mark Erikson/redux-ecosystem-links/blob/master/store.md>

³¹<https://github.com/mark Erikson/redux-ecosystem-links>

Summary

In this chapter we learned about the central, most important part of Redux, the store. It holds the whole state of the application, receives actions, passes them to the reducer function to replace the state, and notifies us on every change. Basically, you could say that Redux is the store implementation.

We learned about higher-order functions, a very powerful functional programming concept that gives us incredible power to enhance code without touching the source. We also covered uses for store enhancers in Redux, and took a look at the most common store enhancer, `applyMiddleware()`. This function allows us to intercept and transform dispatched actions before they are propagated to reducers, and we will take a deeper look at it in [Chapter 10](#).

In the next chapter we will look at actions and action creators, the entities we dispatch to the store to make changes to the application state.

Chapter 8. Actions and Action Creators

Actions are the driving force of every dynamic application, as they are the medium by which all changes are communicated within a Redux application. In a Redux application we have two sides: the senders of actions and their receivers. The senders might be event handlers (like keypresses), timeouts, network events, or middleware. The receivers are more limited; in the case of Redux they are middleware and reducers.

A connection between a sender and a receiver is not necessarily one-to-one. A keypress might cause a single action to be sent that will in turn cause both a middleware to send a message to the server and a reducer to change the state, resulting in a pop-up appearing. This also holds true in the other direction, where a single reducer might be listening to multiple actions. While in very simple Redux applications there might be a reducer for each action and vice versa, in large applications this relation breaks down, and we have multiple actions handled by a single reducer and multiple reducers and middleware listening to a single action.

Since the side emitting the actions doesn't know who might be listening to it, our actions have to carry all the information needed for the receiving end to be able to understand how to respond.

The simplest way to hold information in JavaScript is to use a plain object, and that is exactly what an action is:

Plain object-based Action

```
1 const action = { type: 'MARK_FAVORITE' };
```

Actions are plain objects containing one required property, the *type*. The type is a unique key describing the action, and it is used by the receiving end to distinguish between actions.



The value of the type property can be anything, though it is considered good practice to use strings to identify actions. While on first thought numbers or ES2016 symbols might sound like a better solution, both have practical downsides: using numbers makes it hard to debug an application and gives little benefit spacewise, whereas ES2016 symbols will cause issues with server rendering and sending actions across the network to other clients.

In Redux, we send actions to the store, which passes them to middleware and then to reducers. In order to notify a store about an action, we use the store's `dispatch()` method.

Unlike many Flux implementations, in Redux the store's `dispatch()` API is not globally available. You have a few options to access it:

1. By holding a reference to the store
2. Inside middleware
3. Through methods provided by special libraries for different frameworks

Here's a simple example for dispatching actions by holding a direct reference to the store:

Dispatching a simple action

```
1 import { store } from './lib/store';  
2  
3 store.dispatch({ type: 'MARK_FAVORITE' });
```

Passing Parameters to Actions

While the type property in an action is enough for reducers and middleware to know what action to process, in most cases more information will be required. For example, instead of sending the INCREMENT_COUNTER action 10 times, we could send a single action and specify 10 as an additional parameter. Since actions in Redux are nothing more than objects, we are free to add as many properties as needed. The only limitation is that the type property is required by Redux:

Standard action object

```
1 store.dispatch({  
2   type: 'MARK_FAVORITE',  
3   recipeId: 21  
4   ...  
5 });
```

The object passed to `dispatch()` will be available to our reducers:

Accessing actions in reducers

```
1 function reducer(state, action) {  
2   console.log(action);  
3   return state;  
4 }  
5  
6 // -> { type: 'MARK_FAVORITE', recipeId: 21, ... }
```

To keep our actions consistent across a large code base, it is a good idea to define a clear scheme for how the action objects should be structured. We will discuss the scheme later in this chapter.

Action Creators

As our applications grow and develop, we will start encountering more and more code like this:

Direct object dispatch

```
1 dispatch({
2   type: 'ADD_RECIPE',
3   title: title.trim(),
4   description: description ? description.trim() : ''
5 });
```

If we decide to use the same action in other places, we will end up duplicating the logic in multiple locations. Such code is hard to maintain, as we will have to synchronize all the changes between all the occurrences of the action.

A better approach is to keep the code in one place. We can create a function that will create the action object for us:

Function to create an action object

```
1 const addRecipe = (title, description = '') => ({
2   type: 'ADD_RECIPE',
3   title: title.trim(),
4   description: description.trim()
5 });
```

Now we can use it in our code:

Using an action creator

```
1 dispatch(addRecipe(title, description));
```

Any modification to the content or logic of the action can now be handled in one place: the action creation function, also known as the *action creator*.

Beyond improving the maintainability of our applications, moving the action object creation to a function allows us to write simpler tests. We can test the logic separately from the place from which the function is called.

In a large project, most—if not all—of our actions will have a corresponding action creator function. We will try to never call the `dispatch()` method by handcrafting the appropriate action object, but rather use an action creator. This might appear to be a lot of overhead initially, but its value will become apparent as the project grows. Also, to help reduce boilerplate, there are a number of libraries and concepts that ease the creation and use of action creators. Those will be discussed later in this chapter.

Directory Organization

In order to better manage our action creators, we will create a separate directory for them in our code base. For smaller projects, it may be enough to group actions in files according to their usage in reducers:

Simple directory structure

```
1 actions/  
2   recipes.js // Recipe manipulation actions  
3   auth.js    // User actions (login, logout, etc.)  
4   ...
```

But as our projects grow in both size and complexity, we will subdivide our action creator directory structure even more. The common approach is to nest actions based on the data type they modify:

Advanced directory structure

```
1 actions/  
2   recipes/  
3     favorites.js // Handle favorite recipe logic  
4     ...  
5   auth/  
6     resetting-password.js // Handle password logic  
7     permissions.js // Some actions for permissions  
8     ...  
9     ...
```



At first glance it might look easier to put action creators with their corresponding reducers, sometimes even in the same files. While this approach might work perfectly in the beginning, it will start breaking down in large projects. As the complexity grows, the application might have multiple reducers acting on the same action or multiple actions watched by a single reducer. In these cases the grouping stops working, and the developer is forced to start decoupling some of the actions or moving them, ending up with the structure suggested here.

Flux Standard Actions

As projects and teams grow in size, it is important to create a convention on the structure of action objects. To this end, the open-source community has come together to create the [Flux Standard Action](https://github.com/acdlite/flux-standard-action)³² (FSA) specification. The goal is to have consistency across both a project and third-party libraries.

The FSA spec defines the structure of actions and a number of optional and required properties. At its base, an action should have up to four fields:

³²<https://github.com/acdlite/flux-standard-action>

FSA object sample

```
1 const action = {  
2   type,  
3   error,  
4   payload,  
5   meta  
6 };
```

Each field has a distinct role:

- `type` is the regular Redux action identifier.
- The `error` property is a Boolean that indicates whether the action is in an error state. The rationale behind this is that instead of having multiple actions, like `'ADD_RECIPE_SUCCESS'` and `'ADD_RECIPE_ERROR'`, we can have only one action, `'ADD_RECIPE'`, and use the `error` flag to determine the status.
- `payload` is an object holding all the information needed by the reducers. In our example, the `title` and `description` would both be passed as the `payload` property of the action.
- The `meta` property holds additional metadata about the action that is not necessarily needed by the reducers, but could be consumed by middleware. We will go into detail on how the `meta` property could be used in the [Middleware Chapter](#).

Implemented as an FSA, our action looks like this:

FSA action example

```
1 store.dispatch({  
2   type: 'ADD_RECIPE',  
3   payload: {  
4     title: 'Omelette',  
5     description: 'Fast and simple'  
6   }  
7 });;
```

If the action were in the error state (for example, in the event of a rejected promise or API failure), the `payload` would hold the error itself, be it an `Error()` object or any other value defining the error:

FSA action in error state

```
1 const action = {  
2   type: 'ADD_RECIPE',  
3   error: true,  
4   payload: new Error('Could not add recipe because...')  
5 };
```

String Constants

In [Chapter 2](#) we briefly discussed the idea of using string constants. To better illustrate the reasoning behind this approach, let's consider the problems that using strings for type can cause in a large code base:

1. *Spelling mistakes*—If we spell the same string incorrectly in the action or the reducer, our action will fire but result in no changes to the state. Worst of all, this will be a silent failure without any message to indicate why our action failed to produce its desired effect.
2. *Duplicates*—Another developer, in a different part of the code base, might use the same string for an action. This will result in issues that are very hard to debug, as our action will suddenly cause that developer's reducers to fire as well, creating unexpected changes to the state.

To avoid these issues, we need to ensure a unique naming convention for our actions to allow both action creators and reducers to use the exact same keys. Since JavaScript doesn't have native enum structures, we use shared constants to achieve this goal. All the keys used for type are stored in a *single constants file* and imported by both action creators and reducers. Using a single file allows us to rely on JavaScript itself to catch duplication errors. The file will have this form:

constants/action-types.js

```
1 export const MARK_FAVORITE = 'MARK_FAVORITE';  
2 export const ADD_RECIPE    = 'ADD_RECIPE';  
3 ...
```

In large applications the naming convention will be more complicated to allow developers more freedom to create constants for different parts of the application. Even in our simple example, being able to mark both recipes and comments as favorites will require two different `MARK_FAVORITE` actions (e.g., `RECIPE__MARK_FAVORITE` and `COMMENT__MARK_FAVORITE`):

constants/action-types.js

```
1 // Recipes
2 export const ADD_RECIPE          = 'ADD_RECIPE';
3 export const DELETE_RECIPE       = 'DELETE_RECIPE';
4 export const RECIPE__MARK_FAVORITE = 'RECIPE__MARK_FAVORITE';
5
6 // Comments
7 export const ADD_COMMENT         = 'ADD_COMMENT';
8 export const DELETE_COMMENT      = 'DELETE_COMMENT';
9 export const COMMENT__MARK_FAVORITE = 'COMMENT__MARK_FAVORITE';
10 ...
```

Full Action Creators and React Example

Here's the full example code for using action creators:

constants/action-types.js

```
1 export const MARK_FAVORITE = 'MARK_FAVORITE';
```

actions/places.js

```
1 import { MARK_FAVORITE } from 'constants/action-types';
2
3 const markFavorite = (recipeId) => ({
4   type: MARK_FAVORITE,
5   recipeId,
6   timestamp: Date.now()
7 });
8
9 export markFavorite;
```

components/recipe.js

```
1 import React from 'react';
2 import { connect } from 'react-redux';
3 import { markFavorite } from 'actions/recipes';
4
5 const Recipe = ({ recipe, dispatch }) => (
6   <li>
7     <h3>{ recipe.title }</h3>
8     <button onClick={ () => dispatch(markFavorite(recipe.id)) }>
9       { recipe.favorite ? 'Unlike' : 'Like' }
10    </button>
11  </li>
12 );
13
14 export default connect()(Recipe);
```

Testing Action Creators

Since action creators are nothing more than plain JavaScript functions that should require nothing but constants and do not rely on state, they are very easy to test. Given the same input, they will always return the same output (unlike, for example, functions that read the local storage or other state data that might change). Action creators also never modify any state directly, but rather only return a new object. Thus, our tests can simply pass input values to action creators and verify that the correct object is returned for each case:

Sample test code

```
1 import { ADD_RECIPE } from 'constants/action-types';
2 import { addRecipe } from 'actions/recipes';
3
4 describe('Recipes Actions', () => {
5   it ('addRecipe', () => {
6     const title = 'Omelette';
7     const description = 'Fast and simple';
8     const expectedAction = {
9       type: ADD_RECIPE,
10      title,
11      description
12    };
13
14    expect(addRecipe(title, description)).to.equal(expectedAction);
```

```
15   });
16
17   it ('should set timestamp to now if not given', () => {
18     const description = 'Fast and simple';
19     const expectedAction = {
20       type: ADD_RECIPE,
21       title: 'Untitled',
22       description
23     };
24
25     expect(addRecipe(null, description)).to.equal(expectedAction);
26   });
27 });
```

More complex action creators might use helper functions to build the action object. A simple example might be a helper function `trimTitle()` that removes whitespace from around a string and is used by a `SET_TITLE` action. We would test the method separately from the action creator function itself, only verifying that the action creator called that method and passed it the needed parameters.

redux-thunk

The real power of actions comes with the use of various *middleware* (discussed more in the [Middleware Chapter](#)). One of the most common and useful ones for learning Redux is [redux-thunk](#)³³. In contrast to what we learned before, actions passed to `dispatch()` don't *have* to be objects, as the only part of Redux that requires actions to be objects is the reducers. Since the middleware get called before an action is passed to the reducers, they can take any type of input and convert it into an object.

This is exactly what `redux-thunk` does. When it notices that the action is of type “function” instead of “object,” it calls the function, passing it the `dispatch()` and `getState()` functions as parameters, and passes on the return value of this function as the action to perform. That is, it replaces the function with its return value, which should be the plain JavaScript object the reducers expect.

This approach makes our action creators much more powerful, since they now have access to the current state via `getState()` and can submit more actions via `dispatch()`.

Adding `redux-thunk` to a project takes two steps:

1. Add the middleware to your project by running `npm install --save redux-thunk`.
2. Load the middleware by adding it to the store using the `applyMiddleware()` function:

³³<https://github.com/gaearon/redux-thunk>

store/store.js

```
1 import { createStore, applyMiddleware } from 'redux';
2 import thunk from 'redux-thunk';
3 import rootReducer from 'reducers/index';
4
5 const store = createStore(
6   rootReducer,
7   applyMiddleware(thunk)
8 );
9
10 export default store;
```



This is generic code for adding middleware to your project. We will cover this in more detail in the [Middleware Chapter](#).

With `redux-thunk` installed, we can start writing action creators that return functions instead of objects. Going back to our previous example, let's create an action creator that simulates server communication by using a delay:

Sample action

```
1 import { trimmedTitle } from 'utils/strings';
2 import { ADD_RECIPE_STARTED } from 'actions/recipes';
3
4 function addRecipe(title) {
5   return function (dispatch, getState) {
6     const trimmedTitle = trimTitle(title);
7
8     dispatch({ type: ADD_RECIPE_STARTED });
9
10    setTimeout(
11      () => dispatch({ type: ADD_RECIPE, title: trimmedTitle }),
12      1000
13    );
14  }
15 }
```

The main difference from our previous creators is that we are no longer returning an object but rather *a function*:

Sample action

```
1 function addRecipe(title) {  
2   return function(dispatch, getState) {  
3     // Action creator's code  
4   };  
5 }
```

Or, if we used the ES2016 arrow function style:

Sample action using ES2016 style

```
1 const addRecipe = (title) => (dispatch, getState) => {  
2   // Action creator's code  
3 };
```

First, we use a helper function to remove unneeded whitespace from our titles:

Using helpers in action creators

```
1 const trimmedTitle = trimTitle(title);
```

Next, we dispatch an action that might show a spinner in our application by setting a *fetching* flag somewhere in our state:

Dispatch on load

```
1 dispatch({ type: ADD_RECIPE_STARTED });
```

The last step is to send the ADD_RECIPE action, but delayed by one second:

Set timeout to add recipe after a delay

```
1 setTimeout(  
2   () => dispatch({ type: ADD_RECIPE, title: trimmedTitle }),  
3   1000  
4 );
```

In this example one action creator ended up dispatching two different actions. This gives us a new tool, allowing us to generate as many granular actions as needed and even to dispatch no actions at all in certain conditions.

Server Communication

The `redux-thunk` method can be used to allow simple server communications, simply by replacing the `setTimeout()` call from the previous example with an Ajax call to the server:

An action that goes to the server

```
1 import * as consts from 'constants/action-types';
2
3 function checkStatus(response) {
4   if (response.status >= 200 && response.status < 300) {
5     return response;
6   }
7
8   throw (new Error(response.statusText));
9 }
10
11 const getRecipes = (limit = 100) => (dispatch) => {
12   dispatch({ type: consts.FETCH_RECIPES_START, limit });
13
14   fetch(`recipes?limit=${ limit }`)
15     .then(checkStatus)
16     .then(response => response.json())
17     .then(data => dispatch({type: consts.FETCH_RECIPES_DONE, data}))
18     .catch(error => dispatch({type: consts.FETCH_RECIPES_ERROR, error}));
19 };
20
21 export getRecipes;
```

This code might be good for a very simple project, but it includes a lot of boilerplate that will be needed for each API call we make. In the [Middleware Chapter](#) we will discuss a more generic and cleaner approach to server communication.

Using State

Another feature we gain by using `redux-thunk` is access to the state when processing the action. This allows us to dispatch or suppress actions according to the current application state. For example, we can prevent actions from trying to add recipes with duplicate titles:

An action that accesses state

```
1  const addRecipe = (title) => (dispatch, getState) => {
2    const trimmedTitle = trimTitle(title);
3
4    // We don't allow duplicate titles
5    if (getState().recipes.find(place => place.title == trimmedTitle)) {
6      return; // No action is performed
7    }
8
9    dispatch({
10      type: ADD_RECIPE,
11      payload: { title: trimmedTitle }
12    });
13  };
```

Two new concepts can be seen in this code. We used `getState()` to get access to the full application state and used a `return` statement that made our action creator emit no action at all:

An action that accesses state

```
1  if (getState().recipes.find(place => place.title == trimmedTitle)) {
2    return; // No action is performed
3  }
```

It is important to consider where such checks are performed. While multiple actions might dispatch recipe-related manipulations, we might think it is best to do the check on the reducer level (as it is the one modifying the state). Unfortunately, there is no way for the reducer to communicate the problem back to us, and while it can prevent an action from adding duplicate titles to the list, it can't dispatch a message out. The only thing a reducer can do in this case is add the error directly to the state tree.

While this approach might work, it adds complications to the reducer and causes it to be aware of multiple parts of the state tree—in our example, not just recipes but also the notifications area—which will make it harder to test and break down to multiple reducers. Thus, it is better to have the validation logic in actions or middleware.

Testing

Testing `redux-thunk`-based actions is usually more complicated than testing regular actions, as it may require the use of mocks and spies. As such, it is recommended to keep the actions as simple as possible and break them into multiple functions and helpers to ease testing and understanding.

Let's create a sample `redux-thunk`-based action:

Sample redux-thunk action

```
1 export const myAction = () => (dispatch, getState) => {  
2   const payload = getState();  
3  
4   dispatch({  
5     type: 'MY_ACTION',  
6     payload  
7   });  
8 };
```

Our action will use the `dispatch()` method to send an action of type `'MY_ACTION'` and use the whole application's state, obtained via `getState()`, as a payload.

Unlike with regular actions, we can't just compare the return value and verify it's a valid object. Instead, we will need to rely on a new feature, `createSpy()`. `jasmine.createSpy()` creates a special function that records any calls made to it by our application. This allows our test to check if the function was called, and if so how many times and with what parameters:

Sample test for redux-thunk action

```
1 describe(actions, () => {  
2   it('MY_ACTION', () => {  
3     const getState = () => 'DATA';  
4     const dispatch = jasmine.createSpy();  
5     const expectedAction = { type: 'MY_ACTION', payload: getState() };  
6  
7     myAction()(dispatch, getState);  
8  
9     expect(dispatch).toHaveBeenCalledWith(expectedAction);  
10   })  
11 });
```

In this example we pass the action creator `myAction()` two mocked functions: a `getState()` function that returns a `const` value and a mocked `dispatch()`. Thus, after calling the action creator, we can verify that the `dispatch()` function was called correctly and a valid action was passed.

redux-actions

When you start writing a large number of actions, you will notice that most of the code looks the same and feels like a lot of boilerplate. There are multiple third-party libraries to make the process

easier and cleaner. The [redux-actions](https://github.com/acdlite/redux-actions)³⁴ library is one of the recommended ones, as it is both simple and FSA-compliant. The library allows us to easily create new actions using the newly provided `createAction()` function. For example:

actions/recipes.js

```
1 import { createAction } from 'redux-actions';
2 import { ADD_RECIPE } from 'constants/action-types';
3
4 const addRecipePayload = (title) => ({ title });
5
6 export const addRecipe = createAction(ADD_RECIPE, addRecipePayload);
```

This code generates an action creator that will return an FSA-compliant action. The generated action creator will have functionality similar to this function:

Generated action creator

```
1 function addRecipe(title) {
2   return {
3     type: ADD_RECIPE,
4     payload: {
5       title
6     }
7   };
8 }
```

If the title is our only payload, we could simplify the call by omitting the second argument:

Simpler action creator

```
1 export const addRecipe = createAction(ADD_RECIPE);
```

The resulting action creator would be as follows:

³⁴<https://github.com/acdlite/redux-actions>

Simpler action creator's result

```
1 function addRecipe(title) {  
2   return {  
3     type: ADD_RECIPE,  
4     payload: {  
5       title  
6     }  
7   };  
8 }
```

We could also pass metadata to the FSA action. For that, we could include a metadata object as a third argument:

Passing metadata

```
1 export const addRecipe = createAction(  
2   ADD_RECIPE,  
3   (title) => ({ title }),  
4   { silent: true }  
5 );
```

Or, instead of a metadata object, we could use a function to calculate the metadata based on the parameters we pass in the payload:

Dynamic metadata

```
1 const addRecipeMetadata = (title) => ({  
2   silent: true,  
3   notifyAdmin: title === 'Omelette'  
4 });  
5  
6 export const addRecipe = createAction(  
7   ADD_RECIPE,  
8   (title) => ({ title }),  
9   addRecipeMetadata  
10 );
```

The usage of the action creator is the same as before. We simply call it with the desired parameters:

Resulting object with dynamic metadata

```
1 dispatch(addRecipe('Belgian Waffles'));
2
3 // The dispatched object:
4 {
5   type: 'ADD_RECIPE',
6   error: false,
7   payload: {
8     title: 'Belgian Waffles'
9   },
10  meta: {
11    silent: true,
12    notifyAdmin: false
13  }
14 }
```

Errors

The action creator will automatically handle errors for us if passed an `Error` object. It will generate an object with `error = true` and the payload set to the `Error` object:

Dispatching errors

```
1 const error = new Error('Server responded with 500');
2
3 dispatch(addRecipe(error));
4
5 // The dispatched object:
6 {
7   type: 'ADD_RECIPE',
8   error: true,
9   payload: Error(...),
10  meta: { ... }
11 }
```

createAction() Example

Here's a full example of using `createAction()`:

Dispatching errors

```
1  const addRecipe = createAction(  
2    ADD_RECIPE,  
3    (title, description ) => (...args),  
4    { silent: true }  
5  );  
6  
7  const addRecipeAsync = (title, description = '') => {  
8    const details = { ...args };  
9  
10   return (dispatch) => {  
11     fetch('/recipes', {  
12       method: 'post',  
13       body: JSON.stringify(details)  
14     })  
15     .then(  
16       response => dispatch(addRecipe(details)),  
17       error    => dispatch(addRecipe(new Error(error)))  
18     );  
19   }  
20 };
```

In this example, we use the fetch promise to determine whether to create a successful action or an error one:

Passing the promise directly to the action creator

```
1  response => dispatch(addRecipe(details)),  
2  error    => dispatch(addRecipe(new Error(error)))
```

Using redux-actions with redux-promise

redux-actions can be used in conjunction with [redux-promise](https://github.com/acdlite/redux-promise)³⁵ to simplify the code even more.

The redux-promise library can automatically dispatch FSA-compliant actions and set the error and payload fields for us. It adds the ability to `dispatch()` a promise (not just an object or function) and knows how to automatically handle the *resolve* and *reject* functionality of promises:

³⁵<https://github.com/acdlite/redux-promise>

Automatically handling promises

```
1  const addRecipe = createAction(ADD_RECIPE);
2
3  export function addRecipeAsync(details) {
4    return () => addRecipe(
5      fetch('/recipes', {
6        method: 'post',
7        body: JSON.stringify(details)
8      })
9      .then(response => response.json())
10   );
11 }
```

The magic part here is that we pass a promise to `addRecipe()` that will take care of creating the appropriate FSA-compliant action depending on whether the promise is resolved or rejected:

Passing a promise to an action creator

```
1  return () => addRecipe(
2    fetch('/recipes', {
```

Our only use of `then()` is to convert the data we get from `fetch()` into JSON:

Adding another stage to promise resolution

```
1  .then(response => response.json())
```

This line doesn't return data, but only modifies the promise that we return from the action creator and that the caller will send to `dispatch()`.

Summary

In this chapter we covered action creators, the fuel running our application's engine. We saw that Redux is all about simplicity—actions are plain objects and action creators are just functions returning plain objects.

We also saw how we can benefit from ES2016 by dramatically simplifying our syntax.

In the next chapter we will look at reducers, the components of our Redux application that respond to actions.

Chapter 9. Reducers

The word *reducer* is commonly associated in computer science with a function that takes an array or object and converts it to a simpler structure—for example, summing all the items in an array. In Redux, the role of the reducer is somewhat different: reducers create a new state out of the old one, based on an action.

In essence, a reducer is a simple JavaScript function that receives two parameters (two objects) and returns an object (a modified copy of the first argument):

A simple reducer example

```
1 const sum = (result, next) => result + next;
2
3 [1,2,3].reduce(sum); // -> 6
```

Reducers in Redux are *pure functions*, meaning they don't have any side effects such as changing local storage, contacting the server, or saving any data in variables. A typical reducer looks like this:

Basic reducer

```
1 function reducer(state, action) {
2   switch (action.type) {
3
4     case 'ADD_RECIPE':
5       // Create new state with a recipe
6
7     default:
8       return state;
9   }
10 }
```

Reducers in Practice

In Redux, reducers are the final stage in the unidirectional data flow. After an action is dispatched to the store and has passed through all the middleware, reducers receive it together with the current state of the application. Then they create a new state that has been modified according to the action and return it to the store.

The way we connect the store and the reducers is via the `createStore()` method, which can receive three parameters: a reducer, an optional initial state, and an optional store enhancer (covered in detail in the [Store and Store Enhancers Chapter](#)).

As an example, we will use the application built in [Chapter 2](#)—a simple Recipe Book application.

Our state contains three substates:

- Recipes – A list of recipes
- Ingredients – A list of ingredients and amounts used in each recipe
- UI – An object containing the state of various UI elements

We support a number of actions, like `ADD_RECIPE`, `FETCH_RECIPES`, and `SET_RECIPES`.

The simplest approach to build a reducer would be to use a large `switch` statement that knows how to handle all the actions our application supports. But it is quite clear that this approach will break down fast as our application (and the number of actions) grows.

Using a switch statement to build a reducer

```
1  switch (action.type) {  
2  
3    case 'ADD_RECIPE':  
4      /* handle add recipe action */  
5  
6    case 'FETCH_RECIPES':  
7      /* handle fetch recipes action */  
8  
9    ...  
10 }
```

Reducer Separation

The obvious solution would be to find a way to split the reducer code into multiple chunks. The way Redux handles this is by creating multiple reducers. The reducer passed as a first argument to `createStore()` is a plain function, and we can extract code out of it to put in other functions.

Splitting and writing reducers becomes a much easier job if we correctly build the structure of the state in our store. Given our example of the Recipe Book, we can see that we can create a reducer for each of the substates. What's more, each of the reducers only needs to know about its part of the state, and they have no dependency on each other. For example, the recipes reducer only handles recipe management, like adding and removing recipes, and doesn't care about how ingredients or the UI states are managed.

Following this separation of concerns, we can put each reducer into a different file and have a single *root reducer* manage all of them. Another side effect of this approach is that the root reducer will pass each of its children only the part of the state that it cares about (e.g., the ingredients reducer will only get the ingredients substate of the store). This ensures the individual reducers can't “break out” out of their encapsulation.

Recipes reducer

```
1  const initialState = [];  
2  
3  export default function recipesReducer(recipes = initialState, action) {  
4    switch (action.type) {  
5      case ADD_RECIPE:  
6        return [...recipes, action.payload];  
7      ...  
8    }  
9  }
```

Ingredients reducer

```
1  const initialState = [];  
2  
3  export default function ingredientsReducer(ingredients = initialState, action) {  
4    switch (action.type) {  
5      case ADD_INGREDIENT:  
6        return [...ingredients, action.payload];  
7      ...  
8    }  
9  }
```

Root reducer

```
1  import recipesReducer from 'reducers/recipes';  
2  import ingredientsReducer from 'reducers/ingredients';  
3  
4  const rootReducer = (state = {}, action) => Object.assign({}, state, {  
5    recipes: recipesReducer(state.recipes, action),  
6    ingredients: ingredientsReducer(state.ingredients, action)  
7  });  
8  
9  export default rootReducer;
```

This approach results in smaller, cleaner, more testable reducers. Each of the reducers receives a subset of the whole state tree and is responsible only for that, without even being aware of the other parts of the state. As the project and the complexity of the state grows, more nested reducers appear, each responsible for a smaller subset of the state tree.

Combining Reducers

This technique of reducer combination is so convenient and broadly used that Redux provides a very useful function named `combineReducers()` to facilitate it. This helper function does exactly what `rootReducer()` did in our previous example, with some additions and validations:

Root reducer using `combineReducers()`

```
1 import { combineReducers } from 'redux';
2 import recipesReducer from 'reducers/recipes';
3 import ingredientsReducer from 'reducers/ingredients';
4
5 const rootReducer = combineReducers({
6   recipes: recipesReducer,
7   ingredients: ingredientsReducer
8 });
9
10 export const store = createStore(rootReducer);
```

We can make this code even simpler by using ES2016's property shorthand feature:

Using ES2016 syntax in `combineReducers()`

```
1 import { combineReducers } from 'redux';
2 import recipes from 'reducers/recipes';
3 import ingredients from 'reducers/ingredients';
4
5 const rootReducer = combineReducers({ recipes, ingredients });
6
7 export const store = createStore(rootReducer);
```

In this example we provided `combineReducers()` with a configuration object holding two keys named `recipes` and `ingredients`. The ES2016 syntax we used automatically assigned the value of each key to be the corresponding reducer.

It is important to note that `combineReducers()` is not limited to the root reducer only. As our state grows in size and depth, nested reducers will be combining other reducers for substate calculations. Using nested `combineReducers()` calls and other combination methods is a common practice in larger projects.

Default Values

One of the requirements of `combineReducers()` is for each reducer to define the default value for its substate. Both our recipes and ingredients reducers defined the initial state for their subtrees as an empty object. Using this approach, the structure of the state tree as a whole is not defined in a single place but rather built up by the reducers. This guarantees that changes to the tree require us only to change the applicable reducers and do not affect the rest of the tree.

This is possible because when the store is created, Redux dispatches a special action called `@@redux/INIT`. Each reducer receives that action together with the undefined initial state, which gets replaced with the default parameter defined inside the reducer. Since our `switch` statements do not process this special action type and simply return the state (previously assigned by the default parameter), the initial state of the store is automatically populated by the reducers.

Tree Mirroring

This brings us to an important conclusion: that we want to structure our reducers tree to mimic the application state tree. As a rule of thumb, we will want to have a reducer for each leaf of the tree. It would also be handy to mimic the folder structure in the *reducers* directory, as it will be self-depicting of how the state tree is structured.

As complicated manipulations might be required to add some parts of the tree, some reducers might not fall into this pattern. We might find ourselves having two or more reducers process the same subtree (sequentially), or a single reducer operating on multiple branches (if it needs to update structures at two different branches). This might cause complications in the structure and composition of our application. Such issues can usually be avoided by normalizing the tree, splitting a single action into multiple ones, and other Redux tricks.

Alternative to switch Statements

After a while, it becomes apparent that most reducers are just `switch` statements over `action.type`. Since the `switch` syntax can be hard to read and prone to errors, there are a few libraries that try to make writing reducers easier and cleaner.



While it is most common for a reducer to examine the `type` property of the action to determine if it should act, in some cases other parts of the action's object are used. For example, you might want to show an error notification on every action that has an error in the payload.

A common library is [redux-create-reducer](https://github.com/kolodny/redux-create-reducer)³⁶, which builds a reducer from a configuration object that defines how to respond to different actions:

³⁶<https://github.com/kolodny/redux-create-reducer>

Reducer using redux-create-reducer

```
1 import { createReducer } from 'redux-create-reducer';
2
3 const initialState = [];
4 const recipesReducer = createReducer(initialState, {
5
6   [ADD_RECIPE](recipes, action) {
7     return [...recipes, action.payload];
8   },
9
10  [REMOVE_RECIPE](recipes, action) {
11    const index = recipes.indexOf(action.payload);
12
13    return [
14      ...recipes.slice(0, index),
15      ...recipes.slice(index + 1)
16    ];
17  }
18 });
19
20 export default recipesReducer;
```

Removing the case and default statements can make the code easier to read, especially when combined with the ES2016 property shorthand syntax. The implementation is trivial:

Reducer using redux-create-reducer with ES2016 syntax

```
1 function createReducer(initialState, handlers) {
2   return function reducer(state, action) {
3     if (state === undefined) state = initialState;
4
5     if (handlers.hasOwnProperty(action.type)) {
6       return handlers[action.type](state, action);
7     } else {
8       return state;
9     }
10  };
11 }
```

If you are using the `redux-actions` library described in the previous chapter, you can also use the `handleActions()` utility function from that library. It behaves basically the same way as `createReducer()`, with one distinction—`initialState` is passed as a second argument:

Using redux-actions instead of createReducer()

```
1 import { handleActions } from 'redux-actions';
2
3 const initialState = [];
4
5 const recipesReducer = handleActions({
6   [ADD_RECIPE](recipes, action) {
7     return [...recipes, action.payload];
8   },
9
10  [REMOVE_RECIPE](recipes, action) {
11    const index = recipes.indexOf(action.payload);
12    return [
13      ...recipes.slice(0, index),
14      ...recipes.slice(index + 1)
15    ];
16  }
17 }, initialState);
18
19 export default recipesReducer;
```

If you are using Immutable.js, you might also want to take a look at the [redux-immutablejs](https://github.com/indexiatech/redux-immutablejs)³⁷ library, which provides you with `createReducer()` and `combineReducers()` functions that are aware of Immutable.js features like getters and setters.

Avoiding Mutations

The most important thing about reducers in Redux is that *they should **never mutate** the existing state*. There are a number of functions in JavaScript that can help when working with immutable objects.

Why Do We Need to Avoid Mutations?

One of the reasons behind the immutability requirement for the reducers is due to *change detection* requirements. After the store passes the current state and action to the root reducer, it and the various UI components of the application need a way to determine what changes, if any, have happened to the global state. For small objects, a deep compare or other similar methods might suffice. But if the state is large and only a small part may have changed due to an action, we need a faster and better method.

³⁷<https://github.com/indexiatech/redux-immutablejs>

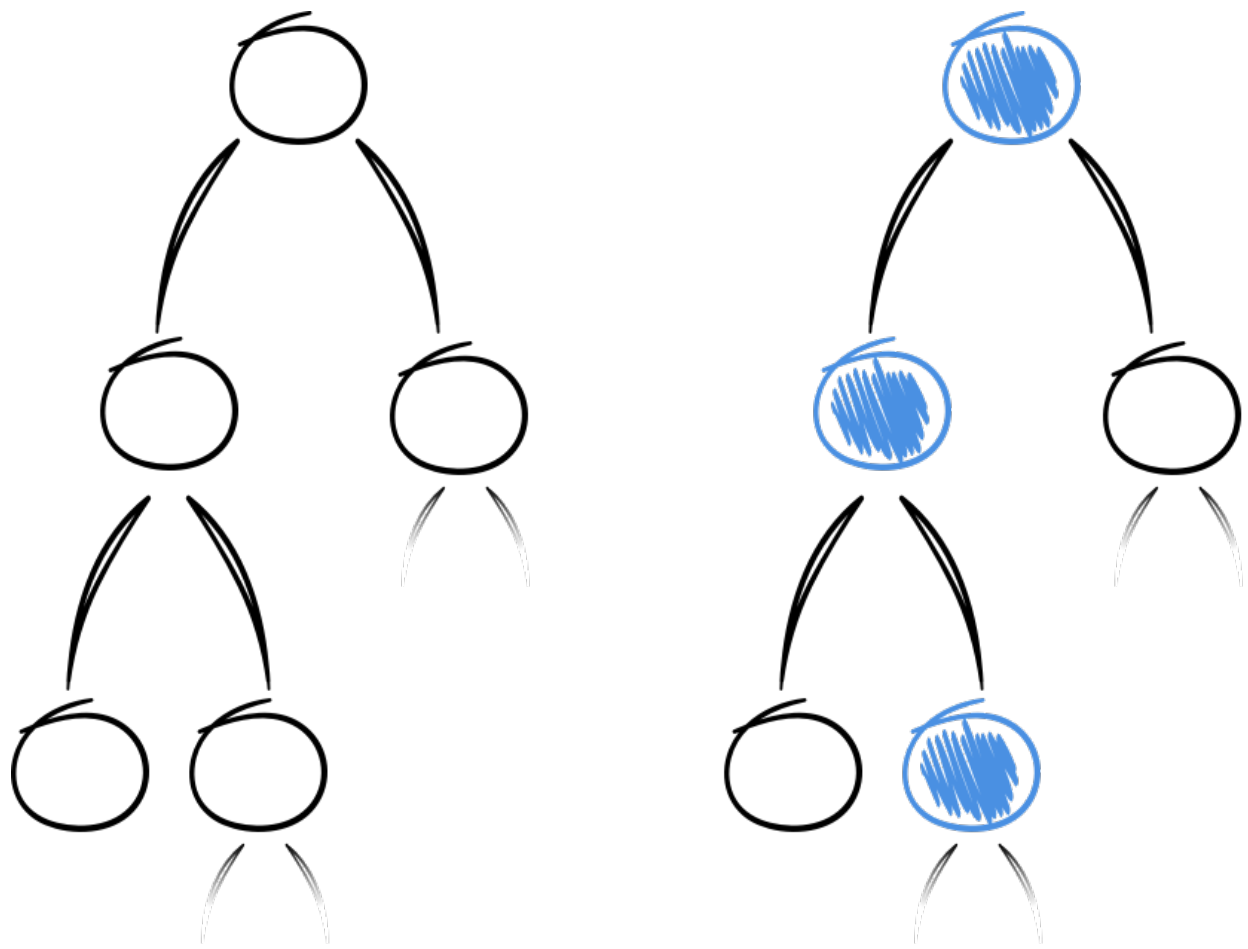
There are a number of ways to detect a change made to a tree, each with its pros and cons. Among the many solutions, one is to mark where changes were made in the tree. We can use simple methods like setting a `dirty` flag, use more complicated approaches like adding a version to each node, or (the preferred Redux way) use *reference comparison*.



If you are unsure of how references work, jump ahead to the next two chapters and come back to this one after.

Redux and its accompanying libraries rely on reference comparison. After the root reducer has run, we should be able to compare the state at each level of the state tree with the same level on the previous tree to determine if it has changed. But instead of comparing each key and value, we can compare only the reference or the *pointer* to the structure.

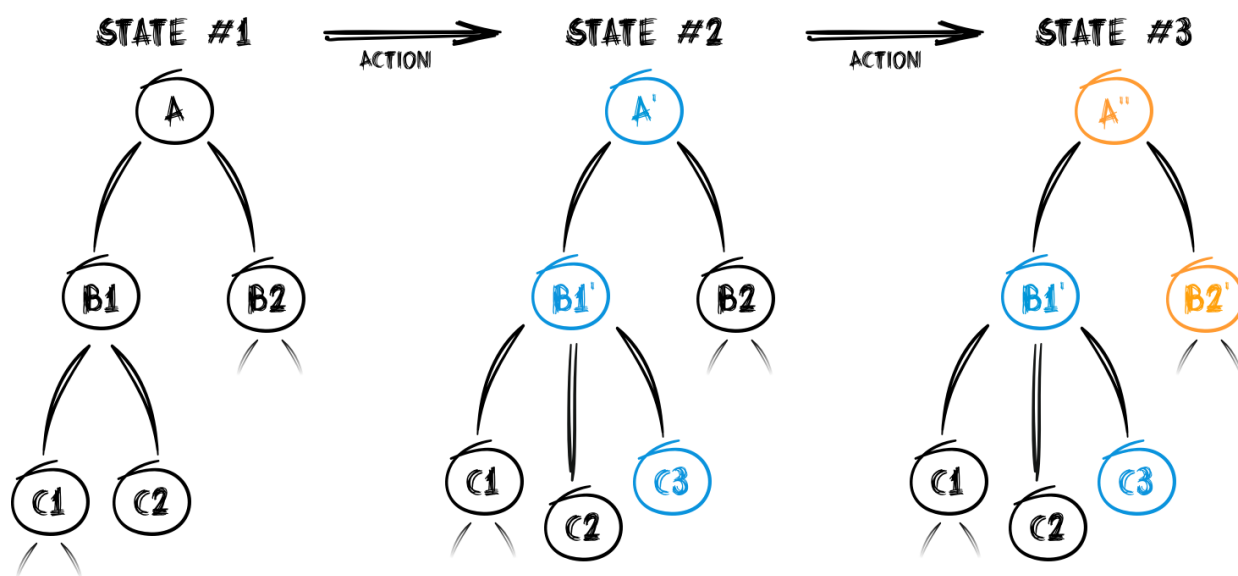
In Redux, each changed node or leaf is replaced by a new copy of itself that has the changed data. Since the node's parent still points to the old copy of the node, we need to create a copy of it as well, with the new copy pointing to the new child. This process continues with each parent being recreated until we reach the root of the tree. This means that a change to a leaf must cause its parent, the parent's parent, etc. to be modified—i.e., it causes new objects to be created. The following illustration shows the state before and after it is run through a reducers tree and highlights the changed nodes.



Example of changing nodes

The main reason reference comparison is used is that this method ensures that each reference to the previous state is kept coherent. We can examine it at any time and get the state exactly as it was before a change. If we create an array and push the current state into it before running actions, we will be able to pick any of the pointers to the previous state in the array and see the state tree exactly as it was before all the subsequent actions happened. And no matter how many more actions we process, our original pointers stay exactly as they were.

This might sound similar to copying the state each time before changing it, but the reference system will not require 10 times the memory for 10 states. It will smartly reuse all the unchanged nodes. Consider the next illustration, where two different actions have been run on the state, and how the three trees look afterward.



Example of saving references

The first action added a new node, C3, under B1. If we look closely we can see that the reducer didn't change anything in the original A tree. It only created a new A' object that holds B2 and a new B1' that holds the original C1 and C2 and the new C3'. At this point we can still use the A tree and have access to all the nodes like they were before. What's more, the new A' tree didn't copy the old one, but only created some new links that allow efficient memory reuse.

The next action modified something in the B2 subtree. Again, the only change is a new A'' root object that points to the previous B1' and the new B2'. The old states of A and A' are still intact and memory is reused between all three trees.

Since we have a coherent version of each previous state, we can implement nifty features like undo and redo (we simply save the previous state in an array and, in the case of "undo," make it the current one). We can also implement more advanced features like "time travel," where we can easily jump between versions of our state for debugging.

What Is Immutability?

The ideas we just discussed are the root of the concept of immutability. If you are familiar with immutability in JavaScript, feel free to skip the remainder of this discussion and proceed to the "Ensuring Immutability" section.

Let's define what the word *mutation* means. In JavaScript, there are two types of variables: ones that are copied by value, and ones that are passed by reference. Primitive values such as numbers, strings, and booleans are copied when you assign them to other variables, and a change to the target variable will not affect the source:

Primitive values example

```
1 let string = "Hello";
2 let copiedString = string;
3
4 copiedString += " World!";
5
6 console.log(string); // => "Hello"
7 console.log(copiedString); => "Hello World!"
```

In contrast, *collections* in JavaScript aren't copied when you assign them; they only receive a pointer to the location in memory of the object pointed to by the source variable. This means that any change to the new variable will modify the same memory location, which is pointed to by both the old and new variables:

Collections example

```
1 const object = {};
2 const referencedObject = object;
3
4 referencedObject.number = 42;
5
6 console.log(object); // => { number: 42 }
7 console.log(referencedObject); // => { number: 42 }
```

As you can see, the original object is changed when we change the copy. We used `const` here to emphasize that a constant in JavaScript holds only a pointer to the object, not its value, and no error will be thrown if you change the properties of the object (or the contents of an array). This is also true for collections passed as arguments to functions, as what is being passed is the reference and not the value itself.

Luckily for us, ES2016 lets us avoid mutations for collections in a much cleaner way than before, thanks to the `Object.assign()` method and the *spread operator*.



The spread operator is fully supported by the ES2016 standard. More information is available [on MDN³⁸](https://developer.mozilla.org/en/docs/Web/JavaScript/Reference/Operators/Spread_operator).

³⁸https://developer.mozilla.org/en/docs/Web/JavaScript/Reference/Operators/Spread_operator

Objects

`Object.assign()` can be used to copy all the key/value pairs of one or more source objects into one target object. The method receives the following parameters:

1. The target object to copy to
2. One or more source objects to copy from



Complete `Object.assign()` documentation is available on [MDN³⁹](https://developer.mozilla.org/en/docs/Web/JavaScript/Reference/Global_Objects/Object/assign).

Since our reducers need to create a new object and make some changes to it, we will pass a new empty object as the first parameter to `Object.assign()`. The second parameter will be the original subtree to copy and the third will contain any changes we want to make to the object. This will result in us always having a fresh object with a new reference, having all the key/value pairs from the original state and any overrides needed by the current action:

Example of `Object.assign()`

```
1 function reduce(state, action) {  
2   const overrides = { price: 0 };  
3  
4   return Object.assign({}, state, overrides);  
5 }  
6  
7 const state = { ... };  
8 const newState = reducer(state, action);  
9  
10 state === newState; // false!
```

Deleting properties can be done in a similar way using ES2016 syntax. To delete the key name from our state we can use the following:

Example of deleting a key from an object

```
1 return Object.assign({}, state, { name: undefined } );
```

Arrays

Arrays are a bit trickier, since they have multiple methods for adding and removing values. In general, you just have to remember which methods create a new copy of the array and which change the original one. For your convenience, here is a table outlining the basic array methods.

³⁹https://developer.mozilla.org/en/docs/Web/JavaScript/Reference/Global_Objects/Object/assign

Mutating arrays

Safe methods	Mutating methods
concat()	push()
slice()	splice()
map()	pop()
reduce()	shift()
reduceRight()	unshift()
filter()	fill()
	reverse()
	sort()

The basic array operations we will be doing in most reducers are appending, deleting, and modifying an array. To keep to the immutability principles, we can achieve these using the following methods:

Adding items to an array with ES2016

```

1 function reducer(state, action) {
2   return state.concat(newValue);
3 }

```

Removing items from an array with ES2016

```

1 function reducer(state, action) {
2   return state.filter(item => item.id !== action.payload);
3 }

```

Changing items in an array with ES2016

```

1 function reducer(state, action) {
2   return state.map((item) => item.id !== action.payload
3     ? item
4     : Object.assign({}, item, { favorite: action.payload }
5   );
6 }

```

Ensuring Immutability

The bitter truth is that in teams with more than one developer, we can't always rely on everyone avoiding state mutations all the time. As humans, we make mistakes, and even with the strictest pull request, code review, and testing practices, sometimes they crawl into the code base. Fortunately,

there are a number of methods and tools that strive to protect developers from these hard-to-find bugs.

One approach is to use libraries like [deep-freeze](#)⁴⁰ that will throw errors every time someone tries to mutate a “frozen” object. While JavaScript provides an `Object.freeze()` method, it freezes only the object it is applied to, not its children. `deep-freeze` and similar libraries perform nested freezes and method overrides to better catch such errors.

Another approach is to use libraries that manage truly immutable objects. While they add additional dependencies to the project, they offer a number of benefits as well: they ensure true immutability, offer cleaner syntax to update collections, support nested objects and provide performance improvements on very large data sets.

The most common library is Facebook’s [Immutable.js](#)⁴¹, which offers a number of key advantages (in addition to many more advanced features):

- Fast updates on very large objects and arrays
- Lazy sequences
- Additional data types not available in plain JavaScript
- Convenient methods for deep mutation of trees
- Batched updates

It also has a few disadvantages:

- Additional large dependency for the project
- Requires the use of custom getters and setters to access the data
- Might degrade performance where large structures are not used

It is important to carefully consider your state tree before choosing an immutable library. The performance gains might only become perceptible for a small percentage of the project, and the library will require all of the developers to understand a new access syntax and collection of methods.

Another library in this space is [seamless-immutable](#)⁴², which is smaller, works on plain JavaScript objects, and treats immutable objects the same way as regular JavaScript objects (though it has similar convenient setters to `Immutable.js`). Its author has written a great [post](#)⁴³ where he describes some of the issues he had with `Immutable.js` and what his reasoning was for creating a smaller library.



`seamless-immutable` does not offer many of the advantages of `Immutable.js` (sequences, batching, smart underlying data structures, etc.), and you can’t use advanced ES2016 data structures with it, such as `Map`, `Set`, `WeakMap`, and `WeakSet`.

⁴⁰<https://www.npmjs.com/package/deep-freeze>

⁴¹<https://facebook.github.io/immutable-js/>

⁴²<https://github.com/rtfeldman/seamless-immutable>

⁴³<http://tech.noredink.com/post/107617838018/switching-from-immutablejs-to-seamless-immutable>

The last approach is to use special helper functions that can receive a regular object and an instruction on how to change it and return a new object as a result. There is such an [immutability helper](#)⁴⁴ named `update()`. Its syntax might look a bit weird, but if you don't want to work with immutable objects and clog object prototypes with new functions, it might be a good option.

Example of using the `update()` function

```
1 import update from 'immutability-helper';
2
3 const newData = update(myData, {
4   x: { y: { z: { $set: 7 }}}},
5   a: { b: { $push: [9] }}
6 });
```

Higher-Order Reducers

The power of Redux is that it allows you to solve complex problems using functional programming. One approach is to use higher-order functions. Since reducers are nothing more than pure functions, we can wrap them in other functions and create very simple solutions for very complicated problems.

There are a few good examples of using higher-order reducers—for example, for implementing undo/redo functionality. There is a library called [redux-undo](#)⁴⁵ that takes your reducer and enhances it with undo functionality. It creates three substates: *past*, *present*, and *future*. Every time your reducer creates a new state, the previous one is pushed to the past states array and the new one becomes the present state. You can then use special actions to undo, redo, or reset the present state.

Using a higher-order reducer is as simple as passing your reducer into an imported function:

Using a higher-order reducer

```
1 import { combineReducers } from 'redux';
2 import recipesReducer from 'reducers/recipes';
3 import ingredientsReducer from 'reducers/ingredients';
4 import undoable from 'redux-undo';
5
6 const rootReducer = combineReducers({
7   recipes: undoable(recipesReducer),
8   ingredients: ingredientsReducer
9 });
```

⁴⁴<https://github.com/kolodny/immutability-helper>

⁴⁵<https://github.com/omnidan/redux-undo>

Another example of a higher-order reducer is [redux-ignore](https://github.com/omnidan/redux-ignore)⁴⁶. This library allows your reducers to immediately return the current state without handling the passed action, or to handle only a defined subset of actions.

The following example will disable removing recipes from our recipe book. You might even use it to filter allowed actions based on user roles:

Using the `ignoreActions()` higher-order reducer

```
1 import { combineReducers } from 'redux';
2 import recipesReducer from 'reducers/recipes';
3 import ingredientsReducer from 'reducers/ingredients';
4 import { ignoreActions } from 'redux-ignore';
5 import { REMOVE_RECIPE } from 'constants/action-types';
6
7 const rootReducer = combineReducers({
8   recipes: ignoreActions(recipesReducer, [REMOVE_RECIPE])
9   ingredients: ingredientsReducer
10 });
```

Testing Reducers

The fact that reducers are just pure functions allows us to write small and concise tests for them. To test a reducer we need to define an initial state, an action and the state we expect to have. Calling the reducer with the first two should always produce the expected state.

This idea works best when we avoid a lot of logic and control flow in reducers.



Two things that are often forgotten while testing reducers are testing unknown actions and ensuring the immutability of initial and expected objects.

Summary

In this chapter we learned about the part of Redux responsible for changing the application state. Reducers are meant to be pure functions that should never mutate the state or make any asynchronous calls. We also learned how to avoid and catch mutations in JavaScript.

In the next and final chapter, we are going to talk about *middleware*, the most powerful entity provided by Redux. When used wisely, middleware can reduce a lot of code and let us handle very complicated scenarios with ease.

⁴⁶<https://github.com/omnidan/redux-ignore>

Chapter 10. Middleware

Middleware are one of Redux's most powerful concepts and will hold the bulk of our application's logic and generic service code.

To understand the concept of middleware, it's best first to examine the regular data flow in Redux. Any action dispatched to the store is passed to the root reducer together with the current state to generate a new one. The concept of middleware allows us to add code that will run before the action is passed to the reducer.

In essence, we can monitor all the actions being sent to the Redux store and execute arbitrary code before allowing an action to continue to the reducers. Multiple middleware can be added in a chain, thus allowing each to run its own logic, one after another, before letting the action pass through. The basic structure of a middleware is as follows:

Basic structure of a middleware

```
1 const myMiddleware = ({ getState, dispatch }) => next => action => {  
2   next(action);  
3 };
```

This declaration might seem confusing, but it should become clear once it's examined step by step. At its base, a middleware is a function that receives from Redux an object that contains the `getState()` and `dispatch()` functions. The middleware returns back a function that receives `next()` and in turn returns another function that receives `action` and finally contains our custom middleware code.



From the user's perspective, a simple `const myMiddleware = ({ getState, dispatch, next, action }) => {}` might have seemed sufficient. The more complicated structure is due to Redux internals.

The `getState()` and `dispatch()` methods should be familiar as they are APIs from the Redux store. The `action` parameter is the current Redux action being passed to the store. Only the `next()` function should look unfamiliar at this point.



It is sometimes incorrectly noted in teaching material that the parameter passed to the middleware is `store` (as it appears to have `getState()` and `dispatch()`). In practice, it's an object holding only those two APIs and not the other APIs exported by the Redux store.

Understanding next()

If we were to build our own implementation of a middleware, we would probably want the ability to run code both before an action is passed to the reducers and after. One approach would be to define two different callbacks for before and after.

Redux middleware takes a different approach and gives us the `next()` function. Calling it with an action will cause it to propagate down the middleware chain, calling the root reducer and updating the state of the store. This allows us to add code before and after passing the action to the reducers:

Example of code

```
1 const logMiddleware => ({ getState, dispatch }) => next => action => {  
2   console.log("Before reducers have run");  
3   next(action);  
4   console.log("After the reducers have run");  
5 }
```

This nifty trick gives us more power than might initially be apparent. Since we are responsible for calling `next()` and passing it the action, we can choose to suppress `next()` in certain conditions or even modify the current action before passing it on. Failing to call `next(action)` inside a middleware will prevent the action from reaching the other middleware and the store.

Our First Middleware

To demonstrate the power of middleware, let's build a special debug middleware that measures how much time it takes for our reducers to process an action.

Folder Structure

A common approach is to keep all our middleware implementations in a middleware directory at our application root (similar to reducers and actions). As our application grows, we might find ourselves adding more subdirectories to organize the middleware, usually by functionality (utility or authorization).



As with software and hardware, we use middleware as both the singular and the plural form of the word. In some sources, including the code for `applyMiddleware()` shown in [Chapter 8](#), you may see middlewares used as the plural form.

The Measure Middleware

Our time measuring middleware looks like this:

middleware/measure.js

```
1 const measureMiddleware = () => next => action => {  
2   console.time(action.type);  
3   next(action);  
4   console.timeEnd(action.type);  
5 };  
6  
7 export default measureMiddleware;
```

To create this middleware we used the `time()` and `timeEnd()` console methods that record a benchmark with the name provided as a string. We start the timing before running an action, using the `action.type` as a name. Then, we tell the browser to print the timing after the action is done. This way we can potentially catch poorly performing reducer implementations.

An interesting thing to note here is that this middleware completely ignores the first parameter (the object holding `getState()` and `dispatch()`), as we simply don't need it for our example.

Connecting to Redux

Adding a middleware to the Redux store can be done only during the store creation process:

Regular Redux store

```
1 import { createStore } from 'redux';  
2 import reducer from 'reducers/root';  
3  
4 const store = createStore(reducer);  
5 };
```

The simplest way to connect a middleware to the Redux store is to use the `applyMiddleware()` store enhancer available as an API from Redux itself (store enhancers are explained in [Chapter 8](#):

Create store and register the measureMiddleware

```
1 import { createStore, applyMiddleware } from 'redux';  
2 import reducer from 'reducers/root';  
3 import measureMiddleware from 'middleware/measure';  
4  
5 const store = createStore(reducer, applyMiddleware(measureMiddleware));
```

The `applyMiddleware()` function can receive an arbitrary number of middleware as arguments and create a chain to be connected to the store:

```
1 applyMiddleware(middlewareA, middlewareB, middlewareC);
```



Note that the order of registration is important. The first middleware, in our case `middlewareA`, will get the action before `middlewareB`. And if the code there decides to modify or suppress the action, it will never reach either `middlewareB` or `middlewareC`.

In real-world applications, you may prefer to apply some middleware only in development or production environments. For example, our `measureMiddleware` might output unwanted information in the live product, and an `analyticsMiddleware` might report false analytics in development.

Using the spread operator from ES2016, we can apply middleware to the store conditionally:

Conditionally apply middleware

```
1 const middleware = [apiMiddleware];
2
3 if (development) {
4   middleware.push(measureMiddleware);
5 } else {
6   middleware.push(analyticsMiddleware);
7 }
8
9 const store = createStore(reducer, applyMiddleware(...middleware));
```

Async Actions

What makes middleware so powerful is the access to both `getState()` and `dispatch()`, as these functions allow a middleware to run asynchronous actions and give it full access to the store. A very simple example would be an action debounce middleware. Suppose we have an autocomplete field, and we want to prevent the `AUTO_COMPLETE` action from running as the user types in a search term. We would probably want to wait 500ms for the user to type in part of the search string, and then run the query with the latest value.

We can create a debounce middleware that will catch any action with the `debounce` key set in its metadata and ensure it is delayed by that number of milliseconds. Any additional action of the same type that is passed before the debounce timer expires will not be passed to reducers but only saved as the “latest action” and executed once the debounce timer has expired:

Debounce flow

```

1  0ms: dispatch({ type: 'AUTO_COMPLETE', payload: 'c', meta: { debounce: 50 }};
2  // Suppressed
3
4  10ms: dispatch({ type: 'AUTO_COMPLETE', payload: 'ca', meta: { debounce: 50 }};
5  // Suppressed
6
7  20ms: dispatch({ type: 'AUTO_COMPLETE', payload: 'cat', meta: { debounce: 50 }};
8  // Suppressed
9
10 50ms:
11 // The action with payload 'cat' is dispatched by the middleware.

```

The skeleton of our middleware needs to inspect only actions that have the required debounce key set in their metadata:

Debounce middleware skeleton

```

1  const debounceMiddleware = () => next => action => {
2    const { debounce } = action.meta || {};
3
4    if (!debounce) {
5      return next(action);
6    }
7
8    // TODO: Handle debouncing
9  };
10
11 export default debounceMiddleware;

```

Since we want each action type to have a different debounce queue, we will create a pending object that will hold information for each action type. In our case, we only need a handle to the latest timeout for each action type:

Saving latest debounced action object

```

1  // Object to hold debounced actions (referenced by action.type)
2  const pending = {};
3
4  const debounceMiddleware = () => next => action => {
5    const { debounce } = action.meta || {};
6
7    if (!debounce) {
8      return next(action);
9    }
10
11    if (pending[action.type]) {
12      clearTimeout(pending[action.type])
13    }
14
15    // Save latest action object
16    pending[action.type] = setTimeout(/* implement debounce */);
17  };

```

If there is already a pending action of this type, we cancel the timeout and create a new timeout to handle this action. The previous one can be safely ignored—for example, in our case if an action { type: 'AUTO_COMPLETE', payload: 'cat' } comes right after { type: 'AUTO_COMPLETE', payload: 'ca' }, we can safely ignore the one with 'ca' and only call the autocomplete API for 'cat':

Timeout handler code

```

1  setTimeout(
2    () => {
3      delete pending[action.type];
4      next(action);
5    },
6    debounce
7  );

```

Once the timeout for the latest action has elapsed, we clear the key from our pending object and next() method to allow the last delayed action to finally pass through to the other middleware and the store:

Complete debounce middleware code

```

1  // Object to hold debounced actions (referenced by action.type)
2  const pending = {};
3
4  const debounceMiddleware = () => next => action => {
5    const { debounce } = action.meta || {};
6
7    if (!debounce) {
8      return next(action);
9    }
10
11    if (pending[action.type]) {
12      clearTimeout(pending[action.type]);
13    }
14
15    pending[action.type] = setTimeout(
16      () => {
17        delete pending[action.type];
18        next(action);
19      },
20      debounce
21    );
22  };
23
24  export default debounceMiddleware;

```

With this basic middleware we have created a powerful tool for our developers. A simple meta setting on an action can now support debouncing of any action in the system. We have also used the middleware's support for the `next()` method to selectively suppress actions. In the [Server Communication Chapter](#) we will learn about more advanced uses of the async flow to handle generic API requests.

Using Middleware for Flow Control

One important usage of middleware is for the control of application flow and logic. Let's consider a sample user login flow:

Send POST request to server to log in
 Save access token in store
 Fetch current user's profile information
 Fetch latest notifications

Usually our flow will begin with a 'LOGIN' action containing the login credentials:

Example of a login action

```
1 {  
2   type: 'LOGIN',  
3   payload: {  
4     email: 'info@redux-book.com',  
5     password: 'will-never-tell'  
6   }  
7 }
```

After our access to the server completes successfully, another action will typically be dispatched, similar to:

Successful login action

```
1 {  
2   type: 'SUCCESSFUL_LOGIN',  
3   payload: 'access_token'  
4 }
```

One of the reducers will make sure to update the access token in the state, but it is unclear who is responsible for issuing the two additional actions required: 'FETCH_USER_INFO' and 'FETCH_NOTIFICATIONS'.

We could always use complex action creators and the `redux-thunk` middleware in our login action creator:

Sample complex login action creator

```
1 const login = (email, password) => dispatch => {  
2   postToServer('login', { email, password })  
3     .then((response) => {  
4       dispatch(successfulLogin(response.accessToken));  
5       dispatch(fetchUserInfo());  
6       dispatch(fetchNotifications());  
7     });  
8   };
```

But this might cause a code reuse problem. If in the future we want to support Facebook Connect, it will require a different action altogether, which will still need to include the calls to 'FETCH_USER_INFO' and 'FETCH_NOTIFICATIONS'. And if in the future we change the login flow, it will need to be updated in multiple places.

A simple solution to the problem is to cause the two actions to be dispatched only after the login is successful. In the regular Redux flow, there is only one actor that can listen for and react to events—the middleware:

Login flow middleware

```
1 const loginFlowMiddleware = ({ dispatch }) => next => action => {  
2   // Let the reducer save the access token in the state  
3   next(action);  
4  
5   if (action.type === SUCCESSFUL_LOGIN) {  
6     dispatch(fetchUserInfo());  
7     dispatch(fetchNotifications());  
8   }  
9 };
```

Our new code holds the flow in a single place and will allow us to easily support login via Twitter, Google Apps, and more.

In practice we can combine flows together and add conditions and more complicated logic, as we have full access to both `dispatch()` and `getState()`.



There are a few external libraries that try to make flow management easier, such as [redux-saga](https://github.com/yelouafi/redux-saga)⁴⁷.

Other Action Types

When learning the basics of Redux, developers are usually taught that actions in Redux can only be objects and they must contain the 'type' key. In practice, reading this book and online material, you'll notice Error objects, functions, and promises being passed to `dispatch()`.

The underlying rule is simple: our root reducer requires an object as an action, but our middleware have no such limits and are free to handle any type of data passed to `dispatch()`.

Try running `dispatch(null)`. You should get an error from Redux similar to:

Passing a non-object to dispatch

```
1 store.dispatch(null);  
2 > Uncaught TypeError: Cannot read property 'type' of null(...)
```

To add support for `null` we can create our own `nullMiddleware`:

⁴⁷<https://github.com/yelouafi/redux-saga>

Simple null middleware

```
1 const nullMiddleware = () => next => action => {  
2   next(action !== null ? action : { type: 'UNKNOWN' });  
3 };
```

In this middleware we catch any attempt to send `null` instead of the action object and `dispatch()` a fake `{ type: 'UNKNOWN' }` instead. While this middleware has no practical value, it should be apparent how we can use the middleware's power to change actions to support any input type.

The famous `redux-thunk`⁴⁸ middleware is in essence the following code:

Simplified redux-thunk

```
1 const thunkMiddleware = ({ dispatch, getState }) => next => action => {  
2   if (typeof action === 'function') {  
3     return action(dispatch, getState);  
4   }  
5  
6   return next(action);  
7 };
```

It checks if the action passed is 'function' instead of the regular object, and if it is a function it “calls” it, passing `dispatch()` and `getState()`.

A similar approach is used by other helper middleware that know how to accept the following, and more:

- Promises (e.g., dispatch a regular action when resolved)
- Error objects (e.g., report errors)
- Arrays (e.g., execute a list of actions provided in parallel or sequentially)

Difference Between `next()` and `dispatch()`

A common point of confusion is the difference between the `next()` and `dispatch()` functions passed to the middleware. While both accept an action, they follow a different flow in Redux.

Calling `next()` within a middleware will pass the action along the middleware chain (from the current middleware) down to the reducer. Calling `dispatch()` will start the action flow from the beginning (the first middleware in the chain), so it will eventually reach the current one as well.

⁴⁸<https://github.com/gaearon/redux-thunk>

Store setup

```
1 createStore(reducer,  
2   applyMiddleware(  
3     middlewareA,  
4     middlewareB,  
5     middlewareC  
6   )  
7 );
```

Calling `next(action)` within `middlewareB` will cause the action to be passed to `middlewareC` and then the reducer.

Calling `dispatch(action)` within `middlewareB` will cause the action to be passed to `middlewareA`, then `middlewareB`, then `middlewareC`, and finally to the reducer, returning the execution back to `middlewareB`.

Calling `dispatch()` multiple times is a common and valid practice. `next()` can also be called more than once, but this is not recommended as any action passed to `next()` will skip the middleware before the current one (for example, potentially skipping the logging middleware).

Parameter-Based Middleware

Beyond the middleware we've discussed so far in this chapter, some middleware might be reusable and support parameters being passed during their creation.

For example, consider the `nullMiddleware` we created earlier in this chapter:

Simple null middleware

```
1 const nullMiddleware = () => next => action => {  
2   next(action !== null ? action : { type: 'UNKNOWN' });  
3 };  
4  
5 export default nullMiddleware;
```

The 'UNKNOWN' key is hardcoded into our middleware and will not allow easy reuse in our other projects. To make this middleware more generic, we might want to be able to support arbitrary action types and use the `applyMiddleware()` stage to specify how we want our middleware to behave:

Customizable middleware

```
1 import { createStore, applyMiddleware } from 'redux';
2 import reducer from 'reducers/root';
3 import nullMiddleware from 'middleware/null';
4
5 const store = createStore(reduce, applyMiddleware(nullMiddleware('OH_NO')));
6 
```

Here we want our `nullMiddleware` to dispatch `'OH_NO'` instead of the default `'UNKNOWN'`. To support this we must turn our middleware into a “middleware creator”:

Null middleware creator

```
1 const nullMiddlewareCreator = param => store => next => action => {
2   next(action !== null ? action : { type: param || 'UNKNOWN' });
3 };
4
5 export default nullMiddlewareCreator;
```

Now instead of returning the middleware directly, we return a function that creates a middleware with custom parameters passed in.

This behavior can be further extended and allow for creation of complex middleware as libraries that can be easily customized when added to the store.

How Are Middleware Used?

In real-life applications, middleware are often where most of the logic and complex code resides. They also hold most of the utility functionality, such as logging, error reporting, analytics, authorization, and more. Many of the enhancement libraries used in this book require the addition of their custom middleware to the chain in order to support their functionality.

There is a long list of open source projects that implement various useful middleware. A few examples are:

- [redux-analytics](https://github.com/markdalgleish/redux-analytics)⁴⁹
- [redux-thunk](https://github.com/gaearon/redux-thunk)⁵⁰
- [redux-logger](https://github.com/fcomb/redux-logger)⁵¹

⁴⁹<https://github.com/markdalgleish/redux-analytics>

⁵⁰<https://github.com/gaearon/redux-thunk>

⁵¹<https://github.com/fcomb/redux-logger>

Summary

Middleware are an exceptionally versatile and useful part of Redux, and they are commonly used to hold the most complicated and generic parts of an application. They have access to the current action, to the store, and to the `dispatch()` method, giving them more power than any other part of Redux.

Our exploration of advanced Redux concepts ends here. In the next section you will find links to materials for further reading and learning. Thank you for reading our book, and don't forget to send us your feedback at info@redux-book.com. Happy coding!

Further Reading

Despite its small size, the Redux library has had a huge effect on the way developers handle data management in single-page applications. It's already used in many large production applications and has grown a large ecosystem around itself.

Today, there are a lot of great materials about Redux all over the Internet. This book attempts to group together all the best practices for real-world use of Redux and show how to use it correctly in large applications. But since the web world is constantly moving forward, it is always good to keep up to date and explore new libraries and methods. In this section of the book, we would like to mention some good Redux-related sources for further learning.

Resource Repositories

The Redux repository on GitHub has an [Ecosystem documentation section](#)⁵² where you'll find a curated list of Redux-related tools and resources.

There is also a less curated (and thus much larger) resource catalog managed by the community called [Awesome Redux](#)⁵³. This repository contains a good amount of resources related to using Redux with different libraries such as Angular, Vue, Polymer, and others.

If you are looking for more React/Redux-focused material, [Mark Erikson](#)⁵⁴ maintains a resource repository called [React/Redux Links](#)⁵⁵. The materials there are separated by difficulty level, and a broad range of topics are covered (state management, performance, forms, and many others).

The same author also maintains a more Redux-focused resource list called [Redux Ecosystem Links](#)⁵⁶, which has a similar structure.

Useful Libraries

The Redux ecosystem now includes dozens (if not hundreds) of useful libraries that complement or extend its features. Here's a short list of libraries that have gained widespread popularity and are strongly recommended for use in large Redux projects—we recommend that you check out the source code of these libraries to get a deeper understanding of the extensibility of Redux:

⁵²<https://github.com/reactjs/redux/blob/master/docs/introduction/Ecosystem.md>

⁵³<https://github.com/xgrommx/awesome-redux>

⁵⁴<https://github.com/mark Erikson>

⁵⁵<https://github.com/mark Erikson/react-redux-links>

⁵⁶<https://github.com/mark Erikson/redux-ecosystem-links>

reselect⁵⁷

If you count the Redux store as a client-side database of your application, you can definitely count selectors as queries to that database. `reselect` allows you to create and manage composable and efficient selectors, which are crucial in any large application.

redux-actions⁵⁸

Written by Redux cocreator [Andrew Clark](#)⁵⁹, this library can reduce the amount of boilerplate code you need to write when working with action creators and reducers. We find it particularly useful for writing reducers in a more ES2016 fashion, instead of using large `switch` statements.

redux-undo⁶⁰

If you ever need to implement undo/redo/reset functionality in some parts of your application, we recommend using this awesome library. It provides a higher-order reducer that can relatively easily extend your existing reducers to support action history.

redux-logger⁶¹

`redux-logger` is a highly configurable middleware for logging Redux actions, including the state before and after the action, in the browser console. It should only be used in development. Our advice is to use the `collapsed: true` option to make the console output more readable and manageable.

redux-localstorage⁶²

This reasonably simple store enhancer enables persisting and rehydrating parts of the store in the browser's `localStorage`. It does not support other storage implementations, such as `sessionStorage`. Beware that `localStorage` isn't supported in private mode in some browsers and always check its performance in large applications.

Courses and Tutorials

"[Getting Started with Redux](#)"⁶³ is a great free video course by Redux cocreator Dan Abramov, where he implements Redux from scratch and shows how to start using it with ReactJS.

[Learn Redux](#)⁶⁴ is a free screencast series by Wes Bos. You can follow along with the series to build a simple photo app using React and Redux.

Finally, the official [Redux documentation](#)⁶⁵ is a truly great resource: a well-maintained, constantly improving source of knowledge for this tiny yet powerful library.

⁵⁷<https://github.com/reactjs/reselect>

⁵⁸<https://github.com/acdlite/redux-actions>

⁵⁹<https://github.com/acdlite>

⁶⁰<https://github.com/omnidan/redux-undo>

⁶¹<https://github.com/evgenyrodionov/redux-logger>

⁶²<https://www.npmjs.com/package/redux-localstorage>

⁶³<https://egghead.io/courses/getting-started-with-redux>

⁶⁴<https://learnredux.com/>

⁶⁵<http://redux.js.org/>