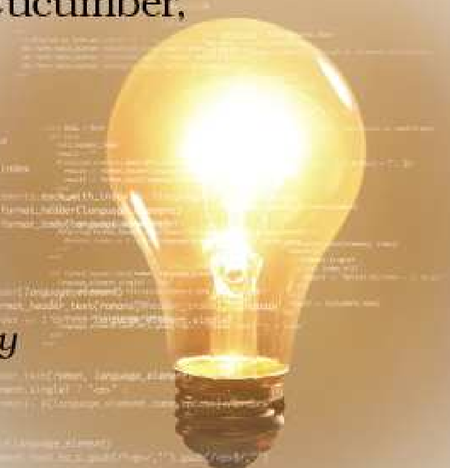
The Pragmatic Programmers

The RSpec Book

Behaviour Driven Development with RSpec, Cucumber, and Friends



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Edited by Jacquelyn Carter

The Facets of Ruby Series

Beta Book

Agile publishing for agile developers

The book you're reading is still under development. As part of our Beta book program, we're releasing this copy well before we normally would. That way you'll be able to get this content a couple of months before it's available in finished form, and we'll get feedback to make the book even better. The idea is that everyone wins!

Be warned. The book has not had a full technical edit, so it will contain errors. It has not been copyedited, so it will be full of typos and other weirdness. And there's been no effort spent doing layout, so you'll find bad page breaks, over-long lines with little black rectangles, incorrect hyphenations, and all the other ugly things that you wouldn't expect to see in a finished book. We can't be held liable if you use this book to try to create a spiffy application and you somehow end up with a strangely shaped farm implement instead. Despite all this, we think you'll enjoy it!

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► **Andy & Dave**

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Printed in the United States of America.

ISBN-10: 1-934356-37-9

ISBN-13: 978-1-934356-37-1

Printed on acid-free paper.

B12.0 printing, December 3, 2009

Version: 2009-12-3

Contents

Important Information for Beta Readers

Welcome to The RSpec Beta Book!

RSpec, Cucumber, and Webrat are all under regular development with frequent releases. The fact that the maintainers of these libraries are also authors of this book means that *you* get to learn about the latest features. In fact, some of the features you'll learn about are so new, they have not even been released yet!

The downside of this is that keeping everything up to date with the latest features during the beta process consumes a lot of time. While we've done our best to keep the code in the book up to date with the latest versions, you may notice some differences in the output you get from RSpec and Cucumber from what's in the book. This will all be fixed before we go to print, as we will lock down the versions and regenerate all of that output by actually running it. We're just not doing that for every beta release because it's extraordinarily time-consuming to do the necessary re-formatting of the output, and our focus is on getting the rest of the material written. Again, this only applies to the output, not the code you write.

For installation instructions for all the library code you need, please see http://wiki.github.com/dchelimsky/rspec/code-for-the-rspec-book-beta.

Please report any problems you run into installing these gems to The RSpec Book Forum at http://forums.pragprog.com/forums/95, and any other sorts of errata to http://www.pragprog.com/titles/achbd/errata (excluding minor discrepancies in the program output).

Thank you *so much* for participating in our beta program. The feedback we've already received has been invaluable, and is making this a better book for everbody.

Changes

Beta 12.0—December 3, 2009

We're very close to the end of beta now! In this release we fixed a number of errata and added a new chapter:

Revisiting The Design

This is the last chapter in the Codebreaker example. We look at new requirements that force us to revisit the design on a grander scale than in the previous chapters. The combination of Cucumber scenarios and RSpec code examples supports making big changes safely, and allows for the application and code-level behaviour to evolve independently of each other.

Beta 11.0—October 28, 2009

For this beta release we've addressed a lot of errata and edited all of the chapters in the Rails section, bringing them up to date with the latest Rails, RSpec, Cucumber, Selenium and Webrat.

Beta 10.0—September 22, 2009

This release sports more fixed errata and one new chapter:

Automating the Browser with Webrat and Selenium

This new chapter shows you how to drive Cucumber scenarios right through your browser using Webrat and Selenium. You'll type a single command and watch a browser fire up and walk through each scenario step by step right before your very eyes, and then see a standard Cucumber report in the shell. It's a sight to behold, and a great way to drive out behaviour that requires JavaScript.

Beta 9.0—August 28, 2009

Writing Software that Matters

Thanks to lots of good feedback, and further experience in the field, this chapter has been completely reworked to reflect the latest information about BDD.

Spec::Mocks

We moved the Mock Objects chapter to Part III of the book and merged in content specific to RSpec's Spec::Mocks framework, and renamed it for the framework it describes.

Beta 8.0—July 17, 2009

This beta release fixes several reported errata and introduces one new chapter:

Managing Complexity in Step Definitions

Chapter 8, *Managing Complexity in Step Definitions*, on page 111 introduces a random generator to the Codebreaker game. This brings up several issues that can add complexity to Cucumber scenarios, RSpec code examples, and the code we're driving out with the aid of these tools and the BDD process. We address these issues and offer strategies to manage the complexity they introduce.

Beta 7.0—June 24, 2009

No new chapters in this one, but even books can have bug-fix releases! This chapter addresses several issues, including:

Codebreaker For reasons best left unspoken, we've changed the name of the game in the tutorial in Part I to Codebreaker.

Update to latest gems We've gone through the book and updated all the practical examples to the latest gem versions, which are:

- rspec-1.2.7
- rspec-rails-1.2.7.1
- cucumber-0.3.11
- webrat-0.4.4

While we plan to update the final print book to the latest versions of all of these gems at the time we go to print, we don't anticpate any significant changes between now and then, as *then* is very soon at this point.

Beta 6.0—June 17, 2009

This release includes a number of fixed errata, two new chapters, and a bit of re-organization.

Hello We added a new chapter with basic install instructions and basic Hello Cucumber and Hello RSpec examples.

Rails Models Covers writing model specs, validations, associations, mocks, test data builders and more.

Automating Features with Cucumber We split Chapter 3, *Describing Features with Cucumber*, on page 33 into two chapters: Chapter 3, *Describing Features with Cucumber*, on page 33 and Chapter 4, *Automating Features with Cucumber*, on page 50. This allowed us to expand the material on planning the first release and iteration in the first chapter, and keep the technical *in the trenches* material in the second.

Even if you've already read through the tutorial in previous beta releases, you're going to want to re-read these two chapters.

Beta 5.0—May 18, 2009

This release introduces two new chapters:

Writing Software that Matters

Having laid out the case for Behaviour Driven Development in Chapter 10, *The Case for BDD*, on page 156, this new chapter explores the principles and strategies that BDD brings to the Agile table. See Chapter 11, *Writing software that matters*, on page 169

Mock Objects

One of the most complex and controversial topics in developer testing is that of Mock Objects. In Chapter 14, *Spec::Mocks*, on page 226, we review some basic terminology and explore the underlying motivations for two essential tools in the BDD toolkit: test stubs and mock objects.

Beta 4.0—April 13, 2009

This new release includes a number of improvements per suggestions submitted by readers,[1] as well as two exciting new chapters:

Rails Controllers

Continuing inward on our outside-in journey, this chapter explores how (and *when*) to write controller specs. We also introduce approaches to dealing with some controller-specific spec'ing challenges like filters, global behaviour defined in ApplicationController, and sending email. See Chapter 24, *Rails Controllers*, on page 385.

Extending RSpec

This chapter introduces techniques for extending RSpec to cater to domain-specific needs. Covered topics include custom example group classes, custom matchers (including an exciting new matcher definition DSL), macros and custom formatters. Whether customizing RSpec for your own app, or in order to ship domain-specific spec'ing extensions with the libraries you're releasing, this chapter is filled with really useful information that will help you make your specs easier to write *and* read. See Chapter 17, *Extending RSpec*, on page 285.

1. http://www.pragprog.com/titles/achbd/errata

Preface

Coming soon ....

Part I

Getting Started with RSpec and Cucumber

Chapter 1

Introduction

Behaviour Driven Development began its journey as an attempt to better understand and explain the process of Test Driven Development. Dan North had observed that developers he was coaching were having a tough time relating to TDD as a design tool and came to the conclusion that it had a lot to do with the word *test*.

Dave Astels took that to the next step in his seminal article, A New Look at Test Driven Development,[1] in which Dave suggested that even some experienced TDD'ers were not getting all the benefit from TDD that they could be getting.

To put this into perspective, perhaps a brief exploration of Test Driven Development is in order.

1.1 Test Driven Development: Where it All Started

Test Driven Development is a developer practice that involves writing tests before writing the code being tested. Begin by writing a very small test for code that does not yet exist. Run the test and, naturally, it fails. Now write just enough code to make that test pass. No more.

Once the test passes, observe the resulting design and refactor [2] to remove any duplication you see. It is natural at this point to judge the design as too simple to handle all of the responsibilities this code will have.

1. http://techblog.daveastels.com/2005/07/05/a-new-look-at-test-driven-development/
2. Refactoring: improving the design of code without changing its behaviour. From Martin Fowler's *Refactoring* [FBB+99]

Joe Asks…

But what if "the testers" is me?

Not all project teams have a separate tester role. On teams that don't, the notion of pushing off the responsibility of testing practices to other people doesn't really fly. In cases like this, it's still helpful to separate testing practices from TDD.

When you're *wearing your TDD hat*, focus on red/green/refactor, design and documentation. Don't think about testing. Once you've developed a body of code, put on your *tester hat*, and think about all the things that could go wrong. This is where you add all the crazy edge cases, using exploratory testing to weed out the nasty bugs hiding in the cracks, documenting them as you discover them with more code examples.

Instead of adding more code, document the next responsibility in the form of the next test. Run it, watch it fail, write just enough code to get it to pass, review the design and remove duplication. Now add the next test, watch it fail, get it to pass, refactor, fail, pass, refactor, fail, pass, refactor, etc, etc, etc.

In many unit testing systems, when a test fails, we see the results printed in red. Then when it passes, the results are printed in green. Because of this, we often refer to this cycle as *red/green/refactor*.

Emergent Design

As the code base gradually increases in size, more and more attention is consumed by the refactoring step. The design is constantly evolving and under constant review, though it is not pre-determined. This is *emergent design* at a granular level, and is one of the most significant by-products of Test Driven Development.

This is not a testing practice at all. Instead, the goal of TDD is to deliver high quality code to testers, but it is the testers who are responsible for testing practices (see the *Joe Asks…* on the current page).

And this is where the *Test* in TDD becomes a problem. Specifically, it is the idea of *Unit Testing* that often leads new TDD'ers to verifying things like making sure that a register() method stores a Registration in a Registry's registrations collection, and that collection is specifically an Array.

This sort of detail in a test creates a dependency in the test on the internal structure of the object being tested. This dependency means that if other requirements guide us to changing the Array to a Hash, this test will fail, even though the behaviour of the object hasn't changed. This brittleness can make test suites much more expensive to maintain, and is the primary reason for test suites to become ignored and, ultimately, discarded.

So if testing internals of an object is counter-productive in the long run, what should we focus on when we write these tests first?

1.2 Behaviour Driven Development: The Next Step

The problem with testing an object's internal structure is that we're testing what an object *is* instead of what it *does*. What an object *does* is significantly more important.

Think of this at the application level. When is the last time you had a conversation with a business analyst who said "when a customer places an order, the order should be stored in an ANSI-compliant relational database"? More likely, he said something like "when a customer places an order, it should be stored in *the database*." And by *the database* he was using a generic metaphor for some sort of persistent storage mechanism.

Of course you may have a more technically savvy business analyst who actually understands the technical differences and implications of ANSI-compliance and relational databases vs object and document databases, etc. But he probably doesn't care about which one you choose as much as whether the person who processes orders can recall that data in order to do his job.

At the object level, the fact that a Registry uses an Array instead of a Hash or some other data structure to store registrations is not important. What is important is that you can ask a Registry to store a registration and you can retrieve that registration later. Whether we're specifying applications or objects, the real value lies in the *behaviour*, not the *structural details*.

1.3 RSpec

RSpec was created by Steven Baker in 2005, inspired by Dave's aforementioned article. One of Dave's suggestions was that with languages like Smalltalk and Ruby, we could more freely explore new TDD frameworks that could encourage focus on behaviour.

While the syntactic details have evolved since Steven's original version of RSpec, the basic premise remains. We use RSpec to write executable examples of the expected behaviour of a small bit of code in a controlled context. Here's how that might look:

```
describe MovieList do
  context "when first created" do
    it "should be empty" do
      movie_list = MovieList.new
      movie_list.should be_empty
    end
  end
end
```

The it() method creates an *example* of the behaviour of a MovieList, with the *context* being that the MovieList was just created. The expression movie_list.should be_empty is self-explanatory. Just read it out loud. You'll see how be_empty() interacts with the movie_list in Section 13.3, *Predicate Matchers*, on page 215.

Running this code in a shell with the spec command yields the following specification:

```
MovieList when first created
- should be empty
```

Add some more contexts and examples, and the resulting output looks even more like a specification for a MovieList object:

```
MovieList when first created
- should be empty

MovieList with 1 item
- should not be empty
- should include that item
```

Of course, we're talking about the specification of an object, not a system. You *could* specify application behaviour with RSpec. Many do. Ideally, however, for specifying application behaviour, we want something that communicates in broader strokes. And for that, we use Cucumber.

1.4 Cucumber

As you'll read about in Chapter 11, *Writing software that matters*, on page 169, BDD has evolved into a full stack agile methodology. It takes some of its cues from Extreme Programming, including a variation of Acceptance Test Driven Development called Acceptance Test Driven *Planning*.

In ATDP, we use customer acceptance tests to drive the development of code. Ideally, these are the result of a collaborative effort between the customer and the delivery team. Sometimes they are written by the delivery team and then reviewed/approved by the customer. In either case, they are customer facing, and must be expressed in a language and format that customers can relate to. Cucumber gives us that language and format.

Cucumber reads plain text descriptions of application features with example scenarios, and uses the scenario steps to automate interaction with the code being developed. For example:

```
Line 1 Feature: pay bill on-line
-        In order to reduce the time I spend paying bills
-        As a bank customer with a checking account
-        I want to pay my bills on-line
5
-        Scenario: pay a bill
-          Given checking account with $50
-          And a payee named Acme
-          And an Acme bill for $37
10         When I pay the Acme bill
-          Then I should have $13 remaining in my checking account
-          And the payment of $37 to Acme should be listed in Recent Payments
```

Everything up to and including the Scenario declaration on line 6 is treated as documentation (not executable). The subsequent lines are steps in the scenario. In Chapter 4, *Automating Features with Cucumber*, on page 50, you'll be writing *step definitions* in Ruby. These step definitions interact with the code being developed, and are invoked by Cucumber as it reads in the scenario.

Don't worry if that doesn't make perfect sense to you just yet. For right now it's only important to understand that both RSpec and Cucumber help us specify the behaviour of code with examples that are programmatically tied to that code. The details will become clear as you read on.

Cucumber Seeds

Even before we had started exploring structures and syntax for RSpec, Dan North had been exploring a completely different model for a BDD tool. He wanted to document and drive behaviour in a simplified language that could be easily understood by customers, developers, testers, business analysts, etc, etc. The early result of that exploration was the JBehave library, which is still in active use and development.

Dan ported JBehave to Ruby as RBehave, and we merged it into RSpec as the Story Runner. It only supported scenarios written in Ruby at first, but we later added support for plain text, opening up a whole new world of expressiveness and access. But as new possibilities were revealed, so were limitations.

In the spring of 2008, Aslak Hellesøy set out to rewrite RSpec's Story Runner with a real grammar defined with Nathan Sobo's Treetop library. Aslak dubbed it Cucumber at the suggestion of his fiancée, Patricia Carrier, thinking it would be a short-lived working title until it was merged back into RSpec. Little did either of them know that Cucumber would develop a life of its own.

1.5 The BDD Cycle

We use Cucumber to describe the behaviour of applications and RSpec to describe the behaviour of objects.[3] If you've ever done TDD before, you're probably familiar with the red/green/refactor cycle. With the addition of a higher level tool like Cucumber, we'll actually have two concentric red/green/refactor cycles, as depicted in Figure 1.1, on the next page.

Both cycles involve taking small steps and listening to the feedback you get from the tools. We start with a failing step (red) in Cucumber (the outer cycle). To get that step to pass, we'll drop down to RSpec (the inner cycle) and drive out the underlying code at a granular level (red/green/refactor).

At each green point in the RSpec cycle, we'll check the Cucumber cycle. If it is still red, the resulting feedback should guide us to the next action

3. Although we use Cucumber to focus on high level behaviour and RSpec on more granular behaviour, each can be used for either purpose.

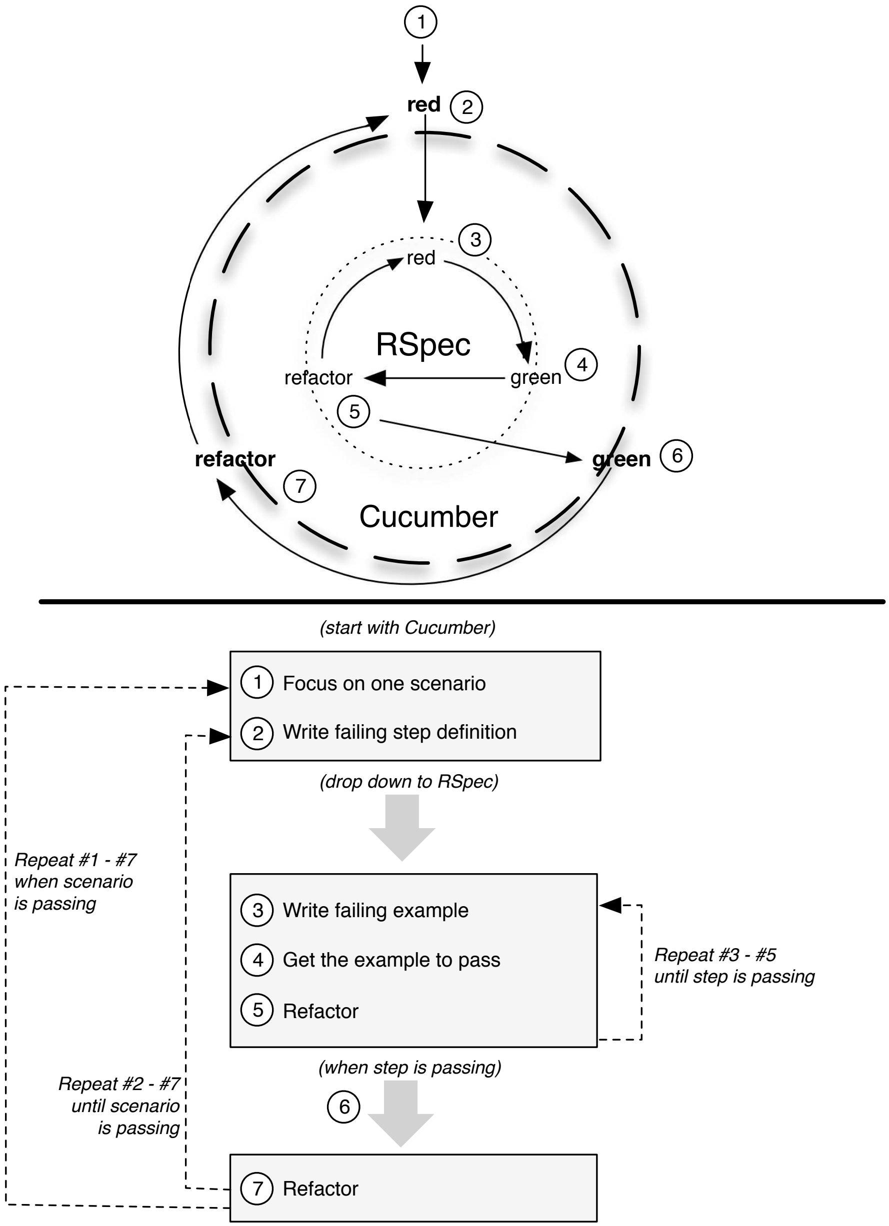

Figure 1.1: The BDD Cycle

in the RSpec cycle. If it is green, we can jump out to Cucumber, refactor if appropriate, and then repeat the cycle by writing a new failing Cucumber step.

This will all become clear as you read through these chapters.

In the tutorial that follows, we'll be using a number of features in Cucumber and RSpec. In most cases we'll only touch the surface of a feature, covering just enough to be able to use it as needed for this project, with references to other places in the book that you can go to learn more of the detail and philosophy behind each feature.

So now it's time to grab some coffee, clear your head, leave your preconceptions at the door and get ready to get your BDD on. See you in the next part of the book, in which we'll begin to drive out a brain teaser game that you can play at the command line.

Chapter 2
Hello

All good programming language books start with the obligatory *Hello World* example. While RSpec is not an all purpose programming language, it is sometimes described as a Domain Specific Language (DSL), for describing the behaviour of objects. Similarly, Cucumber is a DSL for describing the behaviour of applications.

To satisfy this requirement, we'll write *Hello* examples for both RSpec and Cucumber. But first things first, let's get the environment set up.

2.1 Installation

If you haven't done so already, the first thing you'll need to do is install the rspec and cucumber gems.[1] Open up a shell and type (you may need to prefix this with sudo on some systems):

```
gem install rspec
```

Now type spec --help, and you should see output that starts like this:

```
Usage: spec (FILE(:LINE)?|DIRECTORY|GLOB)+ [options]

    -p, --pattern [PATTERN]          Limit files loaded ...
```

If you don't see that, or something close, then the installation failed for any number of reasons. If that happened, we recommend you email the rspec-users mailing list and we'll try to help you sort it out.[2]

1. We assume that you already have a basic working knowledge of Ruby and Rubygems. If you don't, we can recommend *Programming Ruby: The Pragmatic Programmers' Guide* [TFH05] to learn about Ruby 1.8 and/or *Programming Ruby 1.9: The Pragmatic Programmers' Guide* [TFH08] if you want to learn about Ruby 1.9.
2. http://rubyforge.org/mailman/listinfo/rspec-users

Assuming all is well so far, the next thing to do is install cucumber by typing gem install cucumber. Again, you may need to prefix this command with sudo on some systems. Now type cucumber --help, and you should see output that starts something like this:

```
Usage: cucumber [options] [ [FILE|DIR|URL][:LINE[:LINE]*] ]+

Examples:
cucumber examples/i18n/en/features
```

In the unlikely event of a cucumber installation failure, please consult the cucumber google group for assistance.[3]

Now that the tools are installed, it's time to *say hello!*

2.2 Hello RSpec

Create a file named greeter_spec.rb anywhere on your system, open it up in your favorite text editor, and type the following code:

Download hello/1/spec/greeter_spec.rb

```
Line 1 describe "RSpec Greeter" do
2        it "should say 'Hello RSpec!' when it receives the greet() message" do
3          greeter = RSpecGreeter.new
4          greeting = greeter.greet
5          greeting.should == "Hello RSpec!"
6        end
7      end
```

We'll get into all the details of this later in the book, but briefly:

We start by declaring an *example group* using the describe() method on line 1. On line 2 we declare an *example* using the it() method.

Within the example, we initialize a new RSpecGreeter on line 3. This is the *given* in this example: the context that we set up and take for granted as a starting point.

On line 4, we assign the value returned by the greet() method to a greeting variable. This is the *when* in this example: the action that we're focused on.

Lastly, on line 5, we set an expectation that the value of greeting should equal "Hello RSpec!" This is the *then* of this example: the expected outcome.

3. http://groups.google.com/group/cukes

this copy is (B12.0 printing, December 3, 2009)

As you'll see throughout this book, we use these three simple words, *given, when, and then* because they are easily understood by both technical and non-technical contributors to a project.

Now save the file, open up a command shell, cd into the directory in which it is saved, and type this command:

```
spec greeter_spec.rb
```

You should see output something like this in the shell:

```
NameError in 'RSpec Greeter should say 'Hello RSpec!' ...
uninitialized constant RSpecGreeter
```

This is RSpec telling you that the example failed because there is no RSpecGreeter class defined yet. To keep things simple, lets just define it in the same file. Adding this definition, the entire file should look like this:

Download hello/2/spec/greeter_spec.rb

```
class RSpecGreeter
  def greet
    "Hello RSpec!"
  end
end

describe "RSpec Greeter" do
  it "should say 'Hello RSpec!' when it receives the greet() message" do
    greeter = RSpecGreeter.new
    greeting = greeter.greet
    greeting.should == "Hello RSpec!"
  end
end
```

Run the spec again by typing spec greeter_spec.rb, and the output should be something like this:

```
$ spec greeter_spec.rb
.

Finished in 0.00160 seconds

1 example, 0 failures
```

Success! The dot on the second line represents the one example that was run, and the summary on the last line verifies that there was one example, and zero failures.

This is a bit different from the *Hello World* examples we're used to seeing in programming language books because it doesn't actually print *Hello*

RSpec to the command line. In this case, the feedback we get tells us the example ran and code works as expected.

2.3 Hello Cucumber

For Cucumber, we're going to need a little bit more structure, so let's create a small project directory named hello. Inside the hello directory, add two directories named features and spec, and move the greeter_spec.rb file from the RSpec example into the hello/spec directory.

Now create a file in the features directory named greeter_says_hello.feature, and enter the following text:

Download hello/3/features/greeter_says_hello.feature

```
Feature: greeter says hello

  In order to start learning RSpec and Cucumber
  As a reader of The RSpec Book
  I want a greeter to say Hello

  Scenario: greeter says hello
    Given a greeter
    When I send it the greet message
    Then I should see "Hello Cucumber!"
```

In the shell, cd to the project root, the hello directory, and type cucumber features. You should see output like this:

```
Feature: greeter says hello

  In order to start learning RSpec and Cucumber
  As a reader of The RSpec Book
  I want a greeter to say Hello

  Scenario: greeter says hello          # features/greeter_says_hello.feature:7
    Given a greeter                     # features/greeter_says_hello.feature:8
    When I send it the greet message    # features/greeter_says_hello.feature:9
    Then I should see "Hello Cucumber!" # features/greeter_says_hello.feature:10

1 scenario (1 undefined)
3 steps (3 undefined)
0m0.001s

You can implement step definitions for undefined steps with these snippets:

Given /^a greeter$/ do
  pending
end
```

```
When /^I send it the greet message$/ do
  pending
end

Then /^I should see "([^\"]*)"$/ do |arg1|
  pending
end
```

We'll go into the details of this output later, but the high points are that we see the feature and scenario text from the greeter_says_hello.feature file, a summary of everything that was run, and then some code snippets that we can use for our *step definitions*.

A step definition is a method that creates a step. In this example, we use the Given(), When(), and Then() methods to write step definitions, each of which takes a Regexp and a block. Cucumber will read the first step in the scenario, *Given a greeter*, look for a step definition whose regular expression matches that step, and then execute that step definition's block.

To get this scenario to pass, we need to store step definitions in a file that cucumber can load. Go ahead and add a step_definitions directory inside hello/features, and add a file named greeter_steps.rb with the following code:

Download hello/4/features/step_definitions/greeter_steps.rb

```
Given /^a greeter$/ do
  @greeter = CucumberGreeter.new
end

When /^I send it the greet message$/ do
  @message = @greeter.greet
end

Then /^I should see "([^\"]*)"$/ do |greeting|
  @message.should == greeting
end
```

This looks a lot like the code snippets that we got from running the cucumber command, but we've added some code in each step definition. Now run cucumber features again and the output should look more like this this time:

```
Feature: greeter says hello

  In order to start learning RSpec and Cucumber
  As a reader of The RSpec Book
  I want a greeter to say Hello
```

```
  Scenario: greeter says hello
                                # features/greeter_says_hello.feature:7
    Given a greeter
                                # features/step_definitions/greeter_steps.rb:1
      uninitialized constant CucumberGreeter (NameError)
      ./features/step_definitions/greeter_steps.rb:2:in `/^a greeter$/'
      features/greeter_says_hello.feature:8:in `Given a greeter'
    When I send it the greet message
                                # features/step_definitions/greeter_steps.rb:5
    Then I should see "Hello Cucumber!"
                                # features/step_definitions/greeter_steps.rb:9

1 scenario (1 failed)
3 steps (1 failed, 2 skipped)
0m0.002s
```

The first step is failing because we haven't defined a CucumberGreeter. The next two steps are being skipped because the first one failed. Again, to keep things simple, go ahead and define the missing class right alongside the step definitions in greeter_steps.rb. Here is the full listing:

Download hello/5/features/step_definitions/greeter_steps.rb

```
class CucumberGreeter
  def greet
    "Hello Cucumber!"
  end
end

Given /^a greeter$/ do
  @greeter = CucumberGreeter.new
end

When /^I send it the greet message$/ do
  @message = @greeter.greet
end

Then /^I should see "([^\"]*)"$/ do |greeting|
  @message.should == greeting
end
```

Now we should get different output from cucumber features:

```
Feature: greeter says hello

  In order to start learning RSpec and Cucumber
  As a reader of The RSpec Book
  I want a greeter to say Hello

  Scenario: greeter says hello
                                # features/greeter_says_hello.feature:7
```

```
    Given a greeter
                          # features/step_definitions/greeter_steps.rb:7
    When I send it the greet message
                          # features/step_definitions/greeter_steps.rb:11
    Then I should see "Hello Cucumber!"
                          # features/step_definitions/greeter_steps.rb:15

1 scenario (1 passed)
3 steps (3 passed)
0m0.002s
```

This time the scenario and all of its steps pass. So now we've got a passing RSpec example and a passing Cucumber scenario. You can type spec spec and the spec command will run everything inside the spec directory. If you moved greeter_spec.rb to the spec directory, then you should see output similar to the output you saw at the end of Section 2.2, *Hello RSpec*, on page 27.

There is certainly a lot of detail yet to cover here, but that's why this is a book and not a blog post! In the chapters that follow you'll learn all about RSpec and Cucumber and how to use them in the context of Behaviour Driven Development. So what are you waiting for? All the good stuff is yet to come. Turn the page already!

Chapter 3

Describing Features with Cucumber

To get started doing BDD with RSpec and Cucumber, we're going to write a problem solving game that we'll call Codebreaker. Our version will be played in a shell, but it is based on the classic board game, Mastermind.

If you've never played it before, just google "mastermind online" and click through to any of the over two million hits, at least a few of which will lead you to in-browser versions of the game that you can play and learn from in just a few minutes.

We picked a game because we thought it would be more fun than a banking or social networking application. We also wanted something that was small enough to accomplish in a few short chapters, but complex enough to provide some interesting edge cases. By the time we get through this tutorial, we'll have planned a small release, planned and executed an iteration, developed some code from the outside-in, and have a game we can play at the command line.

We'll develop the game using the process and practices of Behaviour Driven Development that we introduced in Chapter 1, *Introduction*, on page 18, and you'll read more about throughout this book. We're going to drive straight on through, stopping only occasionally to review things and answer questions at the end of each chapter. When you're looking for more detail, we'll tell you where you can find it, but we won't get hung up in too much detail during this part of the book so that we can experience the feel of BDD in the trenches.

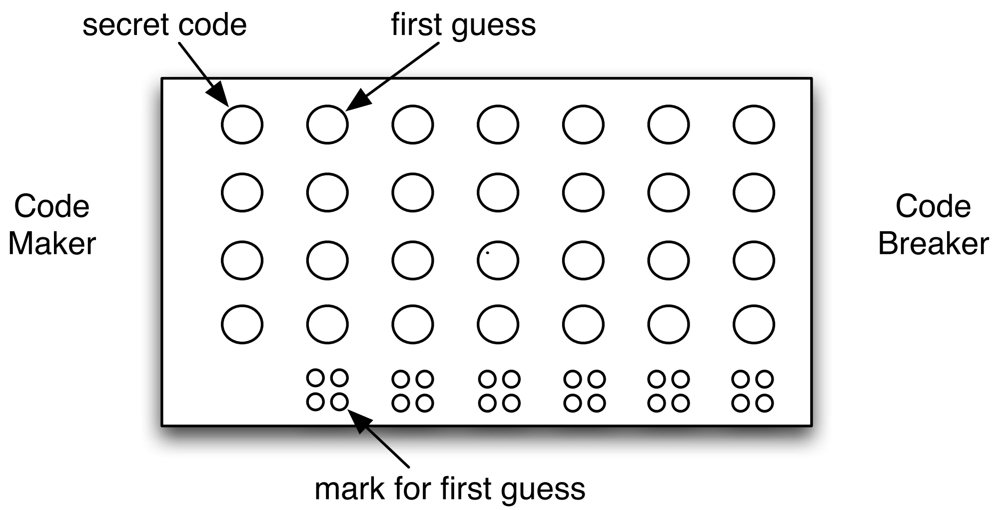

Figure 3.1: Codebreaker

But before we develop anything, let's start with an overview of the game and its rules.

3.1 Introducing Codebreaker

Codebreaker is a logic game in which a *code-breaker* tries to break a secret code created by a *code-maker*. The game is typically played on a board that looks like the one depicted in Figure 3.1. The code-maker, which will be played by the application we're going to write, creates a secret code of four colored pegs, placing them in the row on the left. The pegs come in six different colors: b=Black, c=Cyan, g=Green, r=Red, y=Yellow, w=White.

The code-maker covers the secret code from view of the code-breaker, who then gets some number of chances to break the code. In each turn, the code-breaker makes a guess by placing 4 of the colored pegs in the left-most empty row. The code-maker then *marks* the guess using smaller black and white *marker* pegs.

A black marker indicates that one of the pegs in the guess is the same color as one of the pegs in the code, and that it is in the exact same position. So if the guess has a green peg in the second position and the secret code also has a green peg in the second position, then the mark would include a black marker peg for the peg in the second position in the guess.

A white marker indicates that one of the pegs in the guess is the same color as one of the pegs in the code, but that it is in a different position. So if the guess has a green peg in the second position and the secret code has a green peg in the *third* position, then the mark would include a white marker peg for the second peg in the guess.

The marker pegs are in no particular order, so we don't know which pegs in the guess each refers to. If, for example, the mark is two black marker pegs and one white, then we know that the guess has three pegs that are part of the code, two of them are in the right positions, and one is in the wrong position. What we don't know is which three are in the guess, which two are in the right position, nor which one is in the wrong position.

3.2 Planning the First Release

As you'll read about in Chapter 11, *Writing software that matters*, on page 169, one of the three principles of BDD is *Enough is Enough*. We want to avoid the pitfalls of the Big Design Up Front,[1] but we also want to do enough planning to know we're heading in the right direction. We'll do some of that planning in this chapter, picking out *user stories* for our first iteration.

For the first release, we simply want to be able to play the game. We should be able to type a command in a shell to start it up, submit guesses, and see the mark for each of our guesses until we crack the code. Now that may sound like an over-simplification, and it certainly leaves open more questions than it answers, but it gives us a target on which to set our sights. And with that target in mind, we can start assembling a list of user stories that will get us there.

1. BDUF means designing an application in significant detail before writing the first line of code.

Focus on the Role

Mike Cohn, author of *User Stories Applied* (Coh04), talked about focusing on the role when writing user stories at the Agile 2006 Conference. The example he gave was that of an airline reservation system, pointing out that the regular business traveler booking a flight wants very different things from such a system than the occasional vacation traveler.

Think about that for a minute. Imagine yourself in these two different roles and the different sorts of details you would want from such a system based on your goals. For starters, the business traveler might want to maintain a profile of regular itineraries, while the vacationer might be more interested in finding package deals that include hotel and car at a discount.

Focusing on this distinction is a very powerful tool in getting down to the details of the features required of a system.

Selecting Stories

A great way to get started gathering user stories is to just do a high level brain dump of the sorts of things we might like to do. Here are some titles to get started.

- Code-breaker starts game
- Code-breaker submits guess
- Code-breaker wins game
- Code-breaker loses game
- Code-breaker plays again
- Code-breaker requests hint
- Code-breaker saves score

See how each of these is phrased as *role* + *action*? In this case the role is the *code-breaker* role each time because this game has only one kind of user. In other applications, we might have several different kinds of users, in which case we want to express stories in terms of a specific role (not just a generic *user*) because that impacts how we think about each requirement and why we're implementing code to satisfy it. See the sidebar on this page for more on this.

These are also very high level, and don't really tell us much about how the system should respond to these actions. Let's take these titles and generate some user stories from them.

A token for a conversation

We'll use the simple format described in *Extreme Programming Installed* [JAH02]. The idea is that there should be just enough information to serve as a *token for a conversation* that should take place as we get closer to implementation.[2]

Code-breaker starts game The code breaker opens up a shell, types a command, and sees a welcome message and a prompt to enter the first guess.

Code-breaker submits guess The code breaker enters a guess and the system replies by marking the guess according to the marking algorithm.

Code-breaker wins game The code breaker enters a guess that matches the secret code exactly. The system responds by marking the guess with four black marker pegs and a message congratulating the code breaker on breaking the guess in how ever many guesses it took.

We can already see some of the challenges ahead. "according to the marking algorithm" is going to require some conversation with the stakeholders. In fact, this is where we'll spend the majority of our time both planning and developing, as the marking algorithm is where much of the complexity lies.

Continuing with stories for the other titles:

Code-breaker loses game After some number of turns, the game tells the code-breaker that the game is over (need to decide how many turns and whether or not to reveal the code).

Code-breaker plays again After the game is won or lost, the system prompts the code-breaker to play again. If the code-breaker indicates yes, a new game begins. If the code-breaker indicates no, the system shuts down.

2. In Extreme Programming, index cards are the preferred medium for user stories. This keeps them lightweight and reinforces the idea that these are not formal documentation. There is an XP joke that if you can't fit a requirement on an index card, you should get a smaller card.

Code-breaker requests hint At any time during a game, the code-breaker can request a hint, at which point the system reveals one of the pegs in the secret code.

Code-breaker saves score After the game is won or lost, the code-breaker can opt to save information about the game: who (initials?), how many turns, etc.

Note the deliberate lack of detail and even some open questions. We'll get into some detail as we choose which of these stories we want to include in the release, and then more detail in each iteration within the release. But at each phase we want to do just enough planning to keep on moving, and no more.

Narrowing things down

Now that we have some stories,[3] let's consider them in the context of the stated goal for the initial release: to simply be able to play the game. Looking at the original list of stories, there are only two that are absolutely necessary to meet that goal:

- Code-breaker starts game
- Code-breaker submits guess

We definitely have to be able to start the game somehow, so that one is a no-brainer. Once we've started the game, if we can submit a guess and get the mark (four black marker pegs), then we can submit more guesses. As soon as we get a perfect mark, the game is won, we hit CTRL-C to stop the game, and start the game back up to play again. What do you think?

Maybe it would be a bit more satisfying to play if the game told us when we won. A bit of positive feedback to motivate us to play again. That sounds like it's pretty important, so let's add the Code-breaker wins game story to our release plan.

Of course, having to hit CTRL-C and then restart the game to play again is a little cheesy, don't you think? That just won't do, so let's also add the Code-breaker plays again story as well. So now our release plan includes these four stories:

- Code-breaker starts game

3. If we were developing this for commercial distribution, we'd likely have dozens more stories, even for such a simple game.

- Code-breaker submits guess
- Code-breaker wins game
- Code-breaker plays again

Hmmm. Seeing those together brings up the question of what will happen if the code-breaker doesn't win after some number of guesses. How else will we know when to prompt the code-breaker to play again? So maybe we should add the Code-breaker loses game story. What do you think?

Wait, wait, wait! We're heading down a slippery slope here. Pretty soon we'll be including our entire backlog of stories in the first release! So let's step back for a second. What is the release goal? To be able to play the game. Let's examine that a bit. Why does playing the game matter? Why do we want to be able to play the game?

Context matters

Perhaps our plan is to sell the game to millions of people and retire young. More likely, it's for a class project for school. OK, which class? If it's a usability class, then hitting CTRL-C just won't fly. But if it's an algorithms class, then the most important thing is that the marking algorithm works correctly.

The point is that our goal is to write software that matters, and what matters depends entirely on context, and is the purview of the stakeholders! In our case, the primary stakeholder is *you*! You're reading this book and trying to learn something about RSpec and Cucumber and the process of BDD. You're also a programmer, so it's quite likely that you are perfectly capable of hitting CTRL-C.

On the flip side, we'll want more than one iteration to get the proper feel of a release cycle,[4] and we'll want more than one story for each iteration as well. So in the interest of learning, let's go with Code-breaker starts game, Code-breaker submits guess for Iteration 1, and Code-breaker wins game and one more story for Iteration 2. But which one should we pick?

The hidden story

Well, there *is* one feature of the game that we haven't discussed yet. We don't really see the evidence of it until we submit a guess and the game

4. iteration != release

marks it. Can you see what it is? Think about how the game will be able to mark the guess. It has to mark it against *something*, right?

The secret code! The game will need to generate a secret code that is different every time in order for it to be truly enjoyable. Now is this a user story? This is one of those gray areas that challenge the boundaries of what a user story is. Ask one experienced XP'er and you'll hear that this is really part of the Code-breaker starts game story based on the idea that the secret code should be generated when the game starts up.

The next person might argue that it's really part of the code-breaker submits guess story because that's the first time the user gets any feedback from the system that depends on the guess.

User stories are a planning tool

We're going to take a third stance and make it a separate story based on practicality. We're going to have a lot to cover in these chapters, and we want to keep things small enough to accomplish in a reasonable time so we can check things off the list as we go. Does that sound selfish? Does that sound like we're putting the developer's needs ahead of those of the stakeholder?

Absolutely not! We're just planning! And user stories are, above all else, a planning tool. While you can find many definitions of what a user story *is*, and therefore *must be* in order to earn the title, here is a simple set of criteria I learned from Bob Koss at Object Mentor. A user story must:

have business value Clearly the game is no fun unless it generates a different secret code each time.

be testable That's easy. We just start up a bunch of games and ask for the code. As you'll see when we develop this part, this reveals some interesting questions about designing for testability.

be small enough to implement in one iteration This is the motivation for separating this story out. It's a guideline that allows us to balance implementation concerns with requirements.

So now we have our release plan with four stories. Time to start breaking it down into iterations.

3.3 Planning the First Iteration

Acceptance Test Driven Planning is one of the three practices of BDD.[5] It is an extension of Acceptance Test Driven *Development*, which involves collaborating with stakeholders on acceptance tests before we write any code.[6]

The difference between the two is simple. ATDD specifies that we write acceptance tests before we write code, but it doesn't otherwise specify when in the process we should write them.

ATDP specifies that the acceptance tests are agreed on *during* or possibly *before*, but no later than, an iteration planning meeting. This lets us consider the acceptance criteria in our estimates, which improves our ability to plan iterations, hence the the name Acceptance Test Driven *Planning*.

Narrative

Cucumber lets us describe application features in a simple plain text format, and then use those descriptions to automate interaction with the application. We're going to use Cucumber to express application features in this chapter, and then automate them in the next.

Cucumber features have three parts: a title, a brief narrative, and an arbitrary number of scenarios which serve as acceptance criteria. Here's what the title and narrative for the "code-breaker starts game" feature might look like:

Download cb/01/features/codebreaker_starts_game.feature

```
Feature: code-breaker starts game

  As a code-breaker
  I want to start a game
  So that I can break the code
```

The title is just enough to remind us who the feature is for, the code-breaker, and what the feature is about, starting a game. Although the narrative is free-form, we generally follow the Connextra format described in the (as yet) unwritten *chp.cucumber*, or variations of it that we'll discuss at different points in the book.

5. The other two are Domain Driven Design and Test Driven Development.
6. The term *acceptance test* means different things to different people. We'll discuss this in the context of BDD in the (as yet) unwritten *chp.cucumber*

With this narrative, we have some understanding of what we want to do with the system, but how will we know when we've started the game? How will we know when we've satisfied this requirement? How will we know when we're done?

Acceptance Criteria

To answer these questions, we'll add acceptance criteria to the feature. Imagine that you sit down to play codebreaker, you fire up a shell, and type the codebreaker command. How do you know it started? Perhaps it says something like "Welcome to Codebreaker!" And then, so you know what to do next, it probably says something like "Enter a guess:"

That will be the acceptance criteria for this feature. To express that with Cucumber, modify features/codebreaker_starts_game.feature so it reads like this:

Download cb/01/features/codebreaker_starts_game.feature

```
Feature: code-breaker starts game

  As a code-breaker
  I want to start a game
  So that I can break the code

  Scenario: start game
    Given I am not yet playing
    When I start a new game
    Then I should see "Welcome to Codebreaker!"
    And I should see "Enter guess:"
```

The Scenario: keyword is followed by a string and then a series of steps. Each step begins with any of five keywords: *Given*, *When*, *Then*, *And* and *But*.

Given steps represent the state of the world before an event. *When* steps represent the event. *Then* steps represent the expected outcomes.

And and *But* steps take on the quality of the previous step. In the start game scenario, the *And* step is a second *Then*; a second expected outcome. If we wanted to expect that the game says "Welcome to Codebreaker!", but not "What is your quest?", we would add a *But* step saying *But I should not see "What is your quest?"*, which would be treated as a *Then*.

See how the Given and When steps in this scenario both use the first person? We choose the first person form because it makes the narrative feel more compelling. Given x, when *I* y, then *I* should see a message saying "z." This helps to keep the focus on how *I* would use the system if *I* were in a given role (the code breaker).

"Given I am not yet playing" expresses the context in which the subsequent steps will be executed. "When I start a new game" is the event or action that occurs because *I* did something. The Thens are the expected outcomes—what we expect to happen as a result of the When.

Let's store this feature in a file. We'll go over the details of the project structure in Chapter 4, *Automating Features with Cucumber*, on page 50, but for now just create a codebreaker directory wherever you like to keep projects on your computer. This will be the root directory for the project, from which we'll type all of our shell commands as we progress.

Inside the codebreaker directory, add a sub-directory named features. Inside features, add a sub-directory named support and inside features/support add a file named env.rb. Even though we'll leave this empty for now, Cucumber needs this file (or any .rb file) in order to know that we're using Ruby.[7]

Now open up a shell and cd into the codebreaker project root directory and type cucumber. You'll see the same text that is in the file with some additional context information and metadata. We'll discuss what all that means in the next chapter when we begin to automate the scenarios.

Submitting a guess

The next feature we want to tackle in the first iteration is:

Download cb/scenarios/features/codebreaker_submits_guess.1.feature

```
Feature: code-breaker submits guess

  The code-breaker submits a guess of four colored
  pegs. The game marks the guess with black and
  white "marker" pegs.

  For each peg in the guess that matches the color
  and position of a peg in the secret code, the
  mark includes one black peg. For each additional
  peg in the guess that matches the color but not
  the position of a peg in the secret code, a
  white peg is added to the mark.
```

7. Cucumber supports several different programming languages.

this copy is (B12.0 printing, December 3, 2009)

This time we used a free form narrative instead of the Connextra format. This seems appropriate given that we're describing an algorithm, which is a bit more complex than a statement like "I should see a welcome message." Could we use the Connextra format? Let's give it a try and see.

Download cb/scenarios/features/codebreaker_submits_guess.2.feature

```
Feature: code-breaker submits guess

  As a code-breaker
  I want to submit a guess
  So that I can try to break the code
```

That doesn't tell us a whole lot, so let's add a scenario:

Download cb/scenarios/features/codebreaker_submits_guess.2.feature

```
Feature: code-breaker submits guess

  As a code-breaker
  I want to submit a guess
  So that I can try to break the code

  Scenario: all four correct colors in correct positions
    Given the secret code is r g y c
    When I guess r g y c
    Then the mark should be bbbb
```

Even when we add this narrative together with this scenario, we don't really supply enough context information to understand the meaning of the mark. Now look at the original narrative plus a single scenario:

Download cb/scenarios/features/codebreaker_submits_guess.1.feature

```
Feature: code-breaker submits guess

  The code-breaker submits a guess of four colored
  pegs. The game marks the guess with black and
  white "marker" pegs.

  For each peg in the guess that matches the color
  and position of a peg in the secret code, the
  mark includes one black peg. For each additional
  peg in the guess that matches the color but not
  the position of a peg in the secret code, a
  white peg is added to the mark.

  Scenario: all four correct colors in correct positions
    Given the secret code is r g y c
    When I guess r g y c
    Then the mark should be bbbb
```

Wow, what a difference that makes. Now we have an explanation of the mark, and an example of how it works in practice. Much more clear, no? So then why don't we add some prose narrative to the Code-breaker starts game feature as well? Well, we don't really need it. In that case, the scenario tells us everything we need to know in order to understand the context.

So which should we use? Connextra format? Free form prose? Some other format? The answer, of course, is: it depends, as we've just seen. In the end it's good to have a number of tools at our disposal, so we can pick the right one for each job. That's true of RSpec and Cucumber. That's also true of narrative formats.

Adding more scenarios

With an algorithm as complex as marking a guess, we're going to need more scenarios to demonstrate what the mark should be under different conditions. Let's add a second scenario, shown here without the narrative:

Download cb/scenarios/features/codebreaker_submits_guess.1.feature

```
Scenario: all four correct colors in correct positions
  Given the secret code is r g y c
  When I guess r g y c
  Then the mark should be bbbb

Scenario: all four correct colors, two in correct positions
  Given the secret code is r g y c
  When I guess r g c y
  Then the mark should be bbww
```

The addition of another scenario increases the expression and our understanding of the rules of the algorithm. Of course, we have a long way to go. Let's add more scenarios with all four colors correct:

Download cb/scenarios/features/codebreaker_submits_guess.1.feature

```
Scenario: all four correct colors in correct positions
  Given the secret code is r g y c
  When I guess r g y c
  Then the mark should be bbbb

Scenario: all four correct colors, two in correct positions
  Given the secret code is r g y c
  When I guess r g c y
  Then the mark should be bbww

Scenario: all four correct colors, one in the correct position
  Given the secret code is r g y c
```

```
  When I guess y r g c
  Then the mark should be bwww

Scenario: all four correct colors, none in correct positions
  Given the secret code is r g y c
  When I guess c r g y
  Then the mark should be wwww
```

If we hadn't seen it before, we can certainly see now that this is not going to scale very well. We've got four scenarios and it's already starting to become difficult to take them all in at a glance. Imagine what this would look like when we add scenarios for three colors correct, two, one, and then none? We'll likely end up with a couple of dozen scenarios, and it's going to be quite difficult to grok them all.

Fortunately, Cucumber offers a few different tools for DRY'ing things up without sacrificing expressiveness and localization.[8] You'll read about all of these tools in the (as yet) unwritten *chp.cucumber*, but the one we're interested in right now is the *Scenario Outline*.

Scenario Outlines

Cucumber lets us define a single *Scenario Outline* and then provide tables of input data and expected output. Here's the Scenario Outline for our submit guess scenarios:

```
Scenario Outline: submit guess
  Given the secret code is <code>
  When I guess <guess>
  Then the mark should be <mark>
```

This looks a lot like the scenario declarations we wrote for the *code-breaker submits guess* feature, with two subtle differences:

- Scenario Outline instead of Scenario
- Variable data placeholders in <angle brackets>

The words in angle brackets are placeholders for variable data that we'll provide in a tabular format, inspired by FIT (see the sidebar on the following page).

8. DRY stands for *Don't Repeat Yourself*. The DRY Principle, as described in *The Pragmatic Programmer* [HT00], states that every piece of knowledge in a system should have one authoritative, unambiguous representation.

FIT

Ward Cunningham's Framework for Integration Test, or FIT, parses display tables in rich documents written with Microsoft Word or HTML, sends the contents of table cells to the system in development, and compares the results from the system to expected values in the table.*

This allows teams who were already using tools like Word for requirements documentation to turn those documents into executable acceptance tests by specifying expected outputs resulting from prescribed inputs. This works especially well when the acceptance criteria are naturally expressed in a table.

Cucumber's Scenario Outlines and Scenario Tables provide a FIT-inspired tabular format for expressing repetitive scenarios like those in our "submit guess" feature, while maintaining the Given, When, and Then language of BDD.

*. See http://fit.c2.com/ for more information about FIT.

Tabular Data

Here is the first of several tables we'll add, supplying data for scenarios in which all four colors are correct:

```
Scenarios: all colors correct
  | code    | guess   | mark |
  | r g y c | r g y c | bbbb |
  | r g y c | r g c y | bbww |
  | r g y c | y r g c | bwww |
  | r g y c | c r g y | wwww |
```

The *Scenarios* keyword indicates that what follows are rows of example data. The first row contains column headers that align with the placeholders in the scenario outline. Each subsequent row represents a single scenario.

Following convention, we've named the columns using the same names that are in angle brackets in the scenario outline, but the placeholders and columns are bound by position, not name.

The <code> variable in the *Given* step is assigned the value r g y c, from the first column in the first data row (after the headers). It's just as though we wrote Given the secret code is r g y c.

The <guess> in the *When* step gets r g y c from the second column, and the <mark> in the *Then* step gets bbbb.

With the Scenario Outline and this first table, we've expressed four scenarios that would have taken sixteen lines in only ten. We've also reduced duplication and created very readable executable documentation in the process. Cucumber lets us supply as many groups of Scenarios as we want, supporting a very natural way to group like scenarios. Here's the whole feature with thirteen scenarios expressed in a mere twenty five lines (beginning with the Scenario Outline):

Download cb/23/features/codebreaker_submits_guess.feature

```
Feature: code-breaker submits guess

  The code-breaker submits a guess of four colored
  pegs. The game marks the guess with black and
  white "marker" pegs.

  For each peg in the guess that matches the color
  and position of a peg in the secret code, the
  mark includes one black peg. For each additional
  peg in the guess that matches the color but not
  the position of a peg in the secret code, a
  white peg is added to the mark.

  Scenario Outline: submit guess
    Given the secret code is <code>
    When I guess <guess>
    Then the mark should be <mark>

  Scenarios: all colors correct
    | code    | guess   | mark |
    | r g y c | r g y c | bbbb |
    | r g y c | r g c y | bbww |
    | r g y c | y r g c | bwww |
    | r g y c | c r g y | wwww |

  Scenarios: 3 colors correct
    | code    | guess   | mark |
    | r g y c | w g y c | bbb  |
    | r g y c | w r y c | bbw  |
    | r g y c | w r g c | bww  |
    | r g y c | w r g y | www  |

  Scenarios: 2 colors correct
    | code    | guess   | mark |
    | r g y c | w g w c | bb   |
    | r g y c | w r w c | bw   |
    | r g y c | g w c w | ww   |
```

```
Scenarios: 1 color correct
  | code    | guess   | mark |
  | r g y c | r w w w | b    |
  | r g y c | w w r w | w    |
```

See how easy that is to read and understand? Even a non-technical team member can read this and figure out what's going on. And therein lies the power of Cucumber. It lets us express requirements in language that the whole team can understand, so we can all speak the same language. When we talk about mark, it means the same thing to the CEO as it does to the developer. Same goes for the secret code and a guess.

We now have the acceptance criteria for the two stories we want to include in our first iteration, so the planning meeting has come to a close. In the next chapter, we'll use these same plain text features to begin to drive out the code for our game, but first let's quickly recap what we've done.

3.4 What we just did

In this chapter we introduced the project that we'll spend the remaining chapters in Part I working on. We planned a release and the first iteration. In the process, we learned about:

Selecting stories for a release. We did this by narrowing down the stories to those that really matter in the context of the release goals.

Selecting stories for an iteration. We picked out two stories that would result in enough working software that we will actually be able to interact with it in a meaningful way.

Acceptance Criteria. We wrote Cucumber features and scenarios for each story. We do this during the Iteration Planning Meeting (known as Acceptance Test Driven Planning) so that we can use what we learn from writing the scenarios to affirm or modify existing estimates.

Scenario Outlines. One of many tools that Cucumber offers to keep features and scenarios DRY and expressive.

Chapter 4

Automating Features with Cucumber

In the last chapter we selected the stories for the first iteration, and wrote them out as features and scenarios in plain text using Cucumber. Now it's time to put those scenarios to work to guide us as we develop code.

At this point, the feature files should be in the features/ directory, each with the .feature file extension. Cucumber recognizes this extension and treats these files as input.

We should also have an env.rb file in features/support directory. The .rb extension tells Cucumber that we're using Ruby.

If you didn't try to run the features in the last chapter, try it now. Just type cucumber in the codebreaker directory and you should see output that looks just like the text in the .feature files, plus some additional information that we'll talk about as we progress.

4.1 Project Structure

We're going to use a directory structure for this project that has become fairly conventional for non-Rails Ruby projects, as shown in Figure 4.1, on the next page. The gray boxes represent directories and the white boxes represent files within those directories. The codebreaker directory is the project root, and contains four sub-directories:

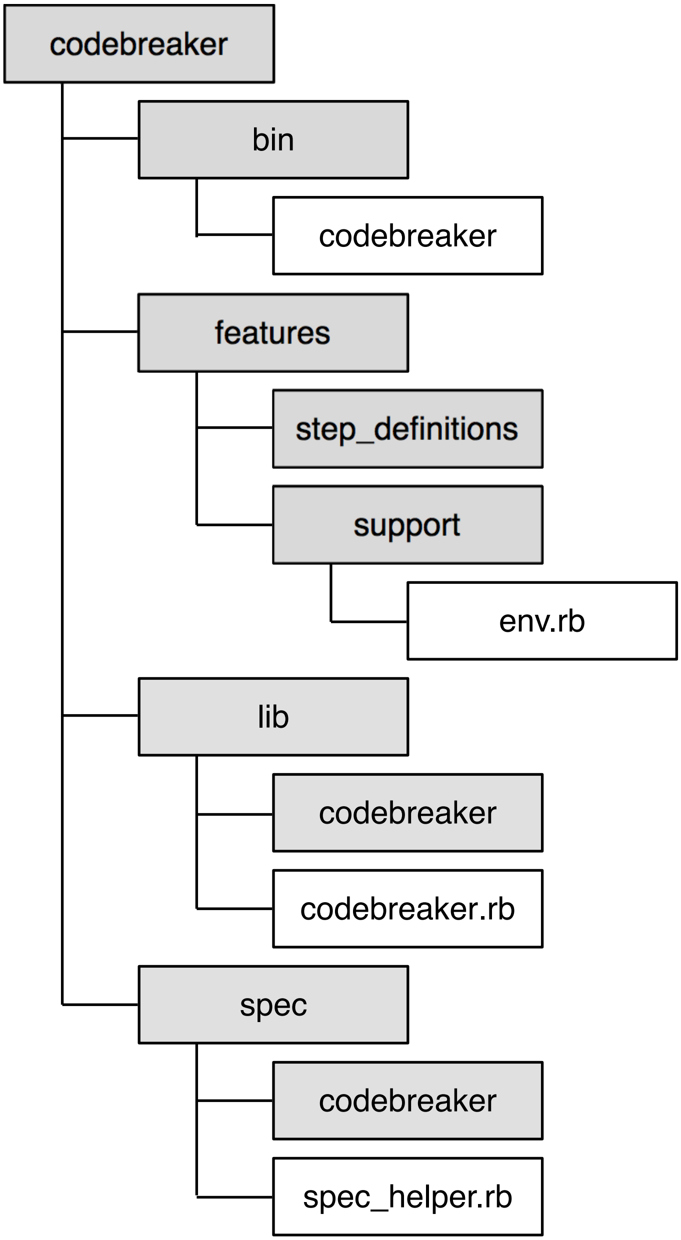

Figure 4.1: Project Structure

bin contains any executable scripts and/or binary files. We'll use it to hold the codebreaker script that will be our entry point to the game.

features contains files related to documenting and automating Cucumber features.[1] This is where we already put our plain text feature files.

The features/step_definitions directory will hold the step definition files. Step definitions are written in Ruby (.rb) files, and are the glue that ties plain text scenarios in the feature files to the application code.

The features/support directory holds env.rb, which is loaded implicitly by Cucumber and is responsible for loading the application code.

lib contains the application code. lib/codebreaker.rb will be responsible for requiring the source files in the lib/codebreaker directory.

spec contains files related to documenting and automating RSpec code examples. spec/spec_helper.rb is required by all of the spec files we'll add later, and is responsible for loading all the application code.

As we develop the game, we'll build a parallel structure below lib/codebreaker and spec/codebreaker. For example, in Chapter 5, *Describing Code with RSpec*, on page 61 we'll describe the behaviour of a Game object in spec/codebreaker/game_spec.rb and we'll put its class definition in lib/codebreaker/game.rb.

4.2 Steps and Step Definitions

When you ran the cucumber command a minute ago, you should have seen a bunch of code snippets at the end of the output that look something like this:[2]

```
Given /I am not yet playing/ do
  pending
```

1. As we'll review later in the (as yet) unwritten *chp.cucumber*, there can also be a cucumber.yml configuration file in the project root directory.
2. If you don't see the step definition snippets, it's likely because cucumber doesn't know what programming language you're using. It determines the language based on the types of files in features/step_definitions or features/support. That's why we added the env.rb file to features/support. If you haven't added it already, do it now so you can see the step definition snippets.

Downloadable Files

The codebreaker source files you download from http://pragprog.com/titles/achbd/source_code are stored in a series of numbered directories like code/cb/01. Each numbered directory represents a snapshot of the development process, which allows you to watch the evolution of the project, rather than just see its ultimate output.

The numbered directories each stand in for the project root. For example, code/cb/01/features and code/cb/02/features each represent the same features directory in the root codebreaker directory on your system.

```
end
```

This is a Cucumber *step definition*. If you think of the steps in scenarios as method calls, then step definitions are like method definitions. Go ahead and create a codebreaker_steps.rb file in features/step_definitions/ and add that snippet to it, removing the pending call from the block, like this:

Download cb/015/features/step_definitions/codebreaker_steps.rb

```
Given /^I am not yet playing$/ do
end
```

Now run cucumber features/codebreaker_starts_game.feature -s from the project root, and you'll see the following output:

```
Feature: code-breaker starts game

  As a code-breaker
  I want to start a game
  So that I can break the code

  Scenario: start game
    Given I am not yet playing
    When I start a new game
    Then I should see "Welcome to Codebreaker!"
    And I should see "Enter guess:"

1 scenario (1 undefined)
4 steps (3 undefined, 1 passed)
0m0.001s

You can implement step definitions for undefined steps with these snippets:
```

```
When /^I start a new game$/ do
  pending
end

Then /^I should see "([^\"]*)"$/ do |arg1|
  pending
end
```

The output starts with the content of the file, followed by a summary that tells us that we have 1 scenario with 4 steps, including 1 passing step and 3 undefined steps, and then code snippets for the remaining undefined steps. So what just happened?

The first argument to the cucumber command was the features/codebreaker_starts_game.feature file. When Cucumber starts up it loads up all of the Ruby files in the same directory as the file and any of its subdirectories. This includes features/step_definitions/codebreaker_steps.rb, where we copied the step definition above.

We can define steps by calling any of the following methods provided by Cucumber: Given(), When(), Then(), And(), or But(). The last two, And() and But() take on the meaning of the previous Given(), When() or Then(), so in this example the And() on the last line of the scenario is treated as a Then().

In this case, we called the Given() method and passed it a Regexp and a block. Cucumber then stores the block in a hash-like structure with the Regexp as its key.

After loading the Ruby files, Cucumber then loads and starts parsing all the .feature files, matching all of the steps in scenarios against the stored step definitions. It does this by searching for a Regexp that matches the step, and then executes the block stored with that Regexp as its key.

In our case, when Cucumber sees the *Given I am not yet playing* step in the scenario, it strips off the *Given* and looks for a Regexp that matches the string I am not yet playing. At this point we only have one step definition, and its Regexp is /^I am not yet playing$/, so Cucumber executes the associated block from the step definition.

Of course, since there is nothing in the block yet, there is nothing that can go wrong, so the step is considered passing. As it turns out, that's exactly what we want in this case. We don't actually want *Given I am not yet playing* to do anything. We just want it in the scenario to provide context for the subsequent steps, but we're going to leave the associated block empty.

The *When* is where the action is. We need to create a new game and then start it. Here's what that might look like:

Download cb/02/features/step_definitions/codebreaker_steps.rb

```
When /^I start a new game$/ do
  Codebreaker::Game.new.start
end
```

At this point we don't have any application code, so we're just writing *the code we wish we had*. We want to keep it simple, and this is about as simple as it can get.

Now let's move on to the *Thens*.

Download cb/03/features/step_definitions/codebreaker_steps.rb

```
Then /^I should see "([^\"]*)"$/ do |message|
end
```

This step definition will handle both the Then and And steps in the scenario, passing whatever is captured to the block as the message parameter.

As for what to write in the block, we need to have some way of knowing what message was returned when we sent start() to the Game object so we can specify that it matches the value of the block argument. Here's one way to handle this:

Download cb/04/features/step_definitions/codebreaker_steps.rb

```
When /^I start a new game$/ do
  game = Codebreaker::Game.new
  @message = game.start
end

Then /^I should see "([^\"]*)"$/ do |message|
  @message.should == message
end
```

Here we store the return value of game.start in a variable named @message in the *When* step definition. The code in the *Then* step borrows from RSpec to set an expectation about the value of the @message variable. You'll read all about RSpec's expectations in Chapter 13, *Spec::Expectations*, on page 202, and learn how to make them available to Cucumber step definitions later in the chapter.

The Code You Wish You Had

In my early days at Object Mentor I attended a TDD class being taught by James Grenning. As he was talking about refactoring a Long Method, he wrote a statement that called a method that didn't exist yet, saying something like "start by writing the code you wish you had."

This was a galvanizing moment for me.

It is common to write the code we wish we had doing TDD. Perhaps we send a message from the code example to an object that does not have a corresponding method. We let the Ruby interpreter tell us that the method does not exist (red), and then implement that method (green).

Doing the same thing within application code, calling the code we wish we had in one module from another module, was a different matter. It was as though an arbitrary boundary was somehow lifted and suddenly all of the code was my personal servant, ready and willing to bend to my will. It didn't matter whether we were starting in a test, or in the code being tested. What mattered was that we started from the view of the code that was going to use the new code we were about to write.

Over the years this has permeated my daily practice. It is very, very liberating, and results consistently in more usable APIs than I would have come up with starting with the object receiving the message.

In retrospect, this also aligns closely with the Outside-In philosophy of BDD, perhaps taking it a step further. If the goal is to provide great APIs then the best place to design them is from their consumers.

In this case, we expect that @message should equal (using Ruby's ==() method) the message from the step in the scenario. This is RSpec's way of setting expectations about equality.

But there's a problem with this setup. Can you see what it is? Take a look at the story we're working on again. How many times do we invoke *Then I should see: ....*? Twice in this scenario! Once using *Then* and once using *And*. We are expecting two different messages to appear when we start the game. Time to make a design decision.

We need another approach. We could have the start() method return an array of messages and expect the array to contain the message we're interested in. That might look like this:

Download cb/05/features/step_definitions/codebreaker_steps.rb

```
When /^I start a new game$/ do
  game = Codebreaker::Game.new
  @messages = game.start
end

Then /^I should see "([^\"]*)"$/ do |message|
  @messages.should include(message)
end
```

That could work, but let's take a step back for a second. How are we going to invoke this when we're actually running the app? What's the outermost layer of our system going to be? It's going to be a Ruby script. And we're going to want to keep that as lightweight as possible. Here's what it might have to look like if we went with this approach:

Download cb/05/bin/codebreaker

```
#!/usr/bin/env ruby
$LOAD_PATH.push File.join(File.dirname(__FILE__),"..","lib")
require 'codebreaker'

game = Codebreaker::Game.new
messages = game.start
messages.each { puts message }
```

If we return an array of messages, then the script needs to take on some of the responsiblity of what to display, and when to display it. Among other problems, this is a violation of the Single Responsibility Principle as described by Robert C. Martin in *Agile Software Development: Principles, Patterns and Practices* [Mar02].

One solution to the SRP violation would be to have the script pass STDOUT to Game.new and have the game post messages directly to it.

The game wouldn't need to know it was STDOUT. It would just need to know it was something it could send messages to. If we do that, the codebreaker script looks like this instead:

Download cb/06/bin/codebreaker

```
#!/usr/bin/env ruby
$LOAD_PATH.push File.join(File.dirname(__FILE__),"..","lib")
require 'codebreaker'

game = Codebreaker::Game.new(STDOUT)
game.start
```

Much better! Let's use this version. It's simple, clean, and pushes the responsibility down into the application code where it's easier to manage.

If you're a *nix user, copy that into bin/codebreaker, and chmod 755 bin/codebreaker so you'll be able to execute it later. Windows users should copy all but the very first line into bin/codebreaker, and also add bin/codebreaker.bat with the following:

Download cb/06/bin/codebreaker.bat

```
@"ruby.exe" "%~dpn0" %*
```

The next question is how to express this design decision in the step definition. We don't want to use STDOUT because Cucumber is using STDOUT to report results when we run the scenarios. We *do* want something that shares an interface with STDOUT so that the Game object won't know the difference.

This is one of those occasions in which Ruby provides a solution that is so simple, it's difficult to stop yourself from chuckling. STDOUT is an instance of IO. The StringIO object is very much like an IO object. We can use one of those, have it store the messages and set our expectations on it like so:

Download cb/06/features/step_definitions/codebreaker_steps.rb

```
When /^I start a new game$/ do
  @messenger = StringIO.new
  game = Codebreaker::Game.new(@messenger)
  game.start
end

Then /^I should see "([^\"]*)"$/ do |message|
  @messenger.string.split("\n").should include(message)
end
```

That's a tiny bit more complex, but it's still straightforward.

Now that we've implemented the code in the step definitions, let's run the *code-breaker starts game* feature and see what we've got. Go back to the command shell and run cucumber -s again and you should see output like this:

```
Feature: code-breaker starts game

  As a code-breaker
  I want to start a game
  So that I can break the code

  Scenario: start game
    Given I am not yet playing
    When I start a new game
      uninitialized constant Codebreaker (NameError)
      ./06/features/step_definitions/codebreaker_steps.rb:7:in
                                     `/^I start a new game$/'
      06/features/codebreaker_starts_game.feature:12:in
                                     `When I start a new game'
    Then I should see "Welcome to Codebreaker!"
    And I should see "Enter guess:"

1 scenario (1 failed)
4 steps (1 failed, 2 skipped, 1 passed)
0m0.001s
```

There is no application code yet, so we're getting a NameError on Codebreaker. Take a look at the backtrace.

The first line of the backtrace is from features/step_definitions/codebreaker_steps.rb, the file with the step definitions in it. It's a Ruby file, and we'd expect that to show up. But check out the second line. It's from features/codebreaker_starts_game.feature, a file written in plain text.[3]

We also see that one step passed (the Given), one failed (the When), and two are skipped (the Thens). When a step fails, all of the subsequent steps are skipped because whether they pass or fail is not necessarily meaningful, as the state is not what you expect it to be.

This is useful feedback, but we can get even more by running the feature without the -s flag; just run cucumber.[4] You should see output like this:

```
Feature: code-breaker starts game
```

3. Cucumber appends the file and line of the failing step to the exception's backtrace before it's printed.
4. Run cucumber --help to see a full listing of Cucumber's command line options

```
  As a code-breaker
  I want to start a game
  So that I can break the code

  Scenario: start game
                      # 06/features/codebreaker_starts_game.feature:10
    Given I am not yet playing
                      # 06/features/step_definitions/codebreaker_steps.rb:1
    When I start a new game
                      # 06/features/step_definitions/codebreaker_steps.rb:5
      uninitialized constant Codebreaker (NameError)
      ./06/features/step_definitions/codebreaker_steps.rb:7:in
                      `/^I start a new game$/'
      06/features/codebreaker_starts_game.feature:12:in
                      `When I start a new game'
    Then I should see "Welcome to Codebreaker!"
                      # 06/features/step_definitions/codebreaker_steps.rb:11
    And I should see "Enter guess:"
                      # 06/features/step_definitions/codebreaker_steps.rb:11

1 scenario (1 failed)
4 steps (1 failed, 2 skipped, 1 passed)
0m0.001s
```

Now we see file names and line numbers for the scenario (from the feature file), and each step (from the step definition file). This makes it quite easy to see where to go when things go wrong, and provides context for the steps we'll take at the beginning of the next chapter.

4.3 What We Just Did

At this point we've made our way through the second step in the concentric cycles described in Section 1.5, *The BDD Cycle*, on page 23: we now have a failing cucumber step. And we've also laid quite a bit of foundation.

We've set up the development environment for the Codebreaker game, with the standard directories for Cucumber and RSpec. We expressed the first feature from the outside using Cucumber, with automatable acceptance criteria using the simple language of Given/When/Then.

So far we've been describing things from the outside with Cucumber. In the next chapter we'll begin to work our way from the Outside-In, using RSpec to drive out behaviour of individual objects.

Chapter 5

Describing Code with RSpec

In the last chapter, we introduced and used Cucumber to describe the behaviour of our Codebreaker game from the outside, at the application level. We wrote a Cucumber feature with a scenario and step definitions that will handle the steps in the scenario, but we're getting an error. The code in a step definition is trying to interact with a Codebreaker::Game object, but there is no application code to support this yet.

In this chapter we're going to use RSpec to *describe* behaviour at a much more granular level: the expected behaviour of instances of the Game class.

5.1 Getting started with RSpec

To get going, create a file named game_spec.rb in spec/codebreaker/ and add the following code:

Download cb/06/spec/codebreaker/game_spec.rb

```
module Codebreaker
  describe Game do
  end
end
```

The describe() method hooks into RSpec's API, and it returns a Spec::ExampleGroup, which is, as it suggests, a group of examples—examples of the expected behaviour of an object. If you're accustomed to xUnit tools like Test::Unit, you can think of an ExampleGroup as being akin to a TestCase.

Open up a shell and cd to the codebreaker project root directory and run the game_spec.rb file with the spec command, [1] like this:

```
spec spec/codebreaker/game_spec.rb
```

The resulting output should include "uninitialized constant Codebreaker::Game (NameError)" To fix that we need to do a few things.

Connect the specs to the code

First, add a file named game.rb with the following code in the lib/codebreaker directory:

Download cb/07/lib/codebreaker/game.rb

```
module Codebreaker
  class Game
  end
end
```

As we progress, we'll maintain a parallel structure like this in which each source file (e.g. lib/codebreaker/game.rb) has a parallel spec file (e.g. spec/codebreaker/game_spec.rb). See the *Joe Asks...* on the next page for more on this.

We'll want to load game.rb and any other source files from a single location, so require the file from lib/codebreaker.rb:

Download cb/07/lib/codebreaker.rb

```
require 'codebreaker/game'
```

Next, the spec helper needs to add the lib directory to the load path and then require codebreaker and spec:

Download cb/07/spec/spec_helper.rb

```
$LOAD_PATH << File.join(File.dirname(__FILE__),"..","lib")
require 'spec'
require 'codebreaker'
```

Lastly we need to require spec_helper.rb from game_spec.rb, which should then look like this:

Download cb/07/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
  end
```

1. The spec command is installed when you install the rspec gem.

Joe Asks...

Shouldn't we avoid a 1-to-1 mapping?

Perhaps you've heard that a 1-to-1 mapping between objects and their specs is a BDD no-no. There is some truth to this, but the devil is in the details.

We want to avoid a strict adherence to a structure in which every object has a single example group, and every method has a single code example. That sort of structure leads to long examples that take an object through many phases, setting expectations at several stopping points in each example. Examples like these are difficult to write to begin with, and much more difficult to understand and debug later.

A 1-to-1 mapping of spec-file to application-code-file, however, is not only perfectly fine, it is actually beneficial. It makes it easier to understand where to find the specs for code you might be looking at. It also makes it easier for tools to automate shortcuts like the one in The RSpec TextMate bundle, which switches between spec-file and application-code-file with CTRL-SHIFT-DOWN.

```
end
```

Now run game_spec.rb with the spec command again. You should see output like this:

```
Finished in 0.001545 seconds

0 examples, 0 failures
```

This tells us that everything is hooked up correctly and we can move on.

Connect the features to the code

To see where we are in relation to our feature, add the lib directory to the load path and require codebreaker in features/support/env.rb:

Download cb/07/features/support/env.rb

```ruby
$LOAD_PATH << File.join(File.dirname(__FILE__),"..","..","lib")
require 'codebreaker'
```

Running features/codebreaker_starts_game.feature gives us a different error now:

```
Feature: code-breaker starts game

  As a code-breaker
  I want to start a game
  So that I can break the code

  Scenario: start game
                          # 07/features/codebreaker_starts_game.feature:10
    Given I am not yet playing
                          # 07/features/step_definitions/codebreaker_steps.rb:1
    When I start a new game
                          # 07/features/step_definitions/codebreaker_steps.rb:5
      wrong number of arguments (1 for 0) (ArgumentError)
      ./07/features/step_definitions/codebreaker_steps.rb:7:in `initialize'
      ./07/features/step_definitions/codebreaker_steps.rb:7:in `new'
      ./07/features/step_definitions/codebreaker_steps.rb:7:in
                          `/^I start a new game$/'
      07/features/codebreaker_starts_game.feature:12:in
                          `When I start a new game'
    Then I should see "Welcome to Codebreaker!"
                          # 07/features/step_definitions/codebreaker_steps.rb:11
    And I should see "Enter guess:"
                          # 07/features/step_definitions/codebreaker_steps.rb:11

1 scenario (1 failed)
4 steps (1 failed, 2 skipped, 1 passed)
0m0.001s
```

We're getting an ArgumentError instead of a NameError. This tells us two things: first, the feature is hooked up to the correct code; second, the Game needs to handle the messenger argument we pass to the initialize method.

The process we're about to go through is the Red-Green-Refactor cycle straight out of Test-Driven Development. The idea is that you write a failing example (red), write only enough code to make the example pass (green), and then remove any unwanted duplication (refactor).

This is a process not unlike music or dancing. You get into a groove and it moves very, very quickly. To strive for that feeling, we're going to go through these steps in rapid succession with very little discussion between each step.

5.2 Red: Start With a Failing Code Example

In game_spec.rb, we want to do what we've done in the feature: specify that when we start the game, it sends the right messages to the messenger. Start by modifying game_spec.rb as follows:

Download cb/08/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
    context "starting up" do
      it "should send a welcome message" do
        messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        game.start
      end
    end
  end
end
```

We *describe* the behaviour of a game object in a specific *context*: the game is just starting up. We start with the smallest amount of code we can write to express the intent of the example. The example expresses an expectation that a game, when starting up, should send a welcome message.

The expectation is expressed using RSpec's built-in mock framework, which is designed to *speak* like English: the *messenger* object *should receive* the puts() message with the string literal "Welcome to Codebreaker!" For the example to pass, this expectation should be met some time after the it is set, in this case by the statement on the second line that reads game.start. We'll cover the mock framework in detail later on in Chapter 14, *Spec::Mocks*, on page 226, but for now we just need to recognize that we have this expectation, and that we want some feedback if it is not met.

The example needs a few more things to be complete, but by starting with an expression of intent, we spend more time describing exactly what we want and less time thinking about how to set things up for an imaginary example. At this point, we're going to run the file and let the feedback we get push us in the right direction. If you run the file with the spec command you'll see output like this:

```
F

1)
NameError in 'Codebreaker::Game starting up should send a welcome message'
```

```
undefined local variable or method `messenger' for \
              #<Spec::Example::ExampleGroup::Subclass_1::Subclass_2:0x112fc18>
01/08/spec/codebreaker/game_spec.rb:7:
01/08/spec/codebreaker/game_spec.rb:4:

Finished in 0.00866 seconds

1 example, 1 failure
```

And voila! We have *red*, a failing example. Sometimes failures are logical failures, sometimes errors. In this case, we have an error. Regardless, once we have red, we want to get to green.

5.3 Green: Get the Example To Pass

The error we got is a NameError on messenger. Observing this feedback, we want to add a messenger object. Since we're using the should_receive() method from the mock framework, we can just create a stock mock object using the mock() method.

Download cb/09/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
    context "starting up" do
      it "should send a welcome message" do
        messenger = mock("messenger")
        messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        game.start
      end
    end
  end
end
```

The mock() method creates an instance of Spec::Mocks::Mock, which will behave however we program it to. As you'll see a bit later in this chapter, the string passed to the mock() method is used for messages when an expectation fails.

Run game_spec.rb again and you should see similar output, but this time with a NameError on game. Following the feedback from RSpec, add the game object:

Download cb/10/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")
```


this copy is (B12.0 printing, December 3, 2009)

```
module Codebreaker
  describe Game do
    context "starting up" do
      it "should send a welcome message" do
        messenger = mock("messenger")
        game = Game.new(messenger)
        messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        game.start
      end
    end
  end
end
```

Now run the spec again and you should see this:

```
F

1)
ArgumentError in 'Codebreaker::Game starting up should send a welcome message'
wrong number of arguments (1 for 0)
01/10/spec/codebreaker/game_spec.rb:8:in `initialize'
01/10/spec/codebreaker/game_spec.rb:8:in `new'
01/10/spec/codebreaker/game_spec.rb:8:
01/10/spec/codebreaker/game_spec.rb:4:

Finished in 0.008357 seconds

1 example, 1 failure
```

This time we get an argument error indicating that Game#initialize() needs to accept the messenger object. Go ahead and skip on over to lib/codebreaker/game.rb and add an initialize() method as follows:

Download cb/11/lib/codebreaker/game.rb

```
module Codebreaker
  class Game
    def initialize(messenger)
    end
  end
end
```

Run game_spec.rb and you should see this error:

```
F

1)
NoMethodError in 'Codebreaker::Game starting up should send a welcome message'
undefined method `start' for #<Codebreaker::Game:0x5d8540>
01/11/spec/codebreaker/game_spec.rb:10:
01/11/spec/codebreaker/game_spec.rb:4:

Finished in 0.008641 seconds
```

```
1 example, 1 failure
```

Time to add a start() method:

Download cb/12/lib/codebreaker/game.rb

```
module Codebreaker
  class Game
    def initialize(messenger)
    end

    def start
    end
  end
end
```

Now run game_spec.rb again and instead of an error, we get our first logical failure.

```
F

1)
Spec::Mocks::MockExpectationError in \
                  'Codebreaker::Game starting up should send a welcome message'
Mock 'messenger' expected :puts with \
                  ("Welcome to Codebreaker!") once, but received it 0 times
01/12/spec/codebreaker/game_spec.rb:9:
01/12/spec/codebreaker/game_spec.rb:4:

Finished in 0.009561 seconds

1 example, 1 failure
```

The expectation that the welcome message is received by the messenger is not being met. To resolve this, we just need to store the messenger in an instance variable and send it the puts() message from the start() method in the game object:

Download cb/13/lib/codebreaker/game.rb

```
module Codebreaker
  class Game
    def initialize(messenger)
      @messenger = messenger
    end

    def start
      @messenger.puts "Welcome to Codebreaker!"
    end
  end
end
```

Now run the file and you should see this glorious output:

```
.

Finished in 0.008373 seconds

1 example, 0 failures
```

Try running it with the format option:

```
spec spec/codebreaker/game_spec.rb --format specdoc


Codebreaker::Game starting up
- should send a welcome message

Finished in 0.008202 seconds

1 example, 0 failures
```

The specdoc format lists all of the examples with all of the text descriptions you include. Assuming that your monitor has more colors than this book, you can also add the --color option to see passing examples in green and failing examples in red.

At this point we move to the third part of the cycle, refactoring to remove duplication. Sometimes, however, there is really not any duplication to remove. This seems one of those cases, so we're done with this cycle. But before we start another cycle, let's see what impact we've had on the feature thus far.

Go ahead and run the feature file with the cucumber command. The output should look like this now:

```
Feature: code-breaker starts game

  As a code-breaker
  I want to start a game
  So that I can break the code

  Scenario: start game
                    # 14/features/codebreaker_starts_game.feature:10
    Given I am not yet playing
                    # 14/features/step_definitions/codebreaker_steps.rb:1
    When I start a new game
                    # 14/features/step_definitions/codebreaker_steps.rb:5
    Then I should see "Welcome to Codebreaker!"
                    # 14/features/step_definitions/codebreaker_steps.rb:11
    And I should see "Enter guess:"
                    # 14/features/step_definitions/codebreaker_steps.rb:11
      expected ["Welcome to Codebreaker!"] to include "Enter guess:"
```

```
                  (Spec::Expectations::ExpectationNotMetError)
      ./14/features/step_definitions/codebreaker_steps.rb:12:in
                  `/^I should see "([^\"]*)"$/'
      14/features/codebreaker_starts_game.feature:14:in
                  `And I should see "Enter guess:"'

1 scenario (1 failed)
4 steps (1 failed, 3 passed)
0m0.002s
```

Progress! Now one of the two *Thens* is passing, so it looks like we're about halfway done with this feature. Actually we're quite a bit more than halfway done, because, as you'll soon see, all of the pieces are already in place for the rest.

The next failing step is the next thing to work on: "And I should see: Enter guess:" Go ahead and add an example for this behaviour to game_spec.rb. Start with the last two lines, like this:

Download cb/14/spec/codebreaker/game_spec.rb

```ruby
it "should prompt for the first guess" do
  messenger.should_receive(:puts).with("Enter guess:")
  game.start
end
```

Then run the RSpec code examples and let the feedback guide you through each step like we did with the first code example. The example should end up looking like this:

Download cb/16/spec/codebreaker/game_spec.rb

```ruby
it "should prompt for the first guess" do
  messenger = mock("messenger")
  game = Game.new(messenger)
  messenger.should_receive(:puts).with("Enter guess:")
  game.start
end
```

And the feedback should end up looking like this:

```
.F

1)
Spec::Mocks::MockExpectationError in \
              'Codebreaker::Game starting up should prompt for the first guess'
Mock 'messenger' expected :puts with ("Enter guess:") \
              but received it with ("Welcome to Codebreaker!")
./01/16/spec/codebreaker/../../lib/codebreaker/game.rb:8:in `start'
01/16/spec/codebreaker/game_spec.rb:17:
01/16/spec/codebreaker/game_spec.rb:4:
```

```
Finished in 0.008954 seconds

2 examples, 1 failure
```

It looks like we need to send the messenger puts() with “Enter guess:” So head back to game.rb and modify it as follows:

Download cb/17/lib/codebreaker/game.rb

```
def start
  @messenger.puts "Welcome to Codebreaker!"
  @messenger.puts "Enter guess:"
end
```

Now run game_spec.rb:

```
FF

1)
Spec::Mocks::MockExpectationError in \
              'Codebreaker::Game starting up should send a welcome message'
Mock 'messenger' expected :puts with \
              ("Welcome to Codebreaker!") but received it with ("Enter guess:")
./01/17/spec/codebreaker/../../lib/codebreaker/game.rb:10:in `start'
01/17/spec/codebreaker/game_spec.rb:10:
01/17/spec/codebreaker/game_spec.rb:4:

2)
Spec::Mocks::MockExpectationError in \
              'Codebreaker::Game starting up should prompt for the first guess'
Mock 'messenger' expected :puts with ("Enter guess:") \
              but received it with ("Welcome to Codebreaker!")
./01/17/spec/codebreaker/../../lib/codebreaker/game.rb:9:in `start'
01/17/spec/codebreaker/game_spec.rb:17:
01/17/spec/codebreaker/game_spec.rb:4:

Finished in 0.009537 seconds

2 examples, 2 failures
```

And *ta da!* Now not only is the second example still failing, but the first example is *failing now as well*! Who’da thunk? This may seem a bit confusing if you’ve never worked with mock objects and message expectations before, but mock objects are like computers. They are extraordinarily obedient, but they are not all that clever. By default, mocks will expect exactly what you tell them to expect, nothing more and nothing less.

We’ve told the mock in the first example to expect puts() with “Welcome to Codebreaker!” and we’ve satisfied that requirement, but we’ve only told it to expect "Welcome to Codebreaker!" It doesn't know anything about "Enter guess:"

Similarly, the mock in the second example expects "Enter guess:" but the first message it gets is "Welcome to Codebreaker!"

We could combine these two into a single example, but we like to follow the guideline of "one expectation per example." The rationale here is that if there are two expectations in an example that should both fail given the implementation at that moment, we'll only see the first failure. No sooner do we meet that expectation than we discover that we haven't met the second expectation. If they live in separate examples, then they'll both fail, and that will provide us with more accurate information than if only one of them is failing.

We could also try to break the messages up into different steps, but we've already defined how we want to talk to the game object. So how can we resolve this?

There are a couple of ways we can go about it, but the simplest way is to tell the mock messenger to only listen for the messages we tell it to expect, and ignore any other messages.[2] This is based on the *Null Object* design pattern described in *Pattern Languages of Program Design 3* [MRB97], and is supported by RSpec's mock framework with the as_null_object() method:

Download cb/18/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
    context "starting up" do
      it "should send a welcome message" do
        messenger = mock("messenger").as_null_object
        game = Game.new(messenger)
        messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        game.start
      end

      it "should prompt for the first guess" do
        messenger = mock("messenger").as_null_object
        game = Game.new(messenger)
        messenger.should_receive(:puts).with("Enter guess:")
        game.start
```

2. Actually, that's not completely true. Unexpected messages are actually recorded because it is sometimes helpful to include them in failure messages.

```
      end
    end
  end
end
```

Hey, there's a fair amount of duplication here. When you observe duplication while you're in the middle of the *red* part of Red-Green-Refactor, it's best to just take note of it and plan to address it once you get to green.

Now run game_spec.rb with --format specdoc:

```
Codebreaker::Game starting up
- should send a welcome message
- should prompt for the first guess

Finished in 0.008966 seconds

2 examples, 0 failures
```

Good news. Both examples are now passing. Now that we have green, it's time to refactor!

5.4 Refactor to Remove Duplication

In the preface to his seminal book on *Refactoring* [FBB+99], Martin Fowler writes: "Refactoring is the process of changing a software system in such a way that it does not alter the external behaviour of the code yet improves its internal structure."

How do we know that we're not changing behaviour? We run the examples between every change. If they pass, we've refactored successfully. If any fail, we know that the very last change we made caused a problem and we either quickly recognize and address the problem, or rollback that step to get back to green and try again.

Fowler talks about changing the designs of systems, but on a more granular scale, we want to refactor to eliminate duplication in the implementation *and* examples. Looking back at game_spec.rb, we can see that the first two lines of each example are identical. Perhaps you noticed this earlier, but we prefer to refactor *in the green* rather than *in the red*. Also, you may recall that we wrote the last two lines of each example first because they expressed intent.

In this case we have a very clear break between what is context and what is behaviour, so let's take advantage of that and move the context to a block that is executed before each of the examples. Not in the least coincidentally, RSpec calls the method before() and it takes a symbol to indicate before *what*.

As with moving from red to green, we're going to go through this one step at a time. The steps are very small, but they happen in rapid succession, running the examples between each step. I'm not going to show you the output after each step, but you should be running the examples between each step to make sure that each change is not affecting the behaviour.

First, change messenger, in the first example only, to an instance variable and move it to a before() method.

Download cb/19/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
    context "starting up" do
      before(:each) do
        @messenger = mock("messenger").as_null_object
      end

      it "should send a welcome message" do
        game = Game.new(@messenger)
        @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        game.start
      end

      it "should prompt for the first guess" do
        messenger = mock("messenger").as_null_object
        game = Game.new(messenger)
        messenger.should_receive(:puts).with("Enter guess:")
        game.start
      end
    end
  end
end
```

Run the examples to make sure they pass. If they don't, make sure that you've changed all the references to messenger in before(:each) and the first example from local variables to instance variables.

Now do the same thing with the game object.

Download cb/20/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")
```

```
module Codebreaker
  describe Game do
    context "starting up" do
      before(:each) do
        @messenger = mock("messenger").as_null_object
        @game = Game.new(@messenger)
      end

      it "should send a welcome message" do
        @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        @game.start
      end

      it "should prompt for the first guess" do
        messenger = mock("messenger").as_null_object
        game = Game.new(messenger)
        messenger.should_receive(:puts).with("Enter guess:")
        game.start
      end
    end
  end
end
```

Again, run the examples and make sure they pass. The last step is to remove the first two lines of the second example and reference the instance variables.

Download cb/21/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
    context "starting up" do
      before(:each) do
        @messenger = mock("messenger").as_null_object
        @game = Game.new(@messenger)
      end

      it "should send a welcome message" do
        @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        @game.start
      end

      it "should prompt for the first guess" do
        @messenger.should_receive(:puts).with("Enter guess:")
        @game.start
      end
    end
  end
end
```

Now that's a bit cleaner, don't you think? As noted earlier, the code before(:each) example sets up the context and the code in each example is restricted to that which expresses intent.

Now run the feature again:

```
Feature: code-breaker starts game

  As a code-breaker
  I want to start a game
  So that I can break the code

  Scenario: start game
                # 21/features/codebreaker_starts_game.feature:10
    Given I am not yet playing
                # 21/features/step_definitions/codebreaker_steps.rb:1
    When I start a new game
                # 21/features/step_definitions/codebreaker_steps.rb:5
    Then I should see "Welcome to Codebreaker!"
                # 21/features/step_definitions/codebreaker_steps.rb:11
    And I should see "Enter guess:"
                # 21/features/step_definitions/codebreaker_steps.rb:11

1 scenario (1 passed)
4 steps (4 passed)
0m0.002s
```

And voila! We now have our first passing code examples and our first passing feature. There were a lot of steps to get there, but in practice this all really takes just a few minutes, even with all the wiring and require statements.

We've also set up quite a bit of infrastructure. You'll see, as we move along, that there is less and less new material needed to add more features, code examples and application code. It just builds gradually on what we've already developed.

In the last chapter, we created the bin/codebreaker script (bin/codebreaker.bat if you're on Windows) that we use to run the codebreaker game. Go ahead and fire up a shell and run the script and you'll see the following output:

```
$ bin/codebreaker
Welcome to Codebreaker!
Enter guess:
```

Now look at that! Who knew that all this code was actually going to start to make something work? Of course, our Codebreaker game just says hello and then climbs back in its cave, so we've got a way to go before you'll want to show this off to all your friends.

In the next chapter, we'll start to get down to the real fun, submitting guesses and having the game score them. By the end of the next chapter, you'll actually be able to play the game! But before we move on, let's review what we've done thus far.

5.5 What We Just Did

We started this chapter with a failing step in a Cucumber scenario. This was our cue to jump from the outer circle (Cucumber) to the inner circle (RSpec) of the BDD cycle.

We then followed the familiar TDD Red/Green/Refactor cycle using RSpec. Once we had a passing code example we re-ran the Cucumber scenario. We saw that we had gotten our first Then step to pass, but there was one more that was failing, so we jumped back down to RSpec, went through another Red/Green/Refactor cycle, and now the whole scenario was passing.

This is the BDD cycle. Driving development from the Outside-In, starting with business facing scenarios in Cucumber and working our way inward to the underlying objects with RSpec.

The material in the next chapter, submitting guesses, is going to present some interesting challenges. It will expose you to some really cool features in Cucumber, as well as some thought provoking discussion about the relationship between Cucumber scenarios and RSpec code examples. So take a few minutes break, drink up that brain juice, and meet me at the top of the next chapter.

Chapter 6

Adding New Features

Welcome back! We left off with the Codebreaker game inviting us to guess the secret code, but then leaving us hanging at the command line. The next feature we're going to tackle is submitting a guess, and getting feedback from the Codebreaker game as to how close the guess is to breaking the secret code.

This feature is going to introduce an algorithm for marking a guess. This is where things start to get really interesting, because algorithms, by their nature, tend to cover a lot of possible cases with a small amount of code. As you'll see, we're going to have a lot more scenarios and specs than we did for the Code-breaker starts game feature. Luckily, we have tools in both RSpec and Cucumber to keep things simultaneously readable and DRY.

6.1 Scenario Outlines in Cucumber

Here's the Cucumber feature we wrote back in Section 3.3, *Planning the First Iteration*, on page 41:

```
Feature: code-breaker submits guess

  The code-breaker submits a guess of four colored
  pegs. The game marks the guess with black and
  white "marker" pegs.

  For each peg in the guess that matches the color
  and position of a peg in the secret code, the
  mark includes one black peg. For each additional
  peg in the guess that matches the color but not
  the position of a peg in the secret code, a
  white peg is added to the mark.
```

```
  Scenario Outline: submit guess
    Given the secret code is <code>
    When I guess <guess>
    Then the mark should be <mark>

  Scenarios: all colors correct
    | code    | guess   | mark |
    | r g y c | r g y c | bbbb |
    | r g y c | r g c y | bbww |
    | r g y c | y r g c | bwww |
    | r g y c | c r g y | wwww |

  Scenarios: 3 colors correct
    | code    | guess   | mark |
    | r g y c | w g y c | bbb  |
    | r g y c | w r y c | bbw  |
    | r g y c | w r g c | bww  |
    | r g y c | w r g y | www  |

  Scenarios: 2 colors correct
    | code    | guess   | mark |
    | r g y c | w g w c | bb   |
    | r g y c | w r w c | bw   |
    | r g y c | g w c w | ww   |

  Scenarios: 1 color correct
    | code    | guess   | mark |
    | r g y c | r w w w | b    |
    | r g y c | w w r w | w    |
```

This feature is quite a bit different from the game-starting feature we wrote in the last couple of chapters. It uses a Scenario Outline with scenarios expressed in a tabular format. Scenario Outlines are one tool that Cucumber offers us to keep features readable and DRY. You'll read about the other tools in the (as yet) unwritten *chp.cucumber*.

To figure out what our next step is, run the Code-breaker submits guess feature with the cucumber command:

```
cucumber features/codebreaker_submits_guess.feature
```

As we saw earlier, the output includes the contents of the file listed above, plus a summary and code snippets for any undefined steps. Here is the summary and just a few of the code snippets:

```
13 scenarios (13 undefined)
39 steps (39 undefined)
0m0.011s

You can implement step definitions for undefined steps with these snippets:
```

```
Given /^the secret code is r g y c$/ do
  pending
end

When /^I guess r g y c$/ do
  pending
end

Then /^the mark should be bbbb$/ do
  pending
end
```

We've got 13 scenarios with 39 steps, all of which are listed as undefined. So now, with that help from Cucumber, let's write some step definitions.

Step Definitions

Step definitions for Scenario Outlines and Tables are just like the step definitions we learned about in Chapter 4, *Automating Features with Cucumber*, on page 50. We'll still provide regular expressions that capture input data, and a block of code that interacts with the subject code.

Copy the first snippet into features/step_definitions/codebreaker_steps.rb and modify it as follows:

Download cb/27/features/step_definitions/codebreaker_steps.rb

```
Given /^the secret code is (. . . .)$/ do |code|
  @messenger = StringIO.new
  game = Codebreaker::Game.new(@messenger)
  game.start(code.split)
end
```

The Regexp captures a group of four characters separated by spaces at the end of the line. This will capture the code (r c g y, for example), and pass it to the body of the step definition. The first two lines of the body should look familiar, as they are just like the *I start a new game* step. Then the last line passes the code from the match group as an array.

Now run cucumber again and you'll see output including this:

```
Scenarios: all colors correct
  | code    | guess   | mark |
  | r g y c | r g y c | bbbb |
  wrong number of arguments (1 for 0) (ArgumentError)
  ./27/features/step_definitions/codebreaker_steps.rb:8:in `start'
  ./27/features/step_definitions/codebreaker_steps.rb:8:in
```

```
                                  `/^the secret code is (. . . .)$/'
  27/features/codebreaker_submits_guess.feature:15:in
                                  `Given the secret code is <code>'
```

You should see the ArgumentError for every scenario. This is actually good news, because the error tells us that everything is wired up correctly, and we now know what we have to do next: get the start() method on Game to accept the code as an argument.

6.2 Responding to Change

At this point, all of the RSpec code examples are passing, but we've got failing Cucumber scenarios. We're *in the meantime*, so to speak, where changing requirements from the outside are rendering our requirements on the inside incorrect.

Our new step definition wants Game.start() to accept the secret code as an argument, but our RSpec examples assume that start() does not take any arguments. We don't want to change two things at once, but it seems as though we can't fix one without breaking the other.

To resolve this situation, we could use brute force and simply add a secret code to the calls to the start() method in Codebreaker::Game, and then modify the method to accept an argument, and then run the examples. That might actually work out OK in this case because there is so little going on in our system. It doesn't take long, however, for a system to grow complex enough that this brute force approach results in long periods of time without all of the examples passing.

The Disciplined Approach

The disciplined approach to this situation is to incrementally add examples that specify the new behaviour, and follow the red/green/refactor cycle to evolve the code to support the new *and the old* behaviour at the same time. Once the new requirements are satisfied, we'll remove support for the old behaviour.

Take a look at the first example that calls the start() method:

Download cb/23/spec/codebreaker/game_spec.rb

```ruby
it "should send a welcome message" do
  @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
  @game.start
end
```

Leaving that in place, add a copy of it in which the only difference is that we're passing the code to the start() method. And let's identify the difference in the docstring passed to it(), so if we get disrupted, we'll be able to look back at this and see what's going on.

Download cb/24/spec/codebreaker/game_spec.rb

```
it "should send a welcome message (passing the code to start)" do
  @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
  @game.start(%w[r g y c])
end
```

Run game_spec.rb like this:

```
spec spec/codebreaker/game_spec.rb --format nested
```

The nested format reflects the nesting of example groups (describe() blocks). As we add examples to this spec, you'll see that this format is very readable and helpful. The output tells us there is one failure:

```
Codebreaker::Game
  starting up
    should send a welcome message
    should send a welcome message (passing the code to start) (FAILED - 1)
    should prompt for the first guess

1)
ArgumentError in 'Codebreaker::Game starting up should send a welcome message \
  (passing the code to start)'
wrong number of arguments (1 for 0)
./24/spec/codebreaker/game_spec.rb:19:in `start'
./24/spec/codebreaker/game_spec.rb:19:

Finished in 0.006355 seconds

3 examples, 1 failure
```

The additional context information we added to the docstring helps us to see that the failing example is the new one we just added. To get it to pass without the others failing, we'll add an optional argument to the start() method:

Download cb/25/lib/codebreaker/game.rb

```
def start(code=nil)
  @messenger.puts "Welcome to Codebreaker!"
  @messenger.puts "Enter guess:"
end
```

If you run game_spec.rb again, you should see that all three examples are passing. With that simple change, the start() method is supporting both the old and the new requirements.

Finding the Way Home

At this point, we're half way home. We want to remove support for the old behaviour by requiring the code argument to the start() method instead of leaving it optional. If we do that, however, the *should prompt for the first guess* example, which is not passing in the secret code to start(), will fail.

Because the start() supports 0 or 1 arguments, we can just modify that example to pass the code to start(), and it should continue to pass. Go ahead and do that yourself, and run all the examples after you change it. They should still pass.

So now we've still got two versions of the first example. We could just remove the old version, but before we do, we can do a sort of reverse-sanity-check-refactoring. Modify the start method such that the code argument is no longer optional:

Download cb/26/lib/codebreaker/game.rb

```
def start(code)
  @messenger.puts "Welcome to Codebreaker!"
  @messenger.puts "Enter guess:"
end
```

Now run the examples and you should see one failure:

```
Codebreaker::Game
  starting up
    should send a welcome message (FAILED - 1)
    should send a welcome message (passing the code to start)
    should prompt for the first guess

1)
ArgumentError in 'Codebreaker::Game starting up should send a welcome message'
wrong number of arguments (0 for 1)
./26/spec/codebreaker/game_spec.rb:13:in `start'
./26/spec/codebreaker/game_spec.rb:13:

Finished in 0.002483 seconds

3 examples, 1 failure
```

The one that is failing is the only example left that is still calling start() with no code, and it's a near duplicate of the passing example that says (passing the code to start). We can now safely remove the failing example, and remove the parenthetical context from the passing example, leaving us with this:

Download cb/27/spec/codebreaker/game_spec.rb

```
it "should send a welcome message" do
  @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
  @game.start(%w[r c g y])
end

it "should prompt for the first guess" do
  @messenger.should_receive(:puts).with("Enter guess:")
  @game.start(%w[r c g y])
end
```

Download cb/27/lib/codebreaker/game.rb

```
def start
  @messenger.puts "Welcome to Codebreaker!"
  @messenger.puts "Enter guess:"
end
```

We've reached our short term destination. The route here was circuitous, but we did things with discipline, taking small steps, with a green bar only moments away at every step. Again, in this particular case, brute force *may* be OK, but it's very useful to have the skill to approach more complex situations in a disciplined way.

A Small Change Goes a Long Way

Now let's see what impact that had on the scenarios. Run the feature again with cucumber, and you should see output including:

```
13 scenarios
26 undefined steps
13 passed steps
```

There are no failures now, and we still have 26 steps undefined, but we now have 13 passing steps: the Given steps in each scenario. Remember, each row in the tables represents a separate scenario. Until we get to the point where the failures are logical failures, as opposed to runtime errors due to structural discrepancies, a small change is likely to impact all of the scenarios at once.

The remaining undefined steps are the When steps that actually submit the guess, and the Then steps that set the expectation that the game should mark the guess. The details of these steps vary across all the different scenarios depending on the content of the guess and the expected mark, but they all have the same structure. So even though you see many code snippets for the undefined steps, we'll really only need two.

The first one is the When step: the action step. Using the snippet provided by Cucumber, and filling in the code block, here is the implementation of this When step, along with some necessary modifications to the Given step.

Download cb/29/features/step_definitions/codebreaker_steps.rb

```
Given /^the secret code is (. . . .)$/ do |code|
  @messenger = StringIO.new
  @game = Codebreaker::Game.new(@messenger)
  @game.start(code.split)
end

When /^I guess (. . . .)$/ do |code|
  @game.guess(code.split)
end
```

We need to make @game an instance variable so it can be shared across the two steps. Now run this feature with the cucumber command and you should see output like this:

```
Scenarios: all colors correct
  | code    | guess   | mark |
  | r g y c | r g y c | bbbb |
  undefined method `guess' for #<Codebreaker::Game:0x18791cc
                              @messenger=#<StringIO:0x18791f4>> (NoMethodError)
  ./29/features/step_definitions/codebreaker_steps.rb:12:in `/^I guess (. . . .)$/'
  29/features/codebreaker_submits_guess.feature:16:in `When I guess <guess>'
```

You should actually see many similar messages. They all tell us that we need to implement a guess() method on Codebreaker::Game.

Loosening the Leash

Earlier, when the Given step told us we needed to add an argument to start(), we already had examples in place that used that method, so we refactored the method definition in the examples in order to drive that change from the code examples.

This situation is a bit different. We'd like to create examples in RSpec before writing any code in the Game class, but we haven't implemented any steps in Cucumber that tell us how that method should behave. Right now, we only need it to exist. We could, in theory, write an example like this:

```
it "should have a guess method" do
  game = Game.new
  game.guess(%w[r y c g])
end
```

Absent the existence of the guess() method, this example would fail, and we'd be able to happily move on knowing that an example drove the method into existence. But BDD is about *behaviour*, not structure. We want to *use* methods in code examples, not specify that they exist. So how can we proceed and stay true to the cycle without adding a silly example like the one above?

The answer is that we can't. And, furthermore, *it's OK!* We're going to sin a little bit here and just add the method to Game without a spec.

Download cb/30/lib/codebreaker/game.rb

```
def guess(guess)
end
```

Scary, huh? Well, relax. We're only moments away from validating the existence of this method, and it *is*, after all, being driven into existence by a failing example. It's just an example that lives up at a higher level.

Now run the feature and you should see some different feedback:

```
13 scenarios (13 undefined)
39 steps (13 undefined, 26 passed)
```

Again there are no failures, but now there are only 13 steps undefined. These are the Then steps. Go ahead and implement the step definition in features/step_definitions/codebreaker_steps.rb like this:

Download cb/31/features/step_definitions/codebreaker_steps.rb

```
Then /^the mark should be (.*)$/ do |mark|
  @messenger.string.split("\n").should include(mark)
end
```

Look familiar? This is just like the Then step from earlier scenarios: I should see "(.*)". We're getting the string from the messenger, splitting it into an array, and expecting the mark to be one of the array elements.

Run the feature and you should see feedback like this:

```
Scenarios: all colors correct
  | code    | guess   | mark |
  | r g y c | r g y c | bbbb |
  expected ["Welcome to Codebreaker!", "Enter guess:"]
          to include "bbbb" (Spec::Expectations::ExpectationNotMetError)
  ./31/features/step_definitions/codebreaker_steps.rb:28:in
          `/^the mark should be (.*)$/'
  31/features/codebreaker_submits_guess.feature:17:in
          `Then the mark should be <mark>'
```

Fantastic! Now all 13 scenarios are failing on the Then step. Again, this is good news. We know everything is wired up correctly, and we now have all of the step definitions we need. Now it's time to drill down to RSpec and drive out the solution with isolated examples.

6.3 The Simplest Thing

Looking back at the scenarios, we'll build a code example around the first one that is failing: all four colors correct and all in the correct positions. Open up spec/codebreaker/game_spec.rb and add the following code inside the describe Game block, after the context "starting up" block.

Download cb/32/spec/codebreaker/game_spec.rb

```
Line 1  context "marking a guess" do
-         context "with all 4 colors correct in the correct places" do
-           it "should mark the guess with bbbb" do
-             messenger = mock("messenger").as_null_object
5             game = Game.new(messenger)
-             game.start(%w[r g y c])
-
-             messenger.should_receive(:puts).with("bbbb")
-
10            game.guess(%w[r g y c])
-           end
-         end
-       end
```

We're nesting the "with all 4 colors correct in the correct places" context inside the "marking a guess" context. Then the code example "should mark the guess with bbbb."

Lines 4, 5, and 6 provide the givens for this example. The next statement, on line 8 might be a bit confusing. Instead of a *when* as we'd normally expect, this line actually represents an expected outcome. It's the *then* step, and it appears *before* the *when* step on line 10.

This is because the expectation is a *message expectation*, or *mock expectation*, and it needs to be expressed before the action, or *when*. After starting the game, this example sets an expectation that the messenger should receive the puts() message with the string "bbbb" as the result of calling game.guess() with the same secret code passed to the start() method.

Running this example produces the following output:

```
Codebreaker::Game
  starting up
    should send a welcome message
    should prompt for the first guess
```


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```
  marking a guess
    with all 4 colors correct in the correct places
      should mark the guess with bbbb (FAILED - 1)

1)
Spec::Mocks::MockExpectationError in \
  'Codebreaker::Game marking a guess with all 4 colors correct in the correct \
    places should mark the guess with bbbb'
Mock 'messenger' expected :puts with ("bbbb") once, but received it 0 times
./32/spec/codebreaker/game_spec.rb:30:

Finished in 0.002856 seconds

3 examples, 1 failure
```

The example is failing, as we would expect. To get it to pass, we'll do *the simplest thing that could possibly work*.

One guideline that comes directly from Test Driven Development is to write only enough code to pass the one failing example, and no more. To do this, we write the simplest thing that we can to get the example to pass. In this case, we'll simply call puts("bbbb") on the messenger from the guess() method.

Download cb/33/lib/codebreaker/game.rb

```ruby
def guess(guess)
  @messenger.puts "bbbb"
end
```

That's all we need to get the example to pass:

```
Codebreaker::Game
  starting up
    should send a welcome message
    should prompt for the first guess
  marking a guess
    with all 4 colors correct in the correct places
      should mark the guess with bbbb

Finished in 0.002176 seconds

3 examples, 0 failures
```

If this idea is new to you and perhaps a little uncomfortable, you have our full support. This code *is* certainly naive, and will tell the user that he's broken the secret code every time he submits a guess. Obviously, this does not solve the problem that we *know* we need to solve. But there are two sides to every story.

Express the problem before solving it

If code is the solution to a problem, and naive code is passing all of its examples, then the problem has not been properly expressed in the examples. Yes, there is something missing here, but it is missing in the examples, not just the code. We'll be writing more examples, and enhancing this code to get them to pass very soon. Promise.

Now run the feature again with the cucumber command, and we get some new feedback:

```
Scenarios: all colors correct
  | code    | guess   | mark |
  | r g y c | r g y c | bbbb |
  | r g y c | r g c y | bbww |
    expected ["Welcome to Codebreaker!", "Enter guess:", "bbbb"] \
              to include "bbww" (Spec::Expectations::ExpectationNotMetError)
    ./08/features/step_definitions/codebreaker_steps.rb:28:in \
              `/^the mark should be (.*)$/'
    08/features/codebreaker_submits_guess.feature:22:in \
              `Then the mark should be bbww'
```

The first scenario is passing now, but the second one is still failing. *Now* we'll add a new code example based on the next failing scenario. That wasn't too long, was it?

This time we'll submit a guess that has all the right colors, but only two in the correct positions.

Download cb/34/spec/codebreaker/game_spec.rb

```
context "with all 4 colors correct and 2 in the correct places" do
  it "should mark the guess with bbww" do
    messenger = mock("messenger").as_null_object
    game = Game.new(messenger)
    game.start(%w[r g y c])

    messenger.should_receive(:puts).with("bbww")

    game.guess(%w[r g c y])
  end
end
```

Run that, and watch it fail:

```
Codebreaker::Game
  starting up
    should send a welcome message
    should prompt for the first guess
  marking a guess
    with all 4 colors correct in the correct places
      should mark the guess with bbbb
```

```
    with all 4 colors correct and 2 in the correct places
      should mark the guess with bbww (FAILED - 1)

1)
Spec::Mocks::MockExpectationError in \
    'Codebreaker::Game marking a guess with all 4 colors correct and \
    2 in the correct places should mark the guess with bbww'
Mock 'messenger' expected :puts with ("bbww") but received it with (["bbbb"])
./34/spec/codebreaker/game_spec.rb:41:

Finished in 0.002952 seconds

4 examples, 1 failure
```

The trick now is to get this example to pass without causing the previous one to fail. One solution would be to start with an empty string and append a "b" for each peg that matches the color of the peg in the same position in the code, and a "w" for each peg that matches the color of a peg in a different position in the code. Once we've looked at all four pegs in the guess, we'll just puts() the string via the messenger.

To do that, we'll need to store the code in an instance variable in the start() method. Then we can access it in the guess() method.

Download cb/35/lib/codebreaker/game.rb

```
def start(code)
  @code = code
  @messenger.puts "Welcome to Codebreaker!"
  @messenger.puts "Enter guess:"
end

def guess(guess)
  result = ""
  guess.each_with_index do |peg, index|
    if @code[index] == peg
      result << "b"
    elsif @code.include?(peg)
      result << "w"
    end
  end
  @messenger.puts result
end
```

There are many ways we could express this, and this one may or may not be your favorite. If it's not, go with this for the duration of the tutorial, and then feel free to refactor later.

At this point all of the examples pass:

```
Codebreaker::Game
```

```
  starting up
    should send a welcome message
    should prompt for the first guess
  marking a guess
    with all 4 colors correct in the correct places
      should mark the guess with bbbb
    with all 4 colors correct and 2 in the correct places
      should mark the guess with bbww

Finished in 0.002502 seconds

4 examples, 0 failures
```

Observe the impact on the scenario

Every time we get to a green bar in the code examples, it's a good idea to run the scenarios we're working on to see what impact we've had. In this case, we've not only gotten all of the examples to pass, but we've also made some progress on the scenarios. The second scenario is passing, but the third one is failing. Look closely at the failure message:

```
Scenarios: all colors correct
  | code    | guess   | mark |
  | r g y c | r g y c | bbbb |
  | r g y c | r g c y | bbww |
  | r g y c | y r g c | bwww |
  expected ["Welcome to Codebreaker!", "Enter guess:", "wwwb"]
            to include "bwww" (Spec::Expectations::ExpectationNotMetError)
  ./35/features/step_definitions/codebreaker_steps.rb:28:in
            `/^the mark should be (.*)$/'
  35/features/codebreaker_submits_guess.feature:17:in
            `Then the mark should be <mark>'
```

We're expecting "bwww", but we got "wwwb" instead. The implementation is returning the correct collection of letters, but in the wrong order. That's because the one peg that is in the correct position is the last peg that is evaluated. Let's create one more example based on this scenario:

Download cb/36/spec/codebreaker/game_spec.rb

```
context "with all 4 colors correct and 1 in the correct place" do
  it "should mark the guess with bwww" do
    messenger = mock("messenger").as_null_object
    game = Game.new(messenger)
    game.start(%w[r g y c])

    messenger.should_receive(:puts).with("bwww")

    game.guess(%w[y r g c])
  end
end
```

Now run it and watch it fail:

```
Codebreaker::Game
  starting up
    should send a welcome message
    should prompt for the first guess
  marking a guess
    with all 4 colors correct in the correct places
      should mark the guess with bbbb
    with all 4 colors correct and 2 in the correct places
      should mark the guess with bbww
    with all 4 colors correct and 1 in the correct place
      should mark the guess with bwww (FAILED - 1)

1)
Spec::Mocks::MockExpectationError in 'Codebreaker::Game marking a guess with all 4 c...*TRUNC*
Mock 'messenger' expected :puts with ("bwww") but received it with (["wwwb"])
./36/spec/codebreaker/game_spec.rb:52:

Finished in 0.003265 seconds

5 examples, 1 failure
```

To get this example to pass, we'll need to put all the "b"s at the beginning of the mark. Since Ruby appends to Strings and to Arrays using the << method, we can just change the string to an array, sort it and join its elements:

Download cb/37/lib/codebreaker/game.rb

```ruby
def guess(guess)
  result = []
  guess.each_with_index do |peg, index|
    if @code[index] == peg
      result << "b"
    elsif @code.include?(peg)
      result << "w"
    end
  end
  @messenger.puts result.sort.join
end
```

With that subtle change, all of the code examples pass:

```
Codebreaker::Game
  starting up
    should send a welcome message
    should prompt for the first guess
  marking a guess
    with all 4 colors correct in the correct places
      should mark the guess with bbbb
    with all 4 colors correct and 2 in the correct places
```

```
      should mark the guess with bbww
    with all 4 colors correct and 1 in the correct place
      should mark the guess with bwww

Finished in 0.002915 seconds

5 examples, 0 failures
```

As it turns out, that was all we needed to get all of the scenarios to pass as well:

```
13 scenarios (13 passed)
39 steps (39 passed)
```

6.4 Examples are Code Too

With all of the scenarios passing, now is a great time to review the code and sniff out some code smell. We want to look at all the code that we've written, including step definitions and code examples.

Refactoring step definitions

Here's the full content of features/step_definitions/codebreaker_steps.rb.

Download cb/37/features/step_definitions/codebreaker_steps.rb

```
Given /^I am not yet playing$/ do
end

Given /^the secret code is (. . . .)$/ do |code|
  @messenger = StringIO.new
  @game = Codebreaker::Game.new(@messenger)
  @game.start(code.split)
end

When /^I guess (. . . .)$/ do |code|
  @game.guess(code.split)
end

When /^I start a new game$/ do
  @messenger = StringIO.new
  game = Codebreaker::Game.new(@messenger)
  game.start(%w[r g y c])
end

Then /^I should see "([^\"]*)"$/ do |message|
  @messenger.string.split("\n").should include(message)
end

Then /^the mark should be (.*)$/ do |mark|
  @messenger.string.split("\n").should include(mark)
```

```
end
```

There's not only a fair amount of duplication here, but the code in the step definitions is not always as expressive as it could be. We can improve this quite a bit by extracting helper methods from the step definitions. After a few minutes refactoring, here's where we ended up:

Download cb/38/features/step_definitions/codebreaker_steps.rb

```
def messenger
  @messenger ||= StringIO.new
end

def game
  @game ||= Codebreaker::Game.new(messenger)
end

def messages_should_include(message)
  messenger.string.split("\n").should include(message)
end

Given /^I am not yet playing$/ do
end

Given /^the secret code is (. . . .)$/ do |code|
  game.start(code.split)
end

When /^I guess (. . . .)$/ do |code|
  game.guess(code.split)
end

When /^I start a new game$/ do
  game.start(%w[r g y c])
end

Then /^I should see "([^\"]*)"$/ do |message|
  messages_should_include(message)
end

Then /^the mark should be (.*)$/ do |mark|
  messages_should_include(mark)
end
```

The use of ||= in the messenger() and game() methods is a common Ruby idiom for initializing an instance variable if it does not exist, and then returning the value of that variable like a standard accessor. This way game points to the same object in the Given /^the secret code is (. . . .)$/ and When /^I guess (. . . .)$/ step definitions.

The messages_should_include() method is a wrapper for the expectation that is repeated in the Then steps. The method name expresses its intent much more clearly than the statement in the body of the method.

In addition to making things more expressive, they are also more DRY. If we decide later to introduce a Messenger type, we'll only have to change that in one place.

Refactoring code examples

Now let's look at game_spec.rb:

Download cb/37/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
    context "starting up" do
      before(:each) do
        @messenger = mock("messenger").as_null_object
        @game = Game.new(@messenger)
      end

      it "should send a welcome message" do
        @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        @game.start(%w[r g y c])
      end

      it "should prompt for the first guess" do
        @messenger.should_receive(:puts).with("Enter guess:")
        @game.start(%w[r g y c])
      end
    end

    context "marking a guess" do
      context "with all 4 colors correct in the correct places" do
        it "should mark the guess with bbbb" do
          messenger = mock("messenger").as_null_object
          game = Game.new(messenger)
          game.start(%w[r g y c])

          messenger.should_receive(:puts).with("bbbb")

          game.guess(%w[r g y c])
        end
      end
      context "with all 4 colors correct and 2 in the correct places" do
        it "should mark the guess with bbww" do
          messenger = mock("messenger").as_null_object
          game = Game.new(messenger)
```


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```
          game.start(%w[r g y c])

          messenger.should_receive(:puts).with("bbww")

          game.guess(%w[r g c y])
        end
      end
      context "with all 4 colors correct and 1 in the correct place" do
        it "should mark the guess with bwww" do
          messenger = mock("messenger").as_null_object
          game = Game.new(messenger)
          game.start(%w[r g y c])

          messenger.should_receive(:puts).with("bwww")

          game.guess(%w[y r g c])
        end
      end
    end
  end
end
```

The starting up context on line 5 includes a before() block that initializes the @messenger and @game instance variables. Looking further down, all of the examples in the marking a guess context use similar local variables.

We could have caught duplication earlier if we had stopped to look at the full listing. You may have already noticed it. In fact you may have already refactored it! But in case you haven't, here's what we did:

Download cb/38/spec/codebreaker/game_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Game do
    before(:each) do
      @messenger = mock("messenger").as_null_object
      @game = Game.new(@messenger)
    end

    context "starting up" do
      it "should send a welcome message" do
        @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
        @game.start(%w[r g y c])
      end

      it "should prompt for the first guess" do
        @messenger.should_receive(:puts).with("Enter guess:")
        @game.start(%w[r g y c])
```

```
-        end
20     end
-
-     context "marking a guess" do
-       context "with all 4 colors correct in the correct places" do
-         it "should mark the guess with bbbb" do
25          @game.start(%w[r g y c])
-           @messenger.should_receive(:puts).with("bbbb")
-           @game.guess(%w[r g y c])
-         end
-       end
30      context "with all 4 colors correct and 2 in the correct places" do
-         it "should mark the guess with bbww" do
-           @game.start(%w[r g y c])
-           @messenger.should_receive(:puts).with("bbww")
-           @game.guess(%w[r g c y])
35        end
-       end
-       context "with all 4 colors correct and 1 in the correct place" do
-         it "should mark the guess with bwww" do
-           @game.start(%w[r g y c])
40          @messenger.should_receive(:puts).with("bwww")
-           @game.guess(%w[y r g c])
-         end
-       end
-     end
45  end
- end
```

We moved the before(each) block to line 5, inside the outer-most describe() block. This makes it available to all of the nested groups, and therefore every example in this file.

Looking back at the three examples in the marking a guess context, they all look pretty much the same except for the values. It is *very* tempting to try to DRY this up, and there are a number of ways we could do it, but none of the ways we tried ended up as simple, expressive, localized, and clear as they are right now.

Remember that the code examples are, well, *code examples*! We want them to communicate on a few different levels. We want the docstrings we pass to the describe() and it() methods to tell a high level story of what it means to be a particular object. We want the code in the examples to show us how to use that object.

Now that we have enough working code to start interacting with the codebreaker game, this would be a good time to start doing some *exploratory testing* to make sure the marking algorithm is complete.

6.5 Exploratory Testing

Exploratory testing is exactly what it sounds like: testing through exploration of the app. Don't be fooled by the seeming haphazard nature of this. Google "exploratory testing" and you'll find upwards of 785,000 results. Testing is a craft of its own, rich with literature, experience, and community. But the details of exploratory testing are outside the scope of this book, and simply "exploring the app" will suffice for our needs.

Now that the codebreaker game can mark a guess for us, we just need a minor adjustment to bin/codebreaker and we can begin interacting with the game. Here's the script for *nix users:

Download cb/38/bin/codebreaker

```
#!/usr/bin/env ruby
$LOAD_PATH.push File.join(File.dirname(__FILE__),"..","lib")
require 'codebreaker'

game = Codebreaker::Game.new(STDOUT)
game.start(%w[r g y c])
while guess = gets
  game.guess guess.split
end
```

Windows users use the same script without the first line, and also add bin/codebreaker.bat with the following:

Download cb/37/bin/codebreaker.bat

```
@"ruby.exe" "%~dpn0" %*
```

Clearly the game won't be too much fun because it's got the same code every time, but at least at this point you can show your friends. You know, the ones who know about CTRL-C, but don't necessarily know about cat.

Perhaps you're wondering why we'd want to do exploratory testing if we've already tested the app. Well, we haven't. Remember, that BDD is a design practice, not a testing practice. We're using executable examples of how we want the application to behave. But just as Big Design Up Front fails to allow for discovery of features and designs that naturally emerge through iterative development, so does driving out behaviour with examples fail to unearth all of the corner cases that we'll naturally discover by simply using the software.

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As you explore the Codebreaker game, try to find the flaws in the marking algorithm. You'll know what the not-so-secret code is, so try different inputs and see what happens. What happens when you guess `rgyb`, with no spaces? What happens when you use the same colors more than once in the secret code? In the guess? What happens when you type characters other than the prescribed r, g, y, c, b and w?

As you're doing this, flaws will appear for a variety of reasons. Perhaps there are missing scenarios or code examples. Some flaws may stem from naive design choices. The reasons for these flaws are not important. What *is* important is that the investment we've made to get this far has been very, very small compared to an exhaustive up-front requirements gathering process. An interactive session with working software is worth a thousand meetings.

6.6 What We Just Did

We began this chapter with a pre-existing set of passing scenarios, passing code examples, and working code. We then set out to extend the code to handle the next feature, submitting a guess to the system and having the system mark that guess.

In introducing this feature, we met some interesting challenges and learned some new techniques, including:

- Scenario outlines and tables to express like scenarios in a clean, readable way.
- Refactoring examples and code together when requirements change, so that we can embrace change *and* keep the bar green.
- Allowing some duplication between scenarios and code examples in order to maintain quick fault isolation and good object design.
- Doing the simplest thing to get a failing code example to pass, and channeling the urge to enhance the code into enhancing its specifications first.
- Refactoring step definitions and code examples, keeping in mind that expressiveness and localization are key factors in keeping them maintainable.
- Exploratory testing to weed out bugs and edge cases that we might not think of until we're actually interacting with the software.

Chapter 7

Evolving Existing Features

Welcome back! How was the exploratory testing? Did you discover anything missing from the marking algorithm? There are certainly edge cases that we missed. As you discovered each one, how did it make you feel? Did you feel frustrated that we had done so much work to produce something so incomplete? Or did you feel happy to make these discoveries before showing your friends? Or perhaps you *did* show your friends, and felt embarrassed when they discovered the bugs for you!

Now imagine that we had attempted to think through all of the edge cases before. We might have gotten further along than we did. This isn't a very complex problem compared to many, after all. But the likelihood is that we would have done roughly the same amount of exploratory testing that we ended up doing, only to catch fewer faults.

So now that we *have* discovered some faults, let's feed that learning back into the process.

7.1 Adding New Scenarios

We're now at the beginning of a new iteration, and it's time to apply the lessons learned from exploratory testing. One flaw that emerged was that the marking algorithm does not handle duplicates properly when duplicate pegs in the guess match a single peg in the secret code.

Here's a Cucumber scenario that should help to clarify this:

Download cb/39/features/codebreaker_submits_guess.feature

```
Scenarios: dups in guess match color in code
  | code    | guess   | mark |
  | r y g c | r y g g | bbb  |
```

In this scenario, the first three pegs in the guess match the first three pegs in the code, so they each get a black marker peg. The fourth peg in the guess is the same color as the third peg. Since the third peg already earned a black mark for matching the third peg in the guess, the fourth peg should not get any mark at all.

Add this scenario to codebreaker_submits_guess.feature and run the feature with cucumber. Here's the output:

```
| r y g c | r y g g | bbb  |
  expected ["Welcome to Codebreaker!", "Enter guess:", "bbbw"]
      to include "bbb" (Spec::Expectations::ExpectationNotMetError)
```

As you can see, the game is giving a black mark for the third peg in the guess, *and* a white mark for the fourth!

Here's another scenario we didn't account for, but learned about through exploratory testing:

Download cb/39/features/codebreaker_submits_guess.feature

```
Scenarios: dups in guess match color in code
  | code    | guess   | mark |
  | r y g c | r y g g | bbb  |
  | r y g c | r y c c | bbb  |
```

The second scenario is similar to the first, but this time the third and fourth pegs in the guess match the *fourth* peg in the secret code instead of the third. In this case, we want the game to give a black marker for the fourth peg in the guess and ignore the third. Here's what we get now:

```
| r y g c | r y c c | bbb  |
  expected ["Welcome to Codebreaker!", "Enter guess:", "bbbw"]
      to include "bbb" (Spec::Expectations::ExpectationNotMetError)
```

This is the same result as the first scenario.

Here's a third scenario along the same lines, with a subtle difference. This time neither of the duplicate pegs are in the right position in the guess:

Download cb/39/features/codebreaker_submits_guess.feature

```
Scenarios: dups in guess match color in code
  | code    | guess   | mark |
  | r y g c | r y g g | bbb  |
  | r y g c | r y c c | bbb  |
  | r y g c | g y r g | bww  |
```

The first green peg in the guess gets a white mark because it matches a color in the code, but in the wrong position. The second peg in the guess, yellow, matches the code in color and position, so it gets a black mark. One black, one white.

The third peg in the guess, red, matches the first peg in the code, so it gets a white mark. One black, two white.

Finally, the last peg in the guess is green. While it matches the color of the third peg in the code, that peg was already accounted for by the first green peg in the guess. So this last peg in the guess does not get a mark at all. This leaves us with a mark of bww. At least that's what we expect. When we run the feature with this third new scenario, we see this in the output:

```
| r y g c | g y r g | bww  |
  expected ["Welcome to Codebreaker!", "Enter guess:", "bwww"]
      to include "bww" (Spec::Expectations::ExpectationNotMetError)
```

7.2 Managing Increasing Complexity

We now have three brand new failing scenarios. Before this chapter we've been blithely cruising down the happy path, but we are now faced with challenging edge cases. And these new scenarios bring us to a whole new level of complexity in the marking algorithm.

Not only do we need to account for each peg as we see it, but we have to keep track of what we've already marked so that we don't mark against the same peg in the code twice. And to make things even more complex, when we hit a peg that we want to give a white mark, we need to see if it might earn a black mark later on!

OK. Settle down. We can do this. And not only can we do this, but we can do this calmly, rationally, and *safely*, by refactoring the existing design step by step.

The three new scenarios are failing due to logical errors, not syntax or structural errors. We don't need any new step definitions at this point. The ones we have are working just fine. We just need to improve the code, so let's head right to RSpec. Again, we'll start with an example mirroring the first failing Cucumber scenario:

Download cb/39/spec/codebreaker/game_spec.rb

```
context "with duplicates in the guess that match a peg in the code" do
  context "by color and position" do
```

Lessons learned while coaching

In March, 2009, after we had released the second beta of this book, and before this chapter was written, I had the good fortune to run the first ever Chicago Ruby Brigade Coding Dojo. Given that I was working on this tutorial, I used the Codebreaker marking algorithm as the problem to solve.

Much to everybody's joy, about twenty minutes into it, all of the scenarios (from the previous chapters) were passing. Much to everybody's dismay, that was all I had prepared for the session. So we decided to explore these more complex scenarios, and an interesting thing happened.

The first few scenarios had allowed for a very gradual increase in complexity. But when it came to these new scenarios, the leap was so severe that it was disorienting. We all, including me, lost sight of the task at hand, forgot the principles we were trying to put into practice, and launched into a theoretical algorithm problem-solving session.

The step by step approach described in this chapter is the antidote for that sort of blockage.

```
    it "should add a single b to the mark" do
      @game.start(%w[r y g c])
      @messenger.should_receive(:puts).with("bbb")
      @game.guess(%w[r y g g])
    end
  end
end
```

Which produces this failure:

```
1)
Spec::Mocks::MockExpectationError in 'Codebreaker::Game \
  marking a guess with duplicates in the guess that \
  match a peg in the code by color and position should \
  add a single b to the mark'
Mock 'messenger' expected :puts with ("bbb") but received it with (["bbbw"])
./39/spec/codebreaker/game_spec.rb:49:

Finished in 0.003503 seconds

6 examples, 1 failure
```

To get this to pass, we need to make sure that we don't add a white mark for the last peg in the guess. One way we could do this is to keep track of each position in the secret code as we iterate through the guess. We would begin by changing result to an array of four nils. If the peg at guess[0] matches the peg at @code[0], then we replace result[0] with a b.

If not, then we check the code to see if the peg is anywhere in the code at all using @code.include?(peg). If it *is* in the code, then we discover its position with @code.index(peg). Here's where it gets interesting. We then ask the result if it still has nil in that position. If not, then we know it's already been marked! If so, then we replace it with a w.

Once we've done all that, we get rid of any remaining nils before sorting and joining the contents of the array to generate the mark.

Now this seems like a good plan, but the current design won't support it very easily. We'll need to do some refactoring *before* we can add this new capability. But there's a catch. We have a failing example right now, so we'd be refactoring *in the red*.

7.3 Refactoring In the Green

Here's a great guideline to follow: only refactor when all of your RSpec code examples are passing. We call this refactoring *in the green*, because we rely on the green bar of passing examples to know that we're preserving behaviour as we go.

We just added a failing example. It's failing because the design doesn't support the new expected behaviour, not because a change to the code introduced a bug. We can therefore safely remove the example, refactor in the green, and then restore the example when we're done. But where do we put it in the meantime?

Many folks just comment the example out. *Do not do this!* There is little more unnerving than discovering an example that was commented out months ago and forgotten about. RSpec offers a better solution in the form of the pending() method.

Pending

To temporarily disable an example, but do so in such a way that you won't lose sight of it, add pending() to the example, like this:

Download cb/40/spec/codebreaker/game_spec.rb

```
context "with duplicates in the guess that match a peg in the code" do
  context "by color and position" do
    it "should add a single b to the mark" do
      pending()
      @game.start(%w[r y g c])
      @messenger.should_receive(:puts).with("bbb")
      @game.guess(%w[r y g g])
    end
  end
end
```

When you run the specs you'll see something like this at the bottom of the output:

```
Pending:

Codebreaker::Game marking a guess with duplicates in the \
  guess that match a peg in the code by color and position \
  should add a single b to the mark (TODO)
./spec/codebreaker/game_spec.rb:48

6 examples, 0 failures, 1 pending
```

Now every time you run the examples, you'll be reminded that you have a pending example waiting for your attention. There are actually three different ways to use pending(). You can read about the others in detail in Section 12.2, *Pending Examples*, on page 187.

Refactor towards the new design

Our goal now is to change the design such that it passes the same code examples and scenarios, but better positions us to satisfy the new requirements. For the next little while, we're going to zip through changing this code very quickly in very small steps. Be sure to run the examples between every step. The reason we can move this quickly is that the green bar tells us that we're safe after every change we make. We'll discuss this more at the end of the chapter. Ready? Set? Go!

Step one:

Download cb/41/lib/codebreaker/game.rb

```
def guess(guess)
  result = []
  temp = [nil,nil,nil,nil]
  guess.each_with_index do |peg, index|
    if @code[index] == peg
      result << "b"
      temp[index] = "b"
```

```
-        elsif @code.include?(peg)
-          result << "w"
10         temp[index] = "w"
-        end
-      end
-      @messenger.puts result.sort.join
-    end
```

Here we add a new array named temp on line 3, and then assign it "b" and "w" values at the current index on lines 7 and 10. This is preparatory work. Nothing in the calculation has changed yet.

Step two (did you run the specs first?):

Download cb/42/lib/codebreaker/game.rb

```
Line 1  def guess(guess)
-         result = []
-         temp = [nil,nil,nil,nil]
-         guess.each_with_index do |peg, index|
5           if @code[index] == peg
-             result << "b"
-             temp[index] = "b"
-           elsif @code.include?(peg)
-             result << "w"
10            temp[index] = "w"
-           end
-         end
-         @messenger.puts temp.sort.join
-       end
```

Here we simply replace the result with temp on line 13. Run the specs. Still passing!

Step 3: remove all the references to result.

Download cb/43/lib/codebreaker/game.rb

```
def guess(guess)
  temp = [nil,nil,nil,nil]
  guess.each_with_index do |peg, index|
    if @code[index] == peg
      temp[index] = "b"
    elsif @code.include?(peg)
      temp[index] = "w"
    end
  end
  @messenger.puts temp.sort.join
end
```

Run the specs. Still passing. Step 4: change temp to result.

Download cb/44/lib/codebreaker/game.rb

```
def guess(guess)
  result = [nil,nil,nil,nil]
  guess.each_with_index do |peg, index|
    if @code[index] == peg
      result[index] = "b"
    elsif @code.include?(peg)
      result[index] = "w"
    end
  end
  @messenger.puts result.sort.join
end
```

Run the specs. Still passing. Now reinstate the pending example by removing or commenting the pending() declaration and run them again. Same failure as before, but we've made progress! We're now interacting with the structure we want internally, and we haven't caused any of the earlier examples to fail.

Check the scenarios

It turns out, however, that all of the earlier code examples involve guessing all four colors in the secret code. The Cucumber scenarios had examples with three, two, one and even no colors correct, so let's run codebreaker_submits_guess.feature and see where we are.

```
Scenarios: 3 colors correct
  | code    | guess   | mark |
  | r g y c | w g y c | bbb  |
    undefined method `<=>' for nil:NilClass (NoMethodError)
    ./44/features/support/../../lib/codebreaker/game.rb:23:in `sort'
    ./44/features/support/../../lib/codebreaker/game.rb:23:in `guess'
    ./44/features/step_definitions/codebreaker_steps.rb:21:in
        `/^I guess (. . . .)$/'
    44/features/codebreaker_submits_guess.feature:28:in
        `When I guess w g y c'
```

There are actually quite a few scenarios failing like this, and they all report the same problem: undefined method `<=>' for nil:NilClass. This is happening because we're sorting all the elements in the array, but there are still going to be nils in there unless we guess all four colors.

Heading back to RSpec, restore the pending() declaration to the example of duplicates, and let's add a new example that matches this first scenario that we just broke:

Download cb/45/spec/codebreaker/game_spec.rb

```
context "with three colors correct in the correct places" do
```

```
  it "should mark the guess with bbb" do
    @game.start(%w[r g y c])
    @messenger.should_receive(:puts).with("bbb")
    @game.guess(%w[r g y w])
  end
end
```

Run the examples and you'll see this in the output:

```
1)
ArgumentError in 'Codebreaker::Game marking a guess with three colors \
  correct in the correct places should mark the guess with bbb'
comparison of String with nil failed
./45/spec/codebreaker/../../lib/codebreaker/game.rb:23:in `sort'
./45/spec/codebreaker/../../lib/codebreaker/game.rb:23:in `guess'
./45/spec/codebreaker/game_spec.rb:49:
```

The comparison of String with nil failed message shows that the example fails in the way we expected. And the fix is simple:

Download cb/46/lib/codebreaker/game.rb

```
Line 1  def guess(guess)
-         result = [nil,nil,nil,nil]
-         guess.each_with_index do |peg, index|
-           if @code[index] == peg
5             result[index] = "b"
-           elsif @code.include?(peg)
-             result[index] = "w"
-           end
-         end
10        @messenger.puts result.compact.sort.join
-       end
```

We just remove all the nils by compacting the array before sorting and joining on line 10.

Now run the scenarios again, and you'll find that we have successfully refactored the design in order to better adapt to the new requirement. We know that the refactoring was successful because all of the previously passing scenarios are still passing.

But don't stop to bask in the glory just yet. We're not quite finished. While the previously passing scenarios and code examples are all passing, all three new scenarios are still failing. And if you get rid of the pending() declaration, you'll see that the new example is still failing.

Slide in the new change

Now that we've refactored towards the structure we want, and we've used the Cucumber scenarios to help us prove that out, it's time to add the logic that we discussed earlier. There are two things we still need to do:

- Put white marks in the position of the matching peg in the secret code instead of the current index.
- Check to see that the peg we're about to give a white mark for has not already been given a black mark.

Step one:

Download cb/47/lib/codebreaker/game.rb

```
def guess(guess)
  result = [nil,nil,nil,nil]
  guess.each_with_index do |peg, index|
    if @code[index] == peg
      result[index] = "b"
    elsif @code.include?(peg)
      result[@code.index(peg)] = "w"
    end
  end
  @messenger.puts result.compact.sort.join
end
```

Run the specs and they all pass. Now remove the pending() declaration and run them again. You'll see that the example is still failing, but now it's failing differently. Instead of getting bbbw, we get bbw. Can you see why this is happening? See if you can before reading the next paragraph.

The guess() method marks the first three pegs with a b, but then it replaces the third b with a w when it evaluates the fourth peg in the guess. So now we're only one step away from getting this to pass. And here is that step:

Download cb/48/lib/codebreaker/game.rb

```
def guess(guess)
  result = [nil,nil,nil,nil]
  guess.each_with_index do |peg, index|
    if @code[index] == peg
      result[index] = "b"
    elsif @code.include?(peg)
      result[@code.index(peg)] ||= "w"
    end
  end
  @messenger.puts result.compact.sort.join
end
```


this copy is (B12.0 printing, December 3, 2009)

We simply change the assignment on line 7 to a conditional assignment using ||=. For those new to Ruby, this will only assign the value if it is currently nil or false.

Now run the specs. They all pass. Now run the feature. All the scenarios are passing.

7.4 What we just did

In this chapter we added new scenarios to an existing feature. We modified the code in baby steps, refactoring in the green nearly the whole time. This sort of approach can seem exhausting at first. We only changed a few lines of code, why not just change them all at once and be done with it?

The truth is that most experienced TDD practitioners will stray from this granularity and make changes in larger strokes, but they have the wisdom to recognize quickly when those changes are heading them in the wrong direction. Once they do, they typically back up to the last known good state, run the examples and watch them pass, and then start again, but this time with smaller steps. But you've got to learn to walk before you can run.

You also learned how to temporarily disable an example with the pending() method. This is one of the many tools that RSpec includes to make the process of driving out code with examples a more pleasurable and productive one.

In the next and last chapter of this tutorial, we'll take the next step in making the Codebreaker game real by driving out a random code generator with Cucumber and RSpec. Before we move on though, were there any other defects in the marking algorithm that you found in your own exploratory testing? If so, add some new scenarios to reflect them. If they fail, drive out the changes on your own, trying to stay in the green as much as possible.

Chapter 8

Managing Complexity in Step Definitions

By now you've spent hours, perhaps days, dazzling your friends family with Codebreaker, playing it over and over again with the same not-so-secret-code that we programmed into bin/codebreaker. As enjoyable as that may be, by the end of this chapter you'll really be able to tease your brain by trying to guess real secret codes that are generated by a random code generator every time you play.

As you'll discover, writing the random code generator is straightforward. The bigger challenge is figuring out how to drive it out with Cucumber scenarios and RSpec code examples. The reason for this is that the outcome of running a random generator is non-deterministic. It changes from run to run, producing an outcome that is likely different each time, though it's possible for it to be the same two times in a row.

A common solution for this problem is to run the generator some meaningful number of times, and set expectations within a range of possible outcomes. Testing against a statistical sample like this is not unique to BDD, but it does present some interesting problems in the context of our BDD toolset, which we'll explore in this chapter.

8.1 Statistical Sampling in Cucumber Features

The first thing we need to do is write a Cucumber feature that expresses our desired outcomes from the outside. We have six different colors, so each color should appear roughly 1/6 of the time, or 16.7%, in each position.

We also need to decide whether or not to allow duplicates in the secret code. From a code-breaker's perspective, it is far easier to break the code in which each color can only appear once, so we'll set that as an expectation to begin with. We can always add a user-selectable option to allow duplicates later in the development process.

Here is a Cucumber feature that expresses these requirements:

```
Feature: game generates random secret code

  In order to keep the codebreaker game interesting
  I want the game to generate a random secret code each time I play

  Scenario: 10,000 games
    Given 6 colors
    And 4 positions
    When I play 10,000 games
    Then each color should appear between 1500 and 1800 times in each position
    And each color should appear no more than once in each secret code
```

No-op Step Definitions

We haven't discussed the possibility of variable numbers of colors and positions, so the Givens may seem unnecessary, but we're using them to provide mathematical context for the acceptable range of outcomes expressed in the first Then step. The definitions for the givens will be no-ops, but should we ever decide to allow for variable numbers of colors and positions, we can enhance them to configure the game appropriately.

Go ahead and copy the feature above into features/game_generates_secret_code.feature and run it with cucumber. Then copy all the resulting code snippets into features/step_definitions/codebreaker_steps.rb and remove the pending statements from Given /^6 colors$/ and Given /^4 positions$/. If you run the feature again you should see 5 steps (2 skipped, 1 pending, 2 passed).

The next step to tackle is When I play 10,000 games. We need to iterate 10,000 times, starting a new game each time and capturing the secret code for each game as we go. Here is a starting implementation of this step definition:

Download cb/50/features/step_definitions/codebreaker_steps.rb

```ruby
When /^I play (.*) games$/ do |number|
  number.scan(/\d/).join.to_i.times do
    game.start
  end
end
```

Line 2 is a bit tricky: we take the “10,000” captured by the regular expression, scan it for digits (to eliminate the comma), join them in a single string and then call to_i() on that string.

Extract Helper Methods

If you’re new to Ruby, this may seem quite complex. In fact, even if you’re not new to Ruby, you really have to study it for a few seconds to understand the intention. We can improve on that with an Extract Method refactoring, moving the complex part out to a helper method with an intention-revealing name:

Download cb/51/features/step_definitions/codebreaker_steps.rb

```
def fixnum_from(string)
  string.scan(/\d/).join.to_i
end

When /^I play (.*) games$/ do |number|
  fixnum_from(number).times do
    game.start
  end
end
```

We haven’t eliminated the complexity, but we’ve moved it to a method whose name explains what the code does. This is no different from the sort of refactoring we do with the application code we’re developing.

Back to the step, inside the loop we call game.start without any arguments. This is different from our previous usage, in which we passed a not-so-secret code to the start() method. If you copy the implementation of the step definition and helper method to features/step_definitions/codebreaker_steps.rb and run cucumber, you should now see the following failure in the output:

```
When I play 10,000 games
  wrong number of arguments (0 for 1) (ArgumentError)
  ./50/features/step_definitions/codebreaker_steps.rb:45:in `start'
  ./50/features/step_definitions/codebreaker_steps.rb:45:in `__instance_exec0'
  ./50/features/step_definitions/codebreaker_steps.rb:44:in `times'
  ./50/features/step_definitions/codebreaker_steps.rb:44:in `/^I play (.*) games$/'
  50/features/game_generates_secret_code.feature:9:in `When I play 10,000 games'
```

Progress! The failure tells us that game.start is expecting the secret code, but we don’t want to provide that any more because we’re specifying that the game should generate its own secret code. We’re changing the requirements, so we need to step back and think about the design we have so far.

Introducing a Polymorphic Dependency

As things stand right now, the start() method in Game expects a code. We need to modify things so that if we don't pass in a code, it generates one itself. The game is already responsible for welcoming the user and marking each guess. One could make the argument that we've already violated the Single Responsibility Principle,[1] but at least in each of those cases there are no decisions to be made. Now we're asking the Game to behave one way when given a code, and another when not.

One of the basic concepts of Object Oriented Programming is that we use polymorphism instead of conditional logic when we want to change runtime behaviour of a program. The Open Closed Principle clarifies this idea by suggesting that software should be open to extension (by adding new components), but closed to modification (by changing existing code).[2] What this all means to our Codebreaker example is that instead of adding conditional logic to the Game, we should consider introducing a new object that generates the code.

For the scenarios, code examples, and exploratory testing in which we need to specify the secret code in advance, we can use a test double that we can program to supply a pre-determined secret code. For real play, and the scenarios and examples we'll be adding now to drive out the code generation, we'll use a real generator that generates a random code every time.

This approach exploits polymorphism, allowing us to extend the software by introducing new generators, while not having to modify the code in the Game object itself. At least that will be true after this modification.

Finding an Entry Point

So the next question is when we should give the generator to the game. The two obvious points of entry are when we construct the game and when we send it the start() message. If we pass the generator to start(), we need to pass it in every time we start a new game. On the other hand, if we pass it to new(), then we have to create a new Game every time we want to play a new game.

1. See *Agile Software Development: Principles, Patterns and Practices* [Mar02] for more on the Single Responsibility Principle.
2. See *Agile Software Development: Principles, Patterns and Practices* [Mar02] for more on the Open Closed Principle.

There are good arguments for both approaches, and without knowing what lies in store further down the road, it seems like a bit of a crap shoot at this point. With that, let's go with the low hanging fruit, and pass the generator to the start() method. That's going to require changing a few things. Here are all the step definitions and helpers that will need to change:

Download cb/52/features/step_definitions/codebreaker_steps.rb

```
Given /^the secret code is (. . . .)$/ do |code|
  game.start(code.split)
end

When /^I start a new game$/ do
  game.start(%w[r g y c])
end

When /^I play (.*) games$/ do |number|
  fixnum_from(number).times do
    game.start
  end
end
```

And all seven code examples in game_spec.rb will need to change as well. Now we're only talking about a relatively small number of changes, so brute force is certainly tempting, but let's take a disciplined approach to this. We're not going to go through every example together, but we'll get you started.

Introduce Temporary Conditional

First, change the start() method as follows:

Download cb/52/lib/codebreaker/game.rb

```
def start(code_or_generator)
  @code = code_or_generator.respond_to?(:code) ?
    code_or_generator.code : code_or_generator
  @messenger.puts "Welcome to Codebreaker!"
  @messenger.puts "Enter guess:"
end
```

Run the examples with spec spec and they should all pass. All we did was say that if the argument to the start() method responds to code(), then we should treat it as a generator and ask it to generate a code. Otherwise, we assume that it *is* the secret code and use it directly

But wait a minute? Didn't we just decide we wanted to use polymorphism instead of conditional logic in this method? Yes! Yes, we did. Modifying the method like this is a temporary measure to get us through this refactoring. Once we're done, we should never have to change this method again in order to introduce new generators.

The next step is to pass in something that responds to code() that we can program to provide the code we need in each example. Start with the first example, starting up should send a welcome message. We'll pass it a stub using RSpec's stub() method (part of RSpec's mocking and stubbing framework):

Download cb/52/spec/codebreaker/game_spec.rb

```
it "should send a welcome message" do
  @messenger.should_receive(:puts).with("Welcome to Codebreaker!")
  @game.start(stub('generator', :code => %w[r g y c]))
end
```

Run the specs again and they should all pass. Now, one at a time, change the start() method in each example just like this one, passing in a stub object that stubs the code() method to return the secret code we need for the example. The specs should pass between every change.

Once you've done that, we need to change the step definitions. In order to use RSpec to generate the stubs for us, we have to do a small bit of wiring in our features directory because Cucumber isn't automatically wired up to tear down stubs at the end a scenario. Making it so is rather trivial, however. Just add the following to features/support/env.rb:

Download cb/53/features/support/env.rb

```
require 'spec/stubs/cucumber'
```

The spec/stubs/cucumber ships with RSpec (as of version 1.2.8), and adds behaviour to the Cucumber World to support using RSpec stubs in Cucumber scenarios.[3]

Next, just update the step definitions to use the stubs:

Download cb/53/features/step_definitions/codebreaker_steps.rb

```
Given /^the secret code is (. . . .)$/ do |code|
  game.start(stub('generator', :code => code.split))
end

When /^I start a new game$/ do
  game.start(stub('generator', :code => %w[r g y c]))
end
```

3. Note that the code included when you require spec/stubs/cucumber does not verify message expectations.

Now run all of the features we had in place before and you should still see 17 scenarios (17 passed):

```
cucumber features/codebreaker_starts_game.feature \
         features/codebreaker_submits_guess.feature
```

Now we can remove the temporary conditional in the start() method. With the exception of the step definition in our newest and failing scenario, every client of that method is passing it something that quacks like a generator.[4] Go ahead and modify lib/codebreaker/game.rb as follows:

Download cb/53/lib/codebreaker/game.rb

```
def start(generator)
  @code = generator.code
  @messenger.puts "Welcome to Codebreaker!"
  @messenger.puts "Enter guess:"
end
```

All of the specs should still pass after that change. Same for all the pre-existing scenarios. Which brings us back to the task at hand!

Introducing a Random Generator

We've still got a failing step in our newest scenario, but now it is failing because we're not passing a generator (or anything at all) to the start() method. Now it's time to introduce our random generator. Modify features/step_definitions/codebreaker_steps.rb as follows:

Download cb/54/features/step_definitions/codebreaker_steps.rb

```
When /^I play (.*) games$/ do |number|
  generator = Codebreaker::Generator.new
  fixnum_from(number).times do
    game.start(generator)
  end
end
```

This adds a reference to the Codebreaker::Generator class, which does not yet exist. Run the feature with cucumber and you should see uninitialized constant Codebreaker::Generator, which is exactly what we'd expect. So now it's time to drive out our generator.

Previously we've started with a spec each time we introduced a new object in a Cucumber step, but let's take a different approach. To get this step to pass, we just need to hand something to the start() method

4. We often refer to Ruby's sense of type as *duck typing*, meaning that if it looks like a duck and it quacks like a duck, then for our purposes, it' a duck!

that implements a code() method. So let's just create that much. Add a generator.rb file to the lib/codebreaker directory with the following code:

Download cb/55/lib/codebreaker/generator.rb

```
module Codebreaker
  class Generator
    def code
    end
  end
end
```

Now require that file from lib/codebreaker.rb:

Download cb/55/lib/codebreaker.rb

```
require 'codebreaker/game'
require 'codebreaker/generator'
```

Run the features and you should see that the step is passing. Success! So, how do you feel? Do you feel dirty? Like you skipped a step? If you do, then you've arrived! At least you've arrived at the stage at which you understand the flow. There's another level that you haven't quite landed on yet, however, which is understanding the process well enough to know when it's OK to skip steps.

The reason to shift gears and jump over to RSpec here would be if we were implementing some non-trivial behaviour that we want to drive at a granular level. In this case, all we're doing is saying this object should exist and it should respond to the code method. That's all we need to pass what we've got so far. If we refactor later and accidentally remove or otherwise change this method, this feature will tell us very quickly that there is no code() method. So we're good for the moment! No harm, no foul.

Balancing Complexity

Moving on, let's take a look at the next pending step: Then each color should appear between 1500 and 1800 times in each position. The step definition is going to have to access the 10,000 secret codes generated in the previous step, loop through each position, loop through each color, count the number of times each color appears in each position, and then expect that number to fall within a specified range. That's quite a bit of complexity in a single step definition.

Is that *too much* complexity in a single step definition? Let's consider some alternatives. We could use Cucumber's Background feature and write twenty four scenarios phrased like this:[5]

```
Background:
  Given 6 colors
  And 4 positions
  When I play 10,000 games

Scenario: red in the first position
  Then r should appear in the first position between 1500 and 1800 times
  And r should not appear in the 2nd, 3rd, and 4th positions

Scenario: yellow in the first position
  Then y should appear in the first position between 1500 and 1800 times
  And y should not appear in the 2nd, 3rd, and 4th positions

etc, etc
```

We could make that a bit less verbose using a Scenario Outline and tabular data:

```
Scenario Outline:
  Given 6 colors
  And 4 positions
  When I play <some number of> times
  Then <color> appear in position <position> between <min> and <max> times

Scenarios:
  | number | color | position |  min |  max |
  | 10,000 |     r |        1 | 1500 | 1800 |
  | 10,000 |     y |        1 | 1500 | 1800 |
  | 10,000 |     g |        1 | 1500 | 1800 |
  etc, etc
```

Of course, that leaves out the expectation that each color appears only once in each code.

The single step definition above is not only more concise than either of these options, it is also more expressive. We're also more likely to cover all twenty four cases, as it would be easy to miss one if we were writing out each scenario separately. It also requires that we only loop through 10,000 games one time, whereas separate scenarios for each case would mean repeating that loop 24 times.

5. Cucumber's Background feature is like before(:each) in RSpec. It lets us specify steps to run before each scenario within a feature. Read more about the Background feature in the (as yet) unwritten *chp.cucumber*

It's pretty clear that having just one scenario makes a lot of sense in this case, but still leaves us with a very complex step definition, with several points of failure. We're going to want to break that up into a few helper methods and, in this case, we're going to drive those methods into existence using RSpec.

8.2 Specifying Step Definition Helpers with RSpec

As a general guideline, the code in step definitions should be so simple that they couldn't possibly break. There can, however, be tension between simplicity in step definitions and expressiveness of the scenarios that use them. When we choose to make step definitions more complex to support expressive scenarios, we need to make sure that those definitions work the way we expect.

That may seem like a daunting task, but remember, the code in a step definition is just code, and we already know how to drive out code that meets our needs in a reliable way: by example, with RSpec.

Discovery

In order to discover what helper methods we need, let's write the code we wish we had in the Then each color should appear between 1500 and 1800 times in each position step:

Download cb/56/features/step_definitions/codebreaker_steps.rb

```
Then /^each color should appear between (\d+) and (\d+) times in each position$/ do
  |min, max|
  %w[r y g c b w].each do |color|
    (1..4).each do |position|
      secret_codes.count_for(color, position).
        should be_between(min.to_i,max.to_i)
    end
  end
end
```

To make this code work, we'll need a secret_codes object that collects all of the codes for us and analyzes them. That's going to take a bit of doing to write, and it has limited utility, but consider the alternative. Here's what this definition might look like if we just encoded everything inside the step directly:

```
Then /^each color should appear between (\d+) and (\d+) times in each position$/ do
  |min, max|
  counts = (1..4).collect { Hash.new {|h,k| h[k] = 0}}
  codes.each do |code|
```

```
5      code.split.each_with_index do |color, index|
         counts[index][color] += 1
       end
     end
     %w[r y g c b w].each do |color|
10     (1..4).each do |position|
         counts[position-1][color].should be_between(min.to_i,max.to_i)
       end
     end
   end
```

Now that is a lot of processing in a single method, with many points of failure and confusion, any one of which would be difficult to track down if we got it wrong. Consider the iterator beginning on line 10. It iterates through the range (1..4), passing a position argument to the block. The fact that we call it position, and positions start at 1, not 0, suggests that the range (1..4) is more clear than (0..3).

Within that block, however, we need zero-based indexes to access the right element in the counts array, so we subtract 1 from the position. Now we could just use (0..3), but then we'd want to change the block argument's name to index, at which point it begins to lose its meaning.

With all that confusion, it's pretty easy to see that the few minutes we'll spend developing a secret_codes object will pay for itself the first time this step fails and we avoid a lengthy debugging session. So let's get to it.

Finding a Home

The first question we need to answer is where do the specs go? As of this writing, there is a lack of consensus on a convention as to where to put specs for helper objects and methods like this. We'll offer up one logical approach, but this is certainly not the only way to do it.

Add a directory named cucumber to the spec directory. This is where we'll put specs for step definition helpers, which will live in files in features/support.

The next question is what to call this object. While secret_codes seems like a good variable name in the step definition, it doesn't really convey the meaning of this object that well. Its role is to collect secret codes and provide statistical information about which colors show up how often in which position. So let's go with Stats for the name of the class, in which case we'll write the spec in stats_spec.rb in spec/cucumber. Go ahead and create that file and start with the following outline:

Download cb/57/spec/cucumber/stats_spec.rb

```
1 require File.join(File.dirname(__FILE__),"..","spec_helper")
2 require File.join(File.dirname(__FILE__), "..","..","features","support","stats")
3
4 module Codebreaker
5   describe Stats do
6   end
7 end
```

The require() statement on line 2 references the specific file in which we'll define the Stats class. Go ahead and add that file with the following:

Download cb/57/features/support/stats.rb

```
module Codebreaker
  class Stats
  end
end
```

We're using the Codebreaker module purely as a namespacing device. This limits the potential of a naming conflict with another Stats object to the code in the Codebreaker app. Much more predictable and manageable than if we define Stats at the top level.

Step Definition Helpers are Just Code

So now we're all set up and ready to drive out the Stats class. Here is a spec with some pending examples that express the requirements:

Download cb/58/spec/cucumber/stats_spec.rb

```
module Codebreaker
  describe Stats do
    context "with 1 code with r in position 1" do
      it "returns 1 for count_for('r',1)"
      it "returns 0 for count_for('y',1)"
    end
    context "with 2 codes with r in position 1 twice and y in position 2 once" do
      it "returns 2 for count_for('r',1)"
      it "returns 0 for count_for('y',1)"
      it "returns 1 for count_for('y',2)"
    end
  end
end
```

Rather than going through this one step at a time together, why don't you use these pending examples as a basis for driving out the Stats class on your own? Work with one example at a time, leaving the others pending until all of the previous examples are passing. Don't hesitate to add new examples if you find them helpful.

Here is what we ended up with. We discovered a couple of things along the way, which we'll discuss in a minute. Don't worry if you ended up with something different. Maybe what you have is even better! But what we came up with was enough to drive out something useful that gives us enough confidence that the Stats object is going to work correctly in the step definition, and it only took a few minutes to actually drive out the code once we had the initial set of pending specs worked out.

First, here's the spec.

Download cb/59/spec/cucumber/stats_spec.rb

```
require File.join(File.dirname(__FILE__),"..","spec_helper")
require File.join(File.dirname(__FILE__), "..","..","features","support","stats")

module Codebreaker
  describe Stats do
    describe "#puts" do
      it "ignores messages that are not secret codes" do
        stats = Stats.new
        stats.puts "r y g this is not a secret code"
        stats.count_for('r',1).should == 0
        stats.count_for('y',2).should == 0
        stats.count_for('g',3).should == 0
      end
    end
    context "with 1 code with r in position 1" do
      before(:each) do
        @stats = Stats.new
        @stats.puts "r y g b"
      end
      it "returns 1 for count_for('r',1)" do
        @stats.count_for('r',1).should == 1
      end
      it "returns 0 for count_for('y',1)" do
        @stats.count_for('y',1).should == 0
      end
    end
    context "with 2 codes with r in position 1 twice and y in position 2 once" do
      before(:each) do
        @stats = Stats.new
        @stats.puts "r y g b"
        @stats.puts "r g b w"
      end
      it "returns 2 for count_for('r',1)" do
        @stats.count_for('r',1).should == 2
      end
      it "returns 0 for count_for('y',1)" do
        @stats.count_for('y',1).should == 0
      end
      it "returns 1 for count_for('y',2)" do
```

```
        @stats.count_for('y',2).should == 1
      end
    end
  end
end
```

And here's the code that satisfies the spec.

Download cb/59/features/support/stats.rb

```
module Codebreaker
  class Stats
    def initialize
      @counts = (1..4).collect { Hash.new {|h,k| h[k] = 0} }
    end

    def puts(code)
      if code =~ /^\w \w \w \w$/
        code.split.each_with_index do |color, index|
          @counts[index][color] += 1
        end
      end
    end

    def count_for(color, position)
      @counts[position-1][color]
    end
  end
end
```

Do you see what we added? We used a puts() method to collect the secret codes. Why? The key is in this step definition, which was modified during this process:

Download cb/59/features/step_definitions/codebreaker_steps.rb

```
When /^I play (.*) games$/ do |number|
  generator = Codebreaker::Generator.new
  @stats = Codebreaker::Stats.new
  game = Codebreaker::Game.new(@stats)
  fixnum_from(number).times do
    game.start(generator)
  end
end
```

By using a puts() method to collect the codes, we can use the Stats as the messenger. That way we don't need to collect the codes in the step definitions and then pass them to the Stats object. Yet another example of how Ruby's approach to duck typing can help us to keep things clean, reusable, and flexible.

Go ahead and copy the code above to spec/cucumber/stats_spec.rb, features/support/stats.rb, and features/step_definitions/codebreaker_steps.rb respectively, and then run the features with cucumber. Everything should be passing except for this:

```
Then each color should appear between 1500 and 1800 times in each position
  expected between?(1500, 1800) to return true, got false \
                (Spec::Expectations::ExpectationNotMetError)
```

The failure message we get isn't very helpful. It's coming from the RSpec be_between() matcher, which is generated dynamically and is deliberately generic. In this case, that genericism leaves us missing an important bit of information: what was the count?

Customize Failure Messages

We can improve the message by supplying a custom message as a second argument to the should() method, like this:[6]

Download cb/60/features/step_definitions/codebreaker_steps.rb

```
Then /^each color should appear between (\d+) and (\d+) times in each position$/ do
  |min, max|
  %w[r y g c b w].each do |color|
    (1..4).each do |position|
      count = @stats.count_for(color,position)
      count.should be_between(min.to_i,max.to_i),
        "expected #{count} to be between #{min} and #{max}"
    end
  end
end
```

This works for any matcher (be_between() in this case) that does not use an operator, like 5.should == 5. Now run cucumber again and the failure message should be more helpful this time:

```
Then each color should appear between 1500 and 1800 times in each position
  expected 0 to be between 1500 and 1800 \
    (Spec::Expectations::ExpectationNotMetError)
```

Much better. The 0 points us in the right direction, suggesting that we're not actually collecting any of the secret codes. So how should we approach that collection? Well, we added the puts() method to the Stats object so that the Game could supply the codes in the same way it supplies console output. As far as the Game is concerned, the Stats is just a messenger. So how would the Game know when to send this message?

6. Custom failure messages were added to rspec-1.2.8.

A New Feature, Revealed

Thinking this through a bit, this is a feature waiting to happen. For manual testing purposes, we're going to want to be able to see the secret code that was generated so that we know the game is marking the guesses correctly. It would be great if we could type something like "reveal" on the command line and see the code. There are a couple of ways we could get that to happen. The simplest way would be to have the guess() method send the code to the messenger when it sees "reveal" instead of something that looks like a code.

Now you can probably hear your inner-designer getting more agitated, saying "Hey, the game is already doing way too much!" That's a good thing if it's happening, but we can't solve every problem at once. Right now we have a failing scenario we want to get passing. Once we've got it passing, we'll sit back and assess the design we've arrived at. For right now, let's stay focused on the task at hand.

Again, we're not going to go step by step together on this. Here are the examples we added (one at a time), followed by the resulting guess() method in lib/codebreaker/game.rb, and then the updated step definition calling guess(('reveal')):

Download cb/61/spec/codebreaker/game_spec.rb

```
module Codebreaker
  describe Game do
    before(:each) do
      @messenger = mock("messenger").as_null_object
      @game = Game.new(@messenger)
    end
    context "marking a guess" do
      context "with the text 'reveal'" do
        it "should send the secret code to the messenger" do
          @game.start(stub('generator', :code => %w[r g y c]))
          @messenger.should_receive(:puts).with("r g y c")
          @game.guess(["reveal"])
        end
      end
    end
  end
end
```

Download cb/61/lib/codebreaker/game.rb

```
def guess(guess)
  if guess == ['reveal']
    @messenger.puts @code.join(" ")
  else
    result = [nil,nil,nil,nil]
```

```
    guess.each_with_index do |peg, index|
      if @code[index] == peg
        result[index] = "b"
      elsif @code.include?(peg)
        result[@code.index(peg)] ||= "w"
      end
    end
    @messenger.puts result.compact.sort.join
  end
end
```

Download cb/61/features/step_definitions/codebreaker_steps.rb

```
When /^I play (.*) games$/ do |number|
  generator = Codebreaker::Generator.new
  @stats = Codebreaker::Stats.new
  game = Codebreaker::Game.new(@stats)
  fixnum_from(number).times do
    game.start(generator)
    game.guess(["reveal"])
  end
end
```

Now run cucumber again, and you should see something new in the output:

```
When I play 10,000 games
  undefined method `join' for nil:NilClass (NoMethodError)
```

Progress! The error is raised on the line we just added to the guess() method: @messenger.puts @code.join(" "). The Game is using the @code generated by our new Codebreaker::Generator, which we left returning nil. So *now* is the time to shift gears from Cucumber to RSpec and start driving out our random code generator.

8.3 Specifying Variable Outcomes

The Codebreaker game needs to generate a randomly selected secret code every time we play it. Thus far we've handled this source of non-determinism by isolating our code examples from it, using mocks and stubs. Now we're going to specify the behaviour of the non-deterministic source, which introduces a new challenge: how can we write code examples with concrete expectations in them if we're dealing with variable outcomes?

We've already addressed this from the outside with a Cucumber feature that uses a statistical sample. From a testing perspective, we can take the same approach at this lower level, but it gets a bit trickier when we consider that TDD is as much about design and process as it is about testing. We need to get from point A to Z in small, verifiable steps.

As with all answers to questions like this in this book, there is no one true way, but we can provide an approach and a couple of guidelines.

Extract Determinism

The first thing we can do is try to find expectations that *are* deterministic. For example, we know that the code should always have four colors in it, so we can write an example with an expectation that the code is a four element array. Go ahead and create spec/codebreaker/generator_spec.rb with the following:

Download cb/62/spec/codebreaker/generator_spec.rb

```
require File.join(File.dirname(__FILE__), "..","spec_helper")

module Codebreaker
  describe Generator do
    it "generates a four-element array" do
      generator = Generator.new
      generator.code.length.should == 4
    end
  end
end
```

That should fail with undefined method `length' for nil:NilClass since we left the code() method returning nil. To get it to pass, we can just return an arbitrary array, like this (in lib/codebreaker/generator.rb):

Download cb/63/lib/codebreaker/generator.rb

```
module Codebreaker
  class Generator
    def code
      [1,2,3,4]
    end
  end
end
```

Next, we expect that each code uses only the single letters that represent the six colors we use in the game: r, y, g, c, b, and w.

Download cb/63/spec/codebreaker/generator_spec.rb

```
it "only uses the game colors: r, y, g, c, b, and w" do
  generator = Generator.new
  generator.code.each do |color|
    %w[r y g c b w].should include(color)
  end
end
```

This fails with expected ["r", "y", "g", "c", "b", "w"] to include 1 because code() returns [1,2,3,4]. We can get this to pass by returning an array for four "r"'s instead:

Download cb/64/lib/codebreaker/generator.rb

```
module Codebreaker
  class Generator
    def code
      (1..4).collect {'r'}
    end
  end
end
```

Devil's Advocate

We could, of course, just think about how we want this to work and just write the code for it, but we want to write the simplest thing that could possibly work to get an example to pass. We do this because, obviously, we want to keep the code as simple as possible, but there are other reasons as well.

We also do it because it allows us to play a game of devil's advocate in which our inner developer tries to force our inner tester to write more examples. There is a balance to be found, of course. TDD beginners who try to take this to heart often end up with lots of examples for things like getters and setters. Unless those getters are performing a non-trivial calculation, specifying them doesn't provide much value. They should only ever come into existence to satisfy the need of some non-trivial behaviour that is being specified elsewhere.

Back to our scenario and code examples, if we run cucumber now, the output has changed slightly:

```
Then each color should appear between 1500 and 1800 times in each position
  expected 10000 to be between 1500 and 1800 \
    (Spec::Expectations::ExpectationNotMetError)
```

The 10000 used to be 0. We can see that the step definition is wiring things up correctly and interacting with the code generator that we're working on. We're generating 10,000 codes and we're getting an r in the first position 10,000 times. Now we want an example that expects that we have four different colors in each secret code. Here's one way we can do this:

Download cb/64/spec/codebreaker/generator_spec.rb

```
it "uses each color no more than once in each code" do
  generator = Generator.new
```

```
3   generator.code.uniq.length.should == 4
4 end
```

This example fails with expected: 4, got: 1 because the array we're getting back is ['r','r','r','r'], which is reduced to ['r'] by the uniq() call on line 3. We can get this to pass with the following:

Download cb/65/lib/codebreaker/generator.rb

```
def code
  ['r','y','g','c']
end
```

So now we've got several examples in place to properly document our expecations, but we're missing the one example that suggests that the code is different each time. Well, different most of the time. Randomization does not preclude duplicates. So we want to expect that, for example, if we generate 100 codes, then some reasonable percentage of them are unique. But how do we define reasonable?

Here is where our process becomes a bit more of a white-box practice. In fact, we can even call it reflexive, rather than white-box. Here is the example we added initially:

Download cb/65/spec/codebreaker/generator_spec.rb

```
it "generates a different code each time" do
  generator = Generator.new
  codes = (1..100).collect {generator.code}
  codes.uniq.length.should be >= 95
end
```

This example expects 95 or more unique codes to appear in a group of 100. It fails with expected >= 95, got 1. That's good, as it now forces us to add some randomization to the code generation. As you'll see in a bit, we'll need to revisit that number. In the mean time, here is some code that makes it pass:

Download cb/66/lib/codebreaker/generator.rb

```
def code
  (1..4).collect do
    %w[r y g c b w][rand(6)]
  end
end
```

Here we build up a four element array by selecting a random element from an array of our six color options. Go ahead and modify the code() method per the above, and run the examples a few times. You may see all of the examples passing, but you're likely to see the uses each color no more than once in each code example fail at one point or another. This is because we've introduced randomization since we wrote that example, and we're not getting the same result every time.

To address this, let's first add an iterator to that example so we can get it to fail every time:

Download cb/66/spec/codebreaker/generator_spec.rb

```
it "uses each color no more than once in each code" do
  generator = Generator.new
  20.times do
    generator.code.uniq.length.should == 4
  end
end
```

We're saying that in 20 generated codes we should see no duplicates. If you run the examples with spec spec you should see this example fail. Now we can modify the code to ensure no duplicates like this:

Download cb/67/lib/codebreaker/generator.rb

```
def code
  colors = %w[r y g c b w]
  (1..4).collect do
    colors.delete_at(rand(colors.length))
  end
end
```

Here we define the colors array first. Then build up an array by iterating four times, each time removing a random selection from the array and adding it to the array we're building up with the collect() method. This allows us to use a random selection and ensure that no item is used more than once. Make that change and run the specs with spec spec and the uses each color no more than once in each code now passes, but the generates a different code each time *probably* fails with something like expected >= 95, got 83.

Acceptable Variance

Probably? Yes, probably. If you run the examples a number of times you'll likely find that most of the time it fails saying that we got somewhere between 80 and 90 uniques, but if you run it enough times you'll find that it passes every so often (with 95+ uniques) and that it fails with less than 80 uniques every so often as well. In our experiments we found that the lowest number of uniques we ever saw was 75.

This is an interesting situation. We started expecting 95% or better uniques because that seemed reasonable. We ended with 75% because that actually worked consistently. The question now becomes, is 75% acceptable? If it is, then we can proceed, but if it's not, then we'll need to write our own random generator instead of exploiting the one we get for free from Ruby!

For our purposes, 75% is certainly acceptable. When we're playing a game, we want to be sure that we're not likely to know what the secret code is based on the previous games we've played. 75% uniques satisfies that need, so let's modify the example, replacing 95 with 75:

Download cb/68/spec/codebreaker/generator_spec.rb

```
it "generates a different code each time" do
  generator = Generator.new
  codes = (1..100).collect {generator.code}
  codes.uniq.length.should be >= 75
end
```

With that resolved, run the features with cucumber and you'll see that the last step is now passing! We've got just one more pending step: And each color should appear no more than once in each secret code, so let's add the step definition for that one. It turns out we've already written an example that is similar to what we need:

Download cb/68/spec/codebreaker/generator_spec.rb

```
it "uses each color no more than once in each code" do
  generator = Generator.new
  20.times do
    generator.code.uniq.length.should == 4
  end
end
```

That's more or less what we want, with a couple of small differences. We've already generated and collected the codes at this point, so we just need a means of accessing them. Here's the step definition using the code we wish we had.

Download cb/68/features/step_definitions/codebreaker_steps.rb

```
Then /^each color should appear no more than once in each secret code$/ do
  @stats.codes.each do |code|
    code.uniq.length.should == 4
  end
end
```

What we *don't* have is a codes() method on the Stats object, so let's add that. A few rounds of red/green/refactor and we get the following spec (or similar) and code:

Download cb/68/spec/cucumber/stats_spec.rb

```
describe "#codes" do
  context "with no codes" do
    it "returns an empty array" do
      stats = Stats.new
      stats.codes.should == []
    end
  end
  context "with one code" do
    it "returns an array with that code in it (as an array of colors)" do
      stats = Stats.new
      stats.puts "r y g c"
      stats.codes.should == [%w[r y g c]]
    end
  end
  context "with several codes and other messages" do
    it "returns an array with all the codes" do
      stats = Stats.new
      stats.puts "r y g c"
      stats.puts "an arbitrary message"
      stats.puts "b w y r"
      stats.puts "another arbitrary message"
      stats.puts "g w b c"
      stats.codes.should == [
        %w[r y g c],
        %w[b w y r],
        %w[g w b c]
      ]
    end
  end
end
```

Download cb/68/features/support/stats.rb

```
module Codebreaker
  class Stats
►   attr_reader :codes

    def initialize
      @counts = (1..4).collect { Hash.new {|h,k| h[k] = 0} }
►     @codes = []
    end

    def puts(code)
      if code =~ /^\w \w \w \w$/
►       codes << code.split
►       codes.last.each_with_index do |color, index|
►         @counts[index][color] += 1
►       end
      end
    end
```

```
  end
end
```

Go ahead and look over those changes. The basic difference is that in addition to collecting the hashes to do the counts, we also collect each code itself as it is supplied to the Stats object.

And with those changes, you should now be able to run all the specs with spec spec and all of the features with cucumber and everything should be passing. And now comes the reward for all of your efforts! Change bin/codebreaker so that it passes a Codebreaker::Generator with the start() message, like so:

Download cb/68/bin/codebreaker

```
#!/usr/bin/env ruby
$LOAD_PATH.push File.join(File.dirname(__FILE__),"..","lib")
require 'codebreaker'

game = Codebreaker::Game.new(STDOUT)
game.start(Codebreaker::Generator.new)
while guess = gets
  game.guess guess.split
end
```

Now fire up the game in a shell by running bin/codebreaker, and you can finally test your powers of deduction by trying to guess a randomly generated code! Hurrah!

8.4 What we've learned

In this chapter we introduced a few new concepts. We learned that it's OK to have complexity in step definitions in order to support more readable and terse scenarios. When we choose to allow such complexity, the code in step definitions is just code, and we can drive out objects and helper methods using RSpec, just as we would drive out the application code.

We talked about specifying variable outcomes and used statistical samples in our Cucumber features to address them from the outside. We also talked about specifying concrete outcomes for RSpec code examples, such as the expectation that every secret code generated by the code generator should have four colors represented. We then discussed accepting a reasonable level of variance based on the requirements of our application.

From a functional standpoint, we've traveled as far as we are going to with the Codebreaker game. It is by no means complete at this point. We've still got features we talked about back in Chapter 3, *Describing Features with Cucumber*, on page 33 that we haven't implemented, and you've probably thought of additonal features of your own by now. Or perhaps you've seen edge cases that we didn't write examples for, and wish to add them. These are all good things. The important thing at this point is that you've developed a sense of the process of driving out code from the outside in, using Cucumber and RSpec together.

In the next, and final chapter in this part of the book, we're going to stop working on features and take a closer look at the design that we've arrived at so far. We'll explore some refactoring opportunities and, more importantly in this context, we'll explore how the features and code examples that we've written thus far can help us to refactor confidently and safely.

Chapter 9

Revisiting the Design

Over the last several chapters we've used Cucumber scenarios and RSpec code examples to drive out the behaviour of our Codebreaker game. Each step of the way, we've been able to evolve the behaviour in small, verifiable steps, following the BDD cycle described in Section 1.5, *The BDD Cycle*, on page 23. We've also done some small refactorings as we've seen opportunities for them.

In this chapter we're going to add a couple of new features that are going to force us to revisit the design at a higher level, and guide us to some more wide reaching refactorings. We won't go step by step through each refactoring, as you should already have a decent feel for how to do go about it, and there are already entire books dedicated to refactoring. Even one in Ruby![1]

Our goal is to demonstrate how the combination of RSpec and Cucumber supports maintainability, and allows us to make significant changes to the implementation of an application with confidence that we are preserving the expected behaviour every step of the way.

9.1 New Requirement/New Design

Sometimes new requirements can change the needs of a design. Imagine, for example, that we get a request for the following new feature:

Download cb/69/features/codebreaker_views_summary.feature

```
Feature: display summary
  In order to more easily review the game I'm playing
```

1. *Refactoring, Ruby Edition* [**?**]

```
As a codebreaker
I want to see all of my guesses and marks
    in a unified, cohesive format

Scenario: two guesses
  Given the secret code is r y g c
  And I guess c g y w
  And I guess g y c b
  When I ask to see the summary
  Then I should see
    """
    c g y w   www
    g y c b   bww
    """
```

For this new scenario to pass, we need to keep track of each guess and the mark it receives. Right now, the guess() method looks like this:

Download cb/68/lib/codebreaker/game.rb

```ruby
def guess(guess)
  if guess == ['reveal']
    @messenger.puts @code.join(" ")
  else
    result = [nil,nil,nil,nil]
    guess.each_with_index do |peg, index|
      if @code[index] == peg
        result[index] = "b"
      elsif @code.include?(peg)
        result[@code.index(peg)] ||= "w"
      end
    end
    @messenger.puts result.compact.sort.join
  end
end
```

Each guess is processed and then discarded, and we'll need to change that. We *could* build up an array in which each element is itself an array of the guess (which is yet another array) and the mark. We *could* store this array in an instance variable named @guesses, and loop through that array of arrays of arrays to display the summary. But is that what we want to do? Absolutely not!

A New Solution

What we want is an array of Guess objects that each hold the guess and the mark. That requires that we do an Extract Class refactoring, which we can do now without changing any of the existing code examples. Why don't you take a stab at this yourself? Remember that the goal is to keep all the specs green as you make each little change. When you're finished, you might end up with something that looks like this:

Download cb/69/lib/codebreaker.rb

```
require 'codebreaker/game'
require 'codebreaker/generator'
require 'codebreaker/guess'
```

Download cb/69/lib/codebreaker/guess.rb

```
module Codebreaker
  class Guess
    attr_reader :guess, :mark
    def initialize(guess, mark)
      @guess = guess
      @mark = mark.compact.sort
    end
  end
end
```

Download cb/69/lib/codebreaker/game.rb

```
module Codebreaker
  class Game
    def initialize(messenger)
      @messenger = messenger
      @guesses = []
    end

    def start(generator)
      @code = generator.code
      @messenger.puts "Welcome to Codebreaker!"
      @messenger.puts "Enter guess:"
    end

    def guess(guess)
      if guess == ['reveal']
        @messenger.puts @code.join(" ")
      else
        result = [nil,nil,nil,nil]
        guess.each_with_index do |peg, index|
          if @code[index] == peg
            result[index] = "b"
          elsif @code.include?(peg)
            result[@code.index(peg)] ||= "w"
          end
        end
        @guesses << Guess.new(guess, result)
        @messenger.puts @guesses.last.mark.join
      end
    end
```

```
  end
end
```

These changes pass all the existing code examples and all of the existing scenarios except the new failing summary scenario. We included the guess attribute in the Guess object even though we're not using it just yet. This might seem like jumping ahead, but we're doing this refactoring because we want to print out a summary, and simply assigning, storing, and exposing an attribute is not very likely to break.

Now it's time to drive out some new code. For this we'll take off the refactoring hat and put on the TDD hat. Starting by implementing the pending steps in the new scenario, go ahead and drive out the implementation of the summary. Remember to start by doing the simplest thing that could possibly work to get the examples to pass. Once the examples are passing, we can review the code we wrote and scan it for code smells and address any that we find.

Here is the code we ended up with in this first phase:

Download cb/70/spec/codebreaker/game_spec.rb

```
      context "with the text 'summary'" do
        context "after no guesses" do
          it "should print the summary" do
            @game.start(stub('generator', :code => %w[r y g c]))
            @messenger.should_receive(:puts).with("")
            @game.guess(['summary'])
          end
        end
        context "after one guess" do
          it "should print the summary" do
            @game.start(stub('generator', :code => %w[r y g c]))
            @game.guess(%w[b w y r])
            @messenger.should_receive(:puts).with("b w y r    ww\n")
            @game.guess(['summary'])
          end
        end
        context "after three guesses" do
          it "should print the summary" do
            @game.start(stub('generator', :code => %w[r y g c]))
            @game.guess(%w[b w y r])
            @game.guess(%w[r y g g])
            @game.guess(%w[r c y c])
            @messenger.should_receive(:puts).with(<<-SUMMARY)
b w y r    ww
r y g g    bbb
r c y c    bbw
SUMMARY
            @game.guess(['summary'])
```

```
          end
        end
      end
    end
  end
end
```

Download cb/70/lib/codebreaker/game.rb

```
    def guess(guess)
      if guess == ['reveal']
        @messenger.puts @code.join(" ")
      elsif guess == ['summary']
        @messenger.puts(@guesses.inject("") do |result, guess|
          result << "#{guess.guess.join(' ')}   #{guess.mark.join}\n"
          result
        end)
      else
        result = [nil,nil,nil,nil]
        guess.each_with_index do |peg, index|
          if @code[index] == peg
            result[index] = "b"
          elsif @code.include?(peg)
            result[@code.index(peg)] ||= "w"
          end
        end
        @guesses << Guess.new(guess, result)
        @messenger.puts @guesses.last.mark.join
      end
```

Emergent . . . Code Smells???

This all works quite well, but sometimes modifying an implementation in order to add new behaviour makes it easier to sniff out code smells that were already brewing but hadn't made themselves quite so obvious. Now that we've added this new conditional branch to the guess() method it is getting a bit unwieldy.

There are a couple of different code smells going on here. The most obvious is that guess() is a Long Method.[2] It is responsible for revealing and formatting the secret code, generating a formatted summary, and calculating (and formatting) the mark for the guess. These things are not only a lot for a method, they're a lot for a single class!

Why is the Game concerned with formatting output? Because we made a decision early on to use the IOAPI for the messenger. This was the

2. A Long Method is a method that does more than one thing.

simplest thing that could work, but if it wasn't obvious before, we now see clearly that it's leaking IO semantics to the Game.

What we'd like instead is a messenger *interface* that exposes methods that accept internal representations of the secret code, guesses, and marks, and then formats them for the appropriate output target. In our case, that is plain text formatted for the console, but we could just as easily be formatting HTML for a response to an HTTP request, or JSON for a response to any sort of network request.[3]

9.2 Designing Interfaces with Mock Objects

Because of the fact that we mocked the messenger in game_spec.rb, we can use that file to design a messenger interface without causing any other examples to fail. Start by changing the expectation in the first example in game_spec.rb so that it expects send_message() instead of puts(), like so:

Download cb/71/spec/codebreaker/game_spec.rb

```
    it "should send a welcome message" do
►     @messenger.should_receive(:send_message).with("Welcome to Codebreaker!")
      @game.start(stub('generator', :code => %w[r g y c]))
    end
```

Get this to pass by changing start() in game.rb as follows:

Download cb/71/lib/codebreaker/game.rb

```
  def start(generator)
    @code = generator.code
►   @messenger.send_message "Welcome to Codebreaker!"
    @messenger.puts "Enter guess:"
  end
```

Now do the same with the second example, watching the change in the spec cause a failure and resolving that failure in the Game before moving on to the next example.

As you continue, you'll encounter several examples for guess() in which we specify that the @messenger.should_receive(:puts) with the mark. While you may tempted to change those to @messenger.should_receive(:send_mark) all at once, you *can* change the first example, adding a line to the guess() method like this:

3. JSON, pronounced like the English male name Jason, stands for JavaScript Object Notation.

Download cb/72/lib/codebreaker/game.rb

```
    def guess(guess)
      # ...
      @messenger.puts(@guesses.last.mark.join)
      @messenger.send_mark(@guesses.last.mark)
    end
  end
```

With both messages being sent, you can change all of the relevant examples one at a time, keeping the bar green all the way. Once you've changed all of the mark-related examples, you can remove the line in guess() that uses puts(), and all of the examples will still pass.

Similarly, there will be some problems with the three examples for send_summary(). The strategy we took was to introduce temporary conditionals (if @guesses.empty? ...) to keep the specs passing as we made each change.

Keep on going through the file, making each of the changes flagged in the following code one at a time, watching the example fail and then making it pass.

Download cb/73/spec/codebreaker/game_spec.rb

```
require 'spec_helper'

module Codebreaker
  describe Game do
    before(:each) do
      @messenger = mock("messenger").as_null_object
      @game = Game.new(@messenger)
    end

    context "starting up" do
      it "should send a welcome message" do
        @messenger.should_receive(:send_message).with("Welcome to Codebreaker!")
        @game.start(stub('generator', :code => %w[r g y c]))
      end

      it "should prompt for the first guess" do
        @messenger.should_receive(:send_message).with("Enter guess:")
        @game.start(stub('generator', :code => %w[r g y c]))
      end
    end

    context "marking a guess" do
      context "with all 4 colors correct in the correct places" do
        it "should mark the guess with bbbb" do
          @game.start(stub('generator', :code => %w[r g y c]))
          @messenger.should_receive(:send_mark).with(%w[b b b b])
```

```
      @game.guess(%w[r g y c])
    end
  end
  context "with all 4 colors correct and 2 in the correct places" do
    it "should mark the guess with bbww" do
      @game.start(stub('generator', :code => %w[r g y c]))
      @messenger.should_receive(:send_mark).with(%w[b b w w])
      @game.guess(%w[r g c y])
    end
  end
  context "with all 4 colors correct and 1 in the correct place" do
    it "should mark the guess with bwww" do
      @game.start(stub('generator', :code => %w[r g y c]))
      @messenger.should_receive(:send_mark).with(%w[b w w w])
      @game.guess(%w[y r g c])
    end
  end
  context "with three colors correct in the correct places" do
    it "should mark the guess with bbb" do
      @game.start(stub('generator', :code => %w[r g y c]))
      @messenger.should_receive(:send_mark).with(%w[b b b])
      @game.guess(%w[r g y w])
    end
  end
  context "with duplicates in the guess that match a peg in the code" do
    context "by color and position" do
      it "should add a single b to the mark" do
        @game.start(stub('generator', :code => %w[r y g c]))
        @messenger.should_receive(:send_mark).with(%w[b b b])
        @game.guess(%w[r y g g])
      end
    end
  end

  context "with the text 'reveal'" do
    it "should send the secret code to the messenger" do
      @game.start(stub('generator', :code => %w[r g y c]))
      @messenger.should_receive(:send_code).with(%w[r g y c])
      @game.guess(["reveal"])
    end
  end

  context "with the text 'summary'" do
    context "after no guesses" do
      it "should print the summary" do
        @game.start(stub('generator', :code => %w[r y g c]))
        @messenger.should_receive(:send_summary).with([])
        @game.guess(['summary'])
      end
    end
    context "after one guess" do
```

```
          it "should print the summary" do
            @game.start(stub('generator', :code => %w[r y g c]))
            @game.guess(%w[b w y r])
            @messenger.should_receive(:send_summary).with(
              [Guess.new(%w[b w y r], %w[w w])]
            )
            @game.guess(['summary'])
          end
        end
        context "after three guesses" do
          it "should print the summary" do
            @game.start(stub('generator', :code => %w[r y g c]))
            @game.guess(%w[b w y r])
            @game.guess(%w[r y g g])
            @game.guess(%w[r c y c])
            @messenger.should_receive(:send_summary).with(
              [
                Guess.new(%w[b w y r], %w[w w]),
                Guess.new(%w[r y g g], %w[b b b]),
                Guess.new(%w[r c y c], %w[b b w])
              ]
            )
            @game.guess(['summary'])
          end
        end
      end
    end
  end
end
```

When you're all done with this refactoring, game.rb should look something like this:

Download cb/73/lib/codebreaker/game.rb

```
module Codebreaker
  class Game
    def initialize(messenger)
      @messenger = messenger
      @guesses = []
    end

    def start(generator)
      @code = generator.code
      @messenger.send_message("Welcome to Codebreaker!")
      @messenger.send_message("Enter guess:")
    end

    def guess(guess)
      if guess == ['reveal']
        @messenger.send_code(@code)
      elsif guess == ['summary']
```

```
          return @messenger.send_summary(@guesses)
        else
          result = [nil,nil,nil,nil]
          guess.each_with_index do |peg, index|
            if @code[index] == peg
              result[index] = "b"
            elsif @code.include?(peg)
              result[@code.index(peg)] ||= "w"
            end
          end
          @guesses << Guess.new(guess, result)
          @messenger.send_mark(@guesses.last.mark)
        end
      end
    end
  end
```

9.3 Cucumber in the Outfield

If you run cucumber now, you'll see some some failures because the step definitions are still configuring the Game with StringIO, which doesn't know how to respond to messages like send_message() and send_mark().

This is one of the great benefits of using Cucumber and RSpec together. We were able to design an interface to an entirely new object in small, verifiable steps using RSpec code examples as a safety net. We know that all of our objects honor their individual contracts in isolation.

Like the outfielder that fields the line drive that squeaks its way between the first and second basemen, Cucumber provides us a wider net for catching integration issues. The Cucumber failures tell us that the contracts are not aligned with each other just yet, and so we have more work to do.

The Cucumber scenario allows us to refactor with confidence at every step of the way even in the presence of the mocks and stubs in the RSpec suite. And without the isolation we get from mocks and stubs, we'd have to make bigger, riskier, and sweeping changes to get through the refactoring.

Add a New Object

We need to add a new object to the system to resolve the failures we're seeing now: an object that implements the messenger interface we defined in game_spec.rb. Because we're using this for a command line implementation of the game, let's make a CommandLineMessenger. Create that now on your own, driving it from a new command_line_messenger_spec.rb, and using the examples in game_spec.rb to guide you in what methods to develop. Hint: each method should format the arrays and/or objects it receives, and delegate to puts() on an IO object.

Here is what we came up with:

Download cb/74/spec/codebreaker/command_line_messenger_spec.rb

```
require 'spec_helper'

module Codebreaker
  describe CommandLineMessenger do

    let(:io)  { mock('io') }
    let(:clm) { CommandLineMessenger.new(io) }

    it "delegates send_message to puts on the output stream" do
      io.should_receive(:puts).with("this message")
      clm.send_message("this message")
    end

    it "formats mark and sends it to puts on the output stream" do
      io.should_receive(:puts).with("bbww")
      clm.send_mark(%w[b b w w])
    end

    it "formats code and sends it to puts on the output stream" do
      io.should_receive(:puts).with("r y g c")
      clm.send_code(%w[r y g c])
    end

    context "with no guesses" do
      it "formats the summary and sends it to puts on the output stream" do
        io.should_receive(:puts).with("")
        clm.send_summary([])
      end
    end
    context "with one guess" do
      it "formats the summary and sends it to puts on the output stream" do
        io.should_receive(:puts).with("r y g c   bbb\n")
        clm.send_summary([Guess.new(%w[r y g c], %w[b b b])])
      end
    end

    context "with three guesses" do
      it "formats the summary and sends it to puts on the output stream" do
        io.should_receive(:puts).
          with("r y g c   bbb\nr y c g   bbw\nr c g y   www\n")
        clm.send_summary([
```

```
          Guess.new(%w[r y g c], %w[b b b]),
          Guess.new(%w[r y c g], %w[b b w]),
          Guess.new(%w[r c g y], %w[w w w])
        ])
      end
    end
  end
end
```

Download cb/74/lib/codebreaker/command_line_messenger.rb

```
module Codebreaker
  class CommandLineMessenger
    def initialize(io)
      @io = io
    end

    def send_message(message)
      @io.puts(message)
    end

    def send_mark(mark)
      @io.puts(mark.join)
    end

    def send_code(code)
      @io.puts(code.join(' '))
    end

    def send_summary(guesses)
      @io.puts(guesses.inject("") do |summary, guess|
        summary << guess.guess.join(' ') << '    ' << guess.mark.join << "\n"
      end)
    end
  end
end
```

Resolve the Remaining Issues

We also need to make some changes to codebreaker_steps.rb, stats.rb, and stats_spec.rb because we were using a StringIO object for the messenger and that now needs to be an object that implements messenger API:

Download cb/74/features/step_definitions/codebreaker_steps.rb

```
▶ def io
▶   @io ||= StringIO.new
▶ end
  def messenger
▶   @messenger ||= Codebreaker::CommandLineMessenger.new(io)
  end
  def messages_should_include(message)
```

```
    io.string.split("\n").should include(message)
  end
```

Download cb/74/spec/cucumber/stats_spec.rb

```
      context "with one code" do
        it "returns an array with that code in it (as an array of colors)" do
          stats = Stats.new
          stats.send_code "r y g c".split
          stats.codes.should == [%w[r y g c]]
        end
      end

      context "with several codes" do
        it "returns an array with all the codes" do
          stats = Stats.new
          stats.send_code "r y g c".split
          stats.send_code "b w y r".split
          stats.send_code "g w b c".split
          stats.codes.should == [
            %w[r y g c],
            %w[b w y r],
            %w[g w b c]
          ]
        end
      end
    context "with 1 code with r in position 1" do
      before(:each) do
        @stats = Stats.new
        @stats.send_code "r y g b".split
      end
      it "returns 1 for count_for('r',1)" do
        @stats.count_for('r',1).should == 1
      end
      it "returns 0 for count_for('y',1)" do
        @stats.count_for('y',1).should == 0
      end
    end

    context "with 2 codes with r in position 1 twice and y in position 2 once" do
      before(:each) do
        @stats = Stats.new
        @stats.send_code "r y g b".split
        @stats.send_code "r g b w".split
      end
      it "returns 2 for count_for('r',1)" do
        @stats.count_for('r',1).should == 2
      end
      it "returns 0 for count_for('y',1)" do
        @stats.count_for('y',1).should == 0
      end
      it "returns 1 for count_for('y',2)" do
```

```
        @stats.count_for('y',2).should == 1
      end
    end
  end
end
```

Download cb/74/features/support/stats.rb

```
module Codebreaker
  class Stats
    attr_reader :codes

    def initialize
      @counts = (1..4).collect { Hash.new {|h,k| h[k] = 0} }
      @codes = []
    end

    def send_code(code)
      codes << code
      codes.last.each_with_index do |color, index|
        @counts[index][color] += 1
      end
    end

    def method_missing(m, *args, &block); end

    def count_for(color, position)
      @counts[position-1][color]
    end
  end
end
```

With those changes, all of the Cucumber scenarios and RSpec code examples should be passing. Things are starting to look a lot nicer, too. A new abstraction has emerged with better names than we were using before. This also adds to cohesion, as we separate out the disparate responsibilities of the Game into this new abstraction.

There's certainly more we can do, but at this point we've covered all the topics we want to cover in this section of the book, so we won't be going through any more exercises together. There are plenty of refactoring opportunities remaining, so we'll identify a few of them and offer them up as exercises for you to approach on your own.

9.4 Refactoring Exercises

Take a look at the guess() method in the Game class. Now that we've made the changes we've made, do you see anything odd or off balance? Look how simple and clean the first two branches are compared to the else branch at the end. There is a clear lack of symmetry there, in that the first two branches simply delegate to the messenger, whereas the last branch performs a calculation.

We *could* move that calculation to another method in the Game, but take a closer look at what's happening there. We're generating the mark, passing the mark to a Guess, and then ask the Guess for the mark. Wouldn't it make more sense to let the Guess calculate the mark? We think so!

Refactoring Exercise #1

For your first solo refactoring exercise, perform an Extract Method and then a Move Method refactoring, extracting the calculation to a new mark() method in the Game, and then moving that method to the Guess. Once you've done that, the guess method should something like this:

Download cb/75/lib/codebreaker/game.rb

```
def guess(guess)
  if guess == ['reveal']
    @messenger.send_code(@code)
  elsif guess == ['summary']
    return @messenger.send_summary(@guesses)
  else
    @guesses << Guess.new(@code, guess)
    @messenger.send_mark(@guesses.last.mark)
  end
end
```

Now there is symmetry in the guess() method, but it's still doing too much. It's parsing the input, and choosing what action to take based on input. It seems like something outside game should be parsing input and calling the right methods. We've got the CommandLineMessenger formatting internal data structures for human readable display on the command line, so why not have another object that handles instructions coming *from* the command line as well? But what to call it?

Refactoring Exercise #2

We're talking about something that is a lot like a controller in a Model-View-Controller framework like Rails. It takes user input and routes it to the correct method on the appropriate model object. In our case, the Game is the model, and we can think of the CommandLineMessenger as a view. This all leads to the following refactorings:

- Rename CommandLineMessenger to CommandLineView

- Rename send_xxx() methods on CommandLineView to render_xxx()
- Extract reveal() and summary() methods from the guess() method in Game
- Introduce a CommandLineController that takes input from the user and calls the correct methods on the Game

When you're all done with this, the Game should look something like this:

Download cb/77/lib/codebreaker/game.rb

```
module Codebreaker
  class Game

    def initialize(view)
      @view = view
      @guesses = []
    end

    def start(generator)
      @secret = generator.code
      @view.render_message("Welcome to Codebreaker!")
      @view.render_message("Enter guess:")
    end

    def guess(guess)
      @guesses << Guess.new(@secret, guess) do |guess|
        @view.render_mark(guess.mark)
      end
    end

    def reveal
      @view.render_secret(@secret)
    end

    def summary
      @view.render_summary(@guesses)
    end

  end
end
```

Refactoring Exercise #3

For the last refactoring exercise, let's see what we do about making the marking algorithm speak a little better. Even though it passes all of the specs, it is a bit sneaky and difficult to understand. So let's think about the algorithm in the abstract and see what we come up with.

We need to count up all the colors in the guess that are exact matches (color and position) with the secret code, and then count up the remaining pegs that are color-only matches. The tricky part is dealing with duplicates. If two pegs in the guess match one in the secret, then we only want one of those to get a marker peg: black if one of the two matches the position, white if neither matches the position.

Similarly, if a peg in the guess matches duplicate pegs in the secret (our generator can't supply that yet, but that's a separate issue), we only want one marker peg for the color: black if it matches one of the two by position, white if matches neither by position.

Now if a color appears twice in both the secret and the guess, then we want two marker pegs. Putting this all together, for each color that appears in both the secret and the guess, we want to count the lower number of occurrences in either. Consider these examples:

```
| secret  | guess   | total occurrences |
| r g y c | r g y y |                 3 |
| r g y y | r g y c |                 3 |
```

The 3 in the first example is the sum of 1 for the red pegs, 1 for the green pegs, and then 1 for the yellow peg that appears once in the secret and twice in the guess. The 3 in the second example is the sum of 1 for the red pegs, 1 for the green pegs, and then 1 for the yellow peg that appears twice in the secret and once in the guess.

Once we know what the total count of matches is, we just need to count up how many are exact matches to know how many marker pegs will be black, and then the remaining pegs (total occurrences - exact matches) will be white. Here's pseudo code for this:

```
for each color that is in both the secret and the guess
  increment the total occurrences by the lower number of occurrences
for each color that is in both the secret and the guess in the same position
  increment the exact match count by 1
return a 'b' for each exact match + a 'w' for (total occurrences - exact matches)
```

With that in mind, your next refactoring exercise, and this is admittedly a doozy, is to convert the current mark algorithm to one that expresses this psuedo-code. Believe it or not, it is quite possible to do this in just a few minutes and keep the bar green between *almost* every step. The only place where it gets tricky is where we count up the total number of occurrences, so you may want to write specs for that method.

Here is what we ended up with, though your result may look a bit different:[4]

Download cb/77/lib/codebreaker/guess.rb

```
module Codebreaker
  class Guess
    attr_reader :guess, :mark

    EXACT_MATCH_INDICATOR = 'b'
    COLOR_MATCH_INDICATOR = 'w'

    def initialize(secret, guess)
      @secret = secret
      @guess = guess
      yield self if block_given?
    end

    def ==(other)
      self.guess == other.guess && self.mark == other.mark
    end

    def mark
      [EXACT_MATCH_INDICATOR]*exact_match_count +
      [COLOR_MATCH_INDICATOR]*color_match_count
    end

    def exact_match_count
      [@secret,@guess].transpose.count {|a,b| a == b}
    end

    def color_match_count
      total_match_count - exact_match_count
    end

    def total_match_count
      shared_colors.inject(0) {|sum,color| sum+min_appearances_of(color)}
    end

    def shared_colors
      @secret & @guess
    end

    def min_appearances_of(color)
      [@secret.count(color),@guess.count(color)].min
    end
  end
```

4. The *we* that ended up with the refactored implementation of the marking algorithm was David Chelimsky, Corey Haines, and Aaron Bedra. Many thanks to Corey and Aaron for contributing their most serious Ruby foo to this exercise.

```
end
```

This refactoring makes for a great *code kata*: a routine that you practice over and over again until you can do it with your eyes closed, metaphorically speaking. Code kata are common in the software craftmanship community, and are a great way to hone your skills. You can read more about them at http://codekata.pragprog.com/ and many other places as well. Just ask *the google*.

9.5 What we've learned

In this chapter we explored two of the beneficial effects of evolving suites of Cucumber scenarios and RSpec code examples with mock objects:

- Mock objects allow us to define new protocols in isolation without impacting the examples for other objects.
- Cucumber scenarios help us catch discrepancies between the objects that expose protocols and those that consume them.

This brings us to the end of this first part of the book. We hope that you now have a sense of what it's like to use Cucumber and RSpec together to discover requirements, flesh them out at the high level, and design objects that provide solutions for them. These are the daily practices of a developer working on a Behaviour Driven Development project, but developer practices are only one component of BDD as a whole.

In the next part of the book, we'll provide a bit of background on BDD: what came before, and where we are today. You'll learn about the motivations for BDD, and the basic principles behind the process that have led us to the practices we just covered.

Part II

Behaviour Driven Development

Chapter 10

The Case for BDD

Most of the software we write will never get used. It's nothing personal—it's just that as an industry we are not very good at giving people what they want. It turns out that the underlying reason for this is that traditional software methods are set up to fail—they actually work against us. Heroic individuals deliver software *in spite of* their development process rather than because of it. In this chapter we look at how and why projects fail, and shine a spotlight on some of the challenges facing Agile development.

10.1 How traditional projects fail

Traditional projects fail for all sorts of reasons. A good way to identify the different failure modes is to ask your project manager what keeps them up at night. (It's nice to do this from time to time anyway—it helps their self-esteem.) It is likely your project manager will come up with a list of fears similar to ours:

Delivering late or over budget

We estimate, we plan, we have every contingency down to the nth degree and then much to our disappointment real life happens. When we slip the first date no-one minds too much. I mean, it will only be a couple of weeks. If it goes on for long enough—slipping week by week and month by month—enough people will have left and joined that we can finally put the project out of its misery. Eighteen months to two years is usually enough. This is software that doesn't matter.

Delivering the wrong thing

Most of us use software that was delivered late and over budget—on our desktops, in our mobile phones, in our offices and homes. In fact we have become used to systems that update themselves with bug fixes and new features in the form of service packs and system updates, or websites that grow new features over time. But none of us use software that doesn't solve the problem we have.

It is surprising how much project management effort is spent looking after the schedule or budget when late software is infinitely more useful than irrelevant software. This is software that doesn't matter.

Unstable in production

Hooray! The project came in on time and on budget, the users looked at it and decided they like it, so we put it into production. The problem is it crashes twice a day. We think it's a memory thing, or a configuration thing, or a clustering thing, or an infrastructure thing, or—but who are we kidding? We don't really know what's causing it except that it's rather embarrassing and it's costing us a lot of money. If only we'd spent more time testing it. People will use this once and then give up when it keeps crashing. This is software that doesn't matter.

Costly to maintain

There are a number of things we don't need to consider if we are writing disposable software. Maintainability is one of them. However if we expect to follow Release 1 with a Release 2, Release 3, or even a Professional Super Cow Power Edition then we can easily paint ourselves into a corner by not considering downstream developers.

Over time the rate at which they can introduce new features will diminish until they end up spending more of their time tracking down unexpected regressions and unpicking spaghetti code than actually getting work done. At some point the software will cost more to improve than the revenue it can generate. This is software that doesn't matter.

10.2 Why traditional projects fail

Most of these failure modes happen with smart people trying to do good work. For the most part software people are diligent and well-intentioned, as are the stakeholders they are delivering to, which makes it especially sad when we see the inevitable "blame-storming" that follows in the wake of another failed delivery. It also makes it unlikely that project failures are the results of incompetence or inability—there must be another reason.

How traditional projects work

Most software projects go through the familiar sequence of Planning, Analysis, Design, Code, Test, Deploy. Your process may have different names but the basic activities in each phase will be fairly consistent. (We are assuming some sort of business justification has already happened, although even that isn't always the case.)

We start with the *Planning phase*: how many people, for how long, what resources will they need, basically how much will it cost to deliver this project and how soon will we see anything?

Then we move into an *Analysis phase*. This is where we articulate in detail the problem we are trying to solve, ideally without prescribing how it should be solved, although this is almost never the case.

Then we have a *Design phase*. This is where we think about how we can use a computer system to solve the problem we articulated in Analysis. During this phase we think about design and architecture, large- and small-scale technical decisions, the various standards around the organization, and we gradually decompose the problem into manageable chunks for which we can produce functional specifications.

Now we move onto the *Coding phase*, where we write the software that is going to solve the problem, according to the specifications that came out of the Design phase. A common assumption by the program board at this stage is that all the "hard thinking" has been done by this stage. This is why so many organizations think it's ok to have their programming and testing carried out by offshore, third party vendors.

Now, because we are responsible adults, we have a *Testing phase* where we test the software to make sure it does what it was supposed to do. This phase contains activities with names like *User Acceptance Testing* or *Performance Testing* to emphasize that we are getting closer to the users now and the final delivery.

Eventually we reach the *Deployment phase* where we deploy the application into production. With a suitable level of fanfare the new software glides into production and starts making us money!

All these phases are necessary. You can't start solving a problem you haven't articulated; you can't start implementing a solution you haven't described; you can't test software that doesn't exist and you can't (or at least shouldn't) deploy software that hasn't been tested. Of course in reality you can do any of these things but it usually ends in tears.

How traditional projects really work

We have delivered projects in pretty much this way since we first started writing computer systems. There have been various attempts at improving the process and making it more efficient and less error-prone, using documents for formalized hand-offs, creating templates for the documents that make up those hand-offs, assembling review committees for the templates for the documents, establishing standards and formalized accreditation for the review committees . . . . You can certainly see where the effort has gone.

The reason for all this ceremony around hand-offs, reviews, and suchlike is that the later in the software delivery lifecycle we detect a defect—or introduce a change—the more expensive it is to put right. And not just a little more—in fact empirical evidence over the years has shown that it is exponentially more expensive the later you find out. With this in mind it makes sense to front-load the process. We want to make sure we have thought through all the possible outcomes and covered all the angles early on so we aren't surprised by "unknown unknowns" late in the day.

But this isn't the whole story. However diligent we are at each of the development phases, anyone who has delivered software in a traditional way will attest to the amount of work that happens "under the radar."

The program team signs off the project plan, resplendent in its detail, dependencies, resource models, and Gantt charts. Then the analysts start getting to grips with the detail of the problem and say things like: "hmm, this seems to be more involved than we thought. We'd better re-plan, this is going to be a biggie."

Then the architects start working on their functional specifications, which uncover a number of questions and ambiguities about the requirements. What happens if this message isn't received by that other system? Sometimes the analysts can immediately answer the question but more often it means we need more analysis and hence more time from the analysts. Better update that plan. And get it signed off. And the new version of the requirements document.

You can see how this coordination cost can rapidly mount up. Of course it really kicks off during the testing phase. When the tester raises a defect, the programmer throws his hands in the air and says he did what was in the functional spec, the architect blames the business analyst, and so on right back up the chain. It's easy to see where this exponential cost comes from.

As this back-and-forth becomes more of a burden, we become more afraid of making changes, which means people do work outside of the process and documents get out of sync with one another and with the software itself. Testing gets squeezed, people work late into the night, and the release itself is usually characterized by wailing and gnashing of teeth, bloodshot eyes, and multiple failed attempts at deciphering the instructions in the release notes.

If you ask experienced software delivery folks why they run a project like that, front-loading it with all the planning and analysis, then getting into the detailed design and programming, and only really integrating and testing it at the end, they will gaze into the distance, looking older than their years, and patiently explain that this is to mitigate against the exponential cost of change. This *top-down* approach seems the only sensible way to hedge against the possibility of discovering a defect late in the day.

A self-fulfilling prophecy

To recap, projects become exponentially more expensive to change the further we get into them, due to the cumulative effect of keeping all the project artifacts in sync, so we front-load the process with lots of risk-mitigating planning, analysis and design activities to reduce the likelihood of rework.

Now, how many of these artifacts—the project plan, the requirements specification, the high- and low-level design documents, the software itself—existed before the project began? That's right, *exactly none!* So all that effort—that exponentially increasing effort—occurs *because we run projects the way we do!* So now we have a chicken-and-egg situation—or a *reinforcing loop* in Systems Thinking terminology. The irony of the traditional project approach is that *the process itself causes the exponential cost of change!*

Digging a little deeper, it turns out the curve originates in civil engineering. It makes sense that you might want to spend a lot of time in the design phases of a bridge or a ship. You wouldn't want to get two thirds of the way through building a hospital only to have someone point out it is in the wrong place. Once the reinforced concrete pillars are sunk things become very expensive to put right!

However, these rules only apply to software development *because we let them!* Software is, well, soft. It is supposed to be the part that's easy to change, and with the right approach and some decent tooling it can be very malleable. So by using the metaphor of civil engineering and equating software with steel and concrete, we've done ourselves a disservice.

10.3 Redefining the problem

It's not all doom and gloom though. There are many teams out there delivering projects on time, within budget, and delighting their stakeholders, and they manage to do it again and again. It's not easy. It takes discipline and dedication, and relies on a high degree of communication and collaboration, but it is possible. People who work like this tend to agree it is also a lot of fun!

Behaviour-driven development is one of a number of *Agile* methodologies. Specifically it is a *second generation* Agile methodology, building on the work of the really smart guys. Let's look at how these Agile methods came about and how they address traditional project risks, then we can see how BDD allows us to concentrate on writing software that matters.

A brief history of Agile

Since we first started delivering software as projects there have been software professionals asking themselves the same questions. Why do so many software projects fail? Why are we so *consistently* bad at delivering software? Why does it seem to happen more on larger projects with bigger teams? And can anything be done about it?

Independently they developed a series of lightweight methodologies whose focus was on delivering working software to users, rather than producing reams of documents or staging ceremonial reviews to show how robust their processes were. They found they could cut through a lot of organizational red tape just by putting everyone in the same room.

Then in early 2001 a few of these practitioners got together and produced a short manifesto describing their common position. You might well have seen it before but it is worth reproducing here because it describes the common ground so perfectly.[1]

The Agile Manifesto

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

Individuals and interactions *over processes and tools*
Working software *over comprehensive documentation*
Customer collaboration *over contract negotiation*
Responding to change *over following a plan*

That is, while there is value in the things on the right, we value the things on the left more.

The Agile Manifesto is empirical—it's based on real experience: "We are uncovering better ways ... *by doing it.*" Also notice that it doesn't *dismiss* traditional ideas like documentation and contracts—a criticism often levelled at Agile methods—but rather it expresses a preference for something different: something lighter weight and more directly relevant to the customer or stakeholder.

How Agile methods address project risks

The authors of the manifesto go further than just the few lines quoted above. They also documented the principles underpinning their thinking. Central to these is a desire to "deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale."

Imagine for a moment you could do this, namely delivering production-quality software *every two weeks* to your stakeholders, on your current project, in your current organization, with your current team, starting tomorrow. How would this address the traditional delivery risks we outlined at the start of the chapter?

No longer delivering late or over budget

Since we are delivering the system in tiny, one- or two-week *iterations* or mini-projects, using a small, fixed-size team, it is easy to calculate our project budget: it is simply the burn rate of the team times the number of weeks, plus some hardware and licenses.

1. You can find the Agile Manifesto online at http://agilemanifesto.org

Provided we start with a reasonable guess at the overall size of the project, that is how much we are prepared to invest in solving the business problem in the first place, and we prioritize the features appropriately, then the team can deliver the really important stuff in the early iterations. (Remember, we are delivering by feature not by module.) So as we get towards the point when the money runs out, we should by definition be working on lower priority features. Also we can measure how much we actually produce in each iteration, known as our *velocity* or *throughput*, and use this to predict when we are really likely to finish.

If, as we approach the deadline, the stakeholders are still having new ideas for features and seeing great things happening, they may choose to fund the project for a further few iterations. Conversely they may decide *before the deadline* that enough of the functionality has been delivered that they want to finish up early and get a release out. This is another option they have.

No longer delivering the wrong thing

We are delivering working software to the stakeholders every two weeks (say), which means we are delivering demonstrable features. We don't have a two week "database schema iteration" or "middleware iteration."

After each iteration we can demonstrate the new features to the stakeholders and they can make any tweaks or correct any misunderstandings while the work is still fresh in the development team's mind. These regular, small-scale micro-corrections ensure that we don't end up several months down the line with software that simply doesn't do what the stakeholders wanted.

To kick off the next iteration we can get together with the stakeholders to reassess the priorities of the features in case anything has changed since last time.[2] This means any new ideas or suggestions can get scheduled, and the corresponding amount of work can be descoped (or extra time added.)

No longer unstable in production

We are delivering every iteration, which means we have to get good at building and deploying the application. In fact we rely heavily on process automation to manage this for us. It is not uncommon for an

2. In practice the planning session often follows directly after the showcase for the previous iteration.

experienced Agile team to produce over 100 good software builds every week.

In this context, releasing to production or testing hardware can be considered just another build to just another environment. Application servers are automatically configured and initialized; database schemas are automatically updated; code is automatically built, assembled and deployed over the wire; all manner of tests are automatically executed to ensure the system is behaving as expected.

In fact in an Agile environment, the relationship between the development team and the downstream operations and DBA folks is often much healthier and more supportive.

No longer costly to maintain

This last one is one of the biggest tangible benefits of an Agile process. After their first iteration the team is effectively in maintenance mode. They are adding features to a system that "works" so they have to be very careful.

Assuming they can solve the issues of safely changing existing code so as not to introduce regression defects, their working practices should be exactly the same as downstream support developers. It is not uncommon for an Agile development team to be working on several versions of an application simultaneously, adding features to the new version, providing early live support to a recently-released version, and providing bug fixing support to an older production version (because we still make mistakes, and the world still moves on!)

10.4 The cost of going Agile

So this is great news! By rethinking the way we approach project delivery we've managed to comprehensively address all our traditional project risks. Instead of seeing a project as a linear sequence of activities that ends up with a big delivery, we find things work better if we deliver frequently in short iterations. So why isn't everyone doing this?

The obvious but unpopular answer is: *because it's really hard!* Or rather, it's really hard to do well. Delivering production quality software week after week takes a lot of discipline and practice. For all their systemic faults, traditional software processes cause you to focus on certain aspects of a system at certain times. In an Agile process the training

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wheels come off and the responsibility now lies with you. That autonomy comes at a cost!

If we want to deliver working software frequently—as often as every week on many projects—there are a number of new problems we need to solve. Luckily Agile has been around for long enough that we have an answer to many of these problems, or at least understand them well enough to have an opinion about them. Let's look at some of the challenges of Agile, then we will see how BDD addresses them.

Outcome-based planning

The only thing we really know at the beginning of a project is that we don't know very much and that what we do know is subject to change. Much like steering a car, we know the rough direction but we don't know every detailed nuance of the journey, such as exactly when we will turn the steering wheel or by how many degrees. We need to find a way to estimate the cost of delivering a project amongst all this uncertainty and accept that the fine details of the requirements are bound to change, and that that's ok.

Streaming requirements

If we want to deliver a few features every week or two we have to start describing requirements in a way that supports this. The traditional requirements process tends to be document-based, where the business analyst takes on the role of author and produces a few kilos of requirements.

Instead of this batch delivery of requirements we need to come up with a way to describe features that we can feed into a more streamlined delivery process.

Evolving design

In a traditional process the senior techies would come up with The Design (with audible capitals, most likely based on The Standards). Before we were allowed to start coding they would have produced high level designs, detailed designs and probably class diagrams describing every interaction. Each stage of this would be signed off. In an Agile world the design needs to flex and grow as we learn more about the problem and as the solution takes shape. This requires rethinking the process of software design.

Changing existing code

Traditional programming is like building little blocks for later assembly. We write a module and then put it to one side while we write the next one, and so on until all the modules are written. Then we bring all the modules together in a (usually painful) process called Integration. An Agile process requires us to keep revisiting the same code as we evolve it to do new things.

Because we take a feature-wise approach to delivery rather than a module-wise one, we will often need to add new behaviour to existing code. This isn't because we got it "wrong" the first time, but because the code is currently exactly fit for purpose, and we need the application to do more now. *Refactoring*, the technique of restructuring code without changing its observable behaviour, is probably the place where most advances have been made in terms of tool support and automation, especially with statically-typed languages like Java and C#.

Frequent code integration

Integrating code ahead of a testing cycle is a thankless and fraught task. All the individual modules "work"—just not together! Imagine doing this every single month? Or every week? What about potentially several times *every day*? This is the frequency of integration an iterative process demands: frequent enough that it is known as *continuous integration*.

Continual regression testing

Whenever we add a new feature it might affect many parts of the codebase. We are doing feature-wise development so different parts of the codebase are evolving at different rates, depending on the kind of feature we are implementing. When we have a single feature the system is easy to test. When we add the one hundredth feature we suddenly have to regression test the previous ninety-nine. Imagine when we add the two hundredth feature—or the one thousandth! We need to get really good at regression testing otherwise we will become ever slower at adding features to our application.

Frequent production releases

This is one of the hardest challenges of Agile software delivery, because it involves co-ordination with the downstream operations team. Things are suddenly outside of the team's control. All the other aspects—streaming requirements, changing design and code, frequent integration and regression testing—are behaviours we can adopt ourselves.

Getting software into formally-controlled environments puts us at odds with the corporate governance structures. But if we can't get into production frequently, there is arguably little value in all the other stuff. It may still be useful for the team's benefit, but software doesn't start making money until it's in production. Remember, we want to be writing software that matters!

Co-located team

To make this all work you can't afford for a developer to be waiting around for her manager to talk to someone else's manager to get permission for her to talk to them. The turnaround is just too slow. There are organisational and cultural changes that need to happen in order to shorten the feedback cycles to minutes rather than days or weeks.

The kind of interactions we require involve the whole team sitting together, or at least as near one another as possible. It simply isn't effective to have the programmers in one office, the project managers in another and the testers elsewhere, whether along the corridor or in a different continent.

10.5 What have we learned?

There are a number of different ways in which traditional software projects fail, and these failures are intrinsic to the way the projects are run. The result of "process improvement" on traditional projects is simply to reinforce these failure modes and ironically make them even more likely.

An analysis of this approach to running software projects leads back to the exponential cost curve that originated in the world of civil engineering, where things are made of steel and concrete. Being aware of this, a number of experienced IT practitioners had been spending some time wondering what software delivery might look like if they ignored the constraints of thinking like civil engineers.

They realized that taking an iterative, collaborative approach to software delivery could systemically eliminate the traditional risks that project managers worry about. They called this approach Agile.

It isn't all plain sailing, however, and adopting an Agile approach introduces its own challenges. There is no free lunch!

In the next chapter we will see how BDD addresses these challenges and where *RSpec* and *Cucumber* fit into the picture.

Chapter 11

Writing software that matters

Although BDD started as a simple reframing of test-driven development, it has grown into a fully-fledged software methodology in its own right. In this chapter we look at the mechanics of BDD and see how *RSpec* and *Cucumber* fit into the picture.

11.1 A description of BDD

Behaviour-driven development is about implementing an application by describing its behaviour from the perspective of its stakeholders.

This description of BDD implies a number of things. Firstly it suggests we need to understand the world from the point of view of our stakeholders if we are to deliver anything useful. We need to understand their domain, the challenges and opportunities they face and the words they use to describe the behaviour they want from an application. We use techniques from *domain-driven design* to help with this.

Secondly it implies there is more than one stakeholder. We don't just look at the world from the point of view of an end user or the person paying the bills, but anyone with an interest in the project.

11.2 The Principles of BDD

When we describe BDD as writing "software that matters", we mean software that has value to a stakeholder, that is neither too little to solve the problem nor over-engineered, and that we can demonstrate works. We sum this up using the following *three principles of BDD*:

1. **Enough is enough** Up-front planning, analysis, and design all have a diminishing return. We shouldn't do less than we need to get started, but any more than that is wasted effort. This also applies to process automation. Have an automated build and deployment, but avoid trying to automate *everything*.

2. **Deliver stakeholder value** If you are doing something that isn't either delivering value or increasing your ability to deliver value, stop doing it and do something else instead.

3. **It's all behaviour** Whether at the code level, the application level or beyond, we can use the same thinking and the same linguistic constructs to describe behaviour at any level of granularity.

11.3 The project inception

Before we get into the day-to-day delivery of a project we need to understand what it is all about. To do this we get all the *stakeholders* together to establish a *vision* or *purpose* for the project: what is it we are trying to achieve here? This should be a single pithy statement, something like: *improve our supply chain* or *understand our customers better*.

BDD defines a stakeholder as *anyone who cares* about the work we are undertaking, whether they are the people whose problem we are trying to solve—known as the *core stakeholders*—or the people who are going to help solve it—who we call the *incidental stakeholders*. This latter group includes the operations folk who will monitor the application, the support team who will diagnose problems and add new features, the legal and security experts who will ensure the application is fit for purpose from an organizational risk perspective, in fact all the people representing what we usually call *non-functional requirements*. From a BDD perspective there is no such thing as a non-functional requirement, just a feature with an incidental stakeholder. Even the people in the delivery team itself are stakeholders. (Who would you say is the stakeholder for having an automated build?)

It is the core stakeholders' responsibility to define the vision, and the incidental stakeholders' to help them understand what's possible, at what cost and with what likelihood. This is the objective of the up-front thinking—that and nothing more.

Now we can't just go off and start coding *improve our supply chain*. We need to understand what that means first, so we work with the

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core stakeholders—the people whose vision it is—to identify *outcomes* or *goals*. How will they know when this project has achieved its purpose? What will they be able to do that they can't do now? There should only be a few of these or the project will quickly lose its focus. If you find yourself looking at more than a handful of outcomes you are either going too low level too quickly or this may be a bigger problem than you think and should be broken out into a program of smaller projects.

For the supply chain example, some outcomes might be: *the ordering process is easier*, or *better access to suppliers' information*. Some people recommend these outcomes should be *SMART* (see the sidebar on the following page) but this becomes less important as you build trust between the core stakeholders and the delivery team.

To achieve these outcomes we are going to need some software. We describe the sorts of things the software needs to do as *feature sets* or *themes*. The terms are synonymous so use whichever feels best for you. Themes are things like *reporting* or *customer registration*, again too high level to start coding, but specific enough to have some useful conversations around.

Finally we are in a position to talk about the specific *features* or *stories* that make up these themes. (See the sidebar on page 173 for a discussion of stories and features.)

This is the level where we will actually be working day-to-day—these describe the behaviour we will implement in software.

You can see how this gives us traceability right back to a specific stakeholder need. Each feature is only there because it is adding value to a feature set. Each feature set is contributing to one or more of the outcomes and each outcome is part of the overall purpose of the project. Too often Agile teams dive straight into the feature or story level without taking the time to think about the overall shape of the delivery.

At this stage you could be forgiven for thinking this looks a lot like traditional top-down decomposition. The difference is that we stop before a traditional analysis phase would, again remembering to only do just enough.

It is dangerous to get too hung up on the detail of features because it can create false expectations with your stakeholders. Remember, they came to us with a need or problem, so success for them will be if we can meet that need and solve that problem. By focusing on the details we

SMART outcomes

The acronym SMART is used to describe outcomes or objectives that have certain characteristics, namely that they are *Specific*, *Measurable*, *Achievable*, *Relevant*, and *Timeboxed*:

Specific means there is enough detail to know that something is done. *Snappier user experience* is not specific, whereas *Faster response time for the four most common user journeys* is.

Measurable means you can determine whether the objective was reached, for example *10% reduction in response times.*

Achievable helps reduce unrealistic expectations. *All credit card transactions should be instantaneous* is unlikely to happen.

Relevant manages the issue of people trying to cram in every conceivable feature just in case. *We want clear, concise reporting, and a puppy.*

Timeboxed simply means we know when to call time if we haven't achieved an outcome, otherwise it could just trundle on forever or for as long as someone is prepared to keep paying.

The emphasis on the SMARTness of objectives or outcomes happens a lot in command-and-control cultures where success is measured in terms of reaching individual targets. More enlightened companies focus on improving throughput and trusting people to act with integrity.

Non-SMART, vaguely-worded outcomes allow the participants—both the stakeholders and the delivery team—to be adaptable in what they deliver so they can all focus on doing the best they can with the resources and time they have. This allows the stakeholders to invest incrementally in a project: as long as they are seeing value delivered they continue to invest, otherwise they can stop the project and assign the team to solving another challenge.

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Stories in, features out

Many people use the words "feature" and "story" interchangeably, but there is a subtle difference. A feature is something that delivers cohesive value to a stakeholder. A story is a piece of demonstrable functionality that shouldn't take more than a few days to implement. So the feature is more useful from the point of view of the stakeholder, and the story is more useful from the point of view of the team delivering the feature.

Often a feature can be delivered as a single story, but sometimes the feature doesn't naturally decompose to that level. For example if we are capturing an email address there might be some validation around that address. This could get quite involved and would take more than a few days of effort. In this case we could separate out the "happy path"—where all the data is valid—and the most important validation cases into one story and some of the less common but still useful validations into another story. Or we might separate out the security concerns into another story (whose stakeholder would be the security folks) so we would look at cross-site scripting or SQL injection attacks as different aspects of the same feature.

As long as your stories are roughly the same size, this decomposition of features into stories provides the same kind of tracking data as having artificial constructs like *story points* or *ideal days*, terms that can feel uncomfortable to your stakeholders. It is more natural to say "We've broken that feature into these three stories that tackle different aspects," rather than "This feature is seven points and this one is four points," or "This week we delivered nine ideal days" (to which the correct response is "Eh?").

It is important to remember that we still decompose along boundaries that make sense to the stakeholder, so we wouldn't break a feature into the database stuff, then the UI stuff, then the wiring up stuff. Instead we would deliver different groups of scenarios.

As we deliver the stories, we arrange any artifacts—such as Cucumber scenario files and step implementations—by feature, because over time it doesn't really matter which story the behaviour was implemented in, so much as which feature benefited from that story. We call this arrangement "stories in, features out": the input happens to be delivered in stories but the result is cohesive features.

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inadvertently shift their attention so that they now associate success with delivering the features we drove out during the planning.

A better use of our efforts during an inception is to try to identify and mitigate the "gotchas." Where are the risky areas—in terms of technology or integration points, an unknown business domain, access to key stakeholders, market conditions, external dependencies—that are likely to derail our nascent project? Keeping a log of these risks and assumptions is at least as important as the breakdown of the project objectives.

11.4 The cycle of delivery

The BDD delivery cycle starts with a stakeholder discussing a requirement with a business analyst.[1] The requirement might be a problem they want solved or an idea they've had. The analyst helps the stakeholder articulate the requirement in terms of *features* that make sense to the stakeholder—using their own domain terms—and maybe further into small, verifiable chunks known as *stories* which represent no more than a few days work.

Next the stakeholder and business analyst work with a tester to determine the stories' scope. What does *done* look like for each story? We don't want to overdesign the solution because that's a waste of effort, but likewise we don't want to do too little; otherwise we won't be meeting the stakeholder's original need.

Where the business analyst thinks in abstract terms (*it should be possible to withdraw money from a checking account*), the tester is typically thinking in terms of concrete scenarios: *If I have $100 in an account and I withdraw $80 what happens? What about if I try to withdraw $120? What happens if I have an overdraft facility on the account? What if I try to go past my overdraft limit?*

By identifying which scenarios are important to the story before development starts, the stakeholder can specify exactly how much they want the programmers to do, or how much development effort they want to invest in delivering the feature. The developers will only implement enough to satisfy the agreed scenarios, *and no more*.

1. The terms *stakeholder*, *business analyst*, and so on, describe roles rather than individuals. On a small team the same person may take on more than one role at different times. You can think of them as different hats people can wear.

The final task before the programmers start implementing the story is to automate the scenarios where it makes sense to do so. In the same way test-driven development[2] uses code examples to drive the design, these automated scenarios will drive the high-level direction of the development effort.

One of the most important characteristics of BDD is that the scenarios are easy to automate, yet are still easily understandable to the stakeholder. Defining and automating these scenarios is the realm of Cucumber.

Now at last we can finally get down to the coding part of the delivery cycle. A developer—or ideally a pair of developers—uses RSpec to code by example to get the scenario working. We start by writing a code example [3] to describe the behaviour we want, then implement the code to make that example work, then we refactor. The RSpec portions of this book describe exactly how we do this so we don't need to say anything more here.

Eventually we end up with just enough software to make the scenario work, and then we iterate through the other scenarios until we are done. This then brings us full circle, such that we can demonstrate the working scenarios back to the stakeholder and the story is done.

Now imagine we could run a mini-project that just contained a single story—something simple enough to develop in a couple of days—and do just enough analysis to understand that story, and then design an application to *only do that one thing!* How hard could that be? We could easily implement it and test that it works, and then deploy it into an environment where we could showcase it to the stakeholder who asked us for it.

It would mean we didn't spend weeks poring over database schemas or entity-relationship diagrams, we didn't go to town with UML code generation tools, and we certainly didn't write down a detailed functional specification of every last aspect of the feature. We also haven't delivered very much yet!

2. BDD calls test-driven development *coding by example*, which places the emphasis on using examples to drive out the behaviour of the code. The fact that these examples become tests once the code is written is a secondary concern.

3. Agile testing expert Brian Marick refers to a code example as an *exemplar*, which is technically a more correct term. An exemplar is an example intended to demonstrate a specific point. We prefer calling them examples because it is a more familiar term.

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Ok. so now we are going to get a little ambitious. Instead of a single story, we are going to deliver a handful of stories together. In fact we are going to try to deliver about as many as we think we could reasonably do in a week. In effect we are going to run a tiny one-week project that we call an *iteration*.[4]

As with any project our estimates will most likely be wrong. Instead of delivering the seven stories we planned, we might only make five. Or we might have a great week and have capacity to spare for an extra bonus story! In any event, we will know at the end of the week how much we actually did deliver *and we can use this to predict our throughput for next week!* But that comes later.

Right now we are more interested in what our stakeholders think about the work we've done, so we arrange a showcase. This feedback happens very close to when the work occurred—because we are only showcasing the work we completed in the last iteration—and usually involves the stakeholder saying: "That's *very nearly* exactly what I wanted, but can I change some stuff?"

And now we are ready to plan the next mini-project. We have feedback from our stakeholders, a backlog of stories and a priority order.

This then is how we work, from day to day and from week to week. We have frequent, regular contact with our stakeholders who get to provide fine-grained steering in the form of feedback and reprioritization. But what does a story look like close up?

11.5 What's in a story?

Up to now we haven't said anything about the anatomy of a story—just about how they fit into the delivery process. Now it's time to take a look inside and see how the structure of the story enables us to concentrate on writing software that matters.

A story is made up of a number of components:

A title so we know which story we are talking about

4. You don't have to work in iterations, and if you do they don't have to be one week long. We have seen teams using iterations lasting from half a day (no, really!) to four weeks. Some teams don't use iterations at all, but have a constant flow of stories that they track using techniques borrowed from Lean manufacturing, such as *kanban* flow control and *finger charts*. The important thing is to ensure you have regular feedback from your stakeholders and a way of measuring throughput.

A narrative which tells us what this story is about. There are a couple of common formats for this, but you can use anything that captures the essentials. At the very least it should identify the *stakeholder* for this story, a description of the *feature* they want, and the reason they want it—the *benefit* they expect to gain by us delivering this behaviour.

The most common format for this is known as the Connextra format, after the company where it was first used: *As a [stakeholder], I want [feature]so that [benefit]*

A recent variant that is becoming popular looks like this: *In order to [benefit], a [stakeholder] wants to [feature].* The content is exactly the same but there is a subtle shift in emphasis by putting the benefit first. It helps keep the focus on the outcome rather than the detail of the feature.

Acceptance criteria so we know when we are done. In BDD, the acceptance criteria take the form of a number of *scenarios* made up of individual *steps*.

Before we can begin implementing a story we need to drive out this level of detail. As we mentioned above, this doesn't need to happen during the inception (and probably shouldn't!) but it *does* need to happen before we do anything that requires an understanding of "Done", like scheduling work during iteration/sprint planning. Some teams ensure they have one or two iterations worth of stories prepared as they go, others drive out the detail of scenarios during a weekly planning session. Our recommendation is to try different approaches and go with what works for you and your team.

The business analyst (again remembering this is a role, not necessarily a specific person) should ensure the story uses the language of the stakeholders so everyone is using a consistent vocabulary. In his book *Domain-Driven Design* [Eva03], Eric Evans uses the phrase *ubiquitous language* to describe this shared vocabulary. The idea is that the domain words find their way right into the codebase, as the names of objects, methods, variables, even modules and namespaces. This allows the code to more accurately model the domain, which in turn enables us to solve problems in that domain more effectively.

Now we get into the acceptance criteria—the scenarios—that define "done" for this story. Which ones do we care about (and by omission which ones don't we care about)? This discussion should be a team effort but the acceptance criteria are "owned" by the tester, or rather by someone in the tester role.

Each scenario has a title. You can think of scenario names like the titles of "Friends" episodes, so they are all "the one where..." for example *[The one where] the account is locked*; or *[the one where] the password is invalid.*[5]

We use the slightly artificial structure of *givens*, *events* and *outcomes* to describe these scenarios. This doesn't mean that every scenario has exactly one Given, When, and Then in that order. Rather it means that each step is *either* setting something up in a known state (a given),*or* exercising some behaviour (an event), *or* verifying something happened (an outcome). Trying to do more than one of these in a single step usually ends up in confusion.

This separation is useful because *it is only the event we care about.* For the setup, the givens, it doesn't matter how we get the world into a known state. We could poke values into a database, drive a UI, read values in from a flat file, it doesn't matter. What matters is that the event steps have no idea how this happened, and interact with the application in exactly the same way the stakeholder would. Similarly it doesn't matter how you verify the outcomes, just that you do. This might involve poking around in a DOM, checking database values, or any manner of other checks. It is possible to get hung up on thinking of scenarios as full-blown integration tests, so that all the setup steps need to use the same UI as the user might. Now there is definitely benefit in having these integration tests, and tools like Cucumber and constructs like scenarios are a pretty good way to do this, but this is not the (primary) purpose of a BDD scenario.

11.6 What have we learned?

Behaviour-driven development has grown from an experiment in reframing TDD to make it easier to understand, into a fully-fledged Agile methodology.

BDD is based on three core principles, namely:

5. You don't need to use the actual words "The one where..." in the scenario title, it just helps with the names.

- **Enough is enough**. We should work to achieve the stakeholder's expectations but avoid doing more than we need to.
- **Deliver stakeholder value**. There are multiple stakeholders—both core and incidental—and everything we do should be about delivering demonstrable value to them.
- **It's all behaviour**. Just as we can describe the application's behaviour from the perspective of the stakeholders, we can describe low-level code behaviour from the perspective of other code that uses it.

At the start of a project or a release, we carry out some sort of inception activities to understand the purpose of the work we are doing, and to create a shared vision. This is about the deliberate discovery of risks and potential pitfalls along the way.

The day-to-day rhythm of delivery involves decomposing requirements into features and then into stories and scenarios, which we automate to act as a guide to keep us focused on what we need to deliver. These automated scenarios become acceptance tests to ensure the application does everything we expect.

BDD stories and scenarios are specifically designed to support this model of working, and in particular to be both easy to automate and clearly understandable by their stakeholders.

Part III

RSpec

Chapter 12

Spec::Example

In this part of the book, we'll explore the details of RSpec's built-in expectations, mock objects framework, command line tools, IDE integration, extension points, and even show you how to integrate RSpec with Test::Unit so that you can take advantage of the myriad extensions that are written for both frameworks.

Our goal is to make Test Driven Development a more joyful and productive experience with tools that elevate the design and documentation aspects of TDD to first class citizenship. Here are some words you'll need to know as we reach for that goal:

subject code The code whose behaviour we are specifying with RSpec.

expectation An expression of how the subject code is expected to behave.
You'll read about state based expectations in Chapter 13, *Spec::Expectations*, on page 202, and interaction expectations in Chapter 14, *Spec::Mocks*, on page 226.

code example An executable example of how the subject code can be used, and its expected behaviour (expressed with expectations) in a given context. In BDD, we write the code examples before the subject code they document.

The *example* terminology comes from Brian Marick, whose website is even named http://exampler.com. Using "example" instead of "test" reminds us that writing them is a design and documentation practice, even though once they are written and the code is developed against them they become regression tests.

example group A group of code examples.

Familiar structure, new nomenclature

If you already have some experience with Test::Unit or similar tools in other languages and/or TDD, the words we're using here map directly to words you're already familiar with:

- *Assertion* becomes *Expectation*.
- *Test Method* becomes *Code Example*.
- *Test Case* becomes *Example Group*.

In addition to finding these new names used throughout this book, you'll find them in RSpec's code base as well.

spec, a.k.a. **spec file** A file that contains one or more example groups.

In this chapter you'll learn how to organize executable *code examples* in *example groups* in a number of different ways, run arbitrary bits of code before and after each example, and even share examples across groups.

12.1 Describe It!

RSpec provides a Domain Specific Language for specifying the behaviour of objects. It embraces the metaphor of describing behaviour the way we might express it if we were talking to a customer, or another developer. A snippet of such a conversation might look like this:

You: *Describe a new account*

Somebody else: *It should have a balance of zero*

Here's that same conversation expressed in RSpec:

```
describe "A new Account" do
  it "should have a balance of 0" do
    account = Account.new
    account.balance.should == Money.new(0, :USD)
  end
end
```

We use the describe() method to define an example group. The string we pass to it represents the facet of the system that we want to describe (a new account). The block holds the code examples that make up that group.

Joe Asks…

Where are the objects?

The declarative style we use to create code examples in example groups is designed to keep you focused on documenting the expected behaviour of an application.

While this works quite well for many, there are some who find themselves distracted by the opacity of this style. If you fall in the latter category, or if you are looking to write custom extensions,* you may want to know what the underlying objects are.

The describe() method creates a subclass of Spec::Example::ExampleGroup. The it() method defines a method on that class, which represents a code example.

While we don't recommend it, it is possible to write code examples in example groups using classes and methods. Here is the new account example expressed that way:

```
class NewAccount < Spec::Example::ExampleGroup
  def should_have_a_balance_of_zero
    account = Account.new
    account.balance.should == Money.new(0, :USD)
  end
end
```

RSpec interprets any method that begins with "should_" to be a code example.

*. See Section 17.2, *Custom Example Groups*, on page 287 to learn about writing custom example group classes.

The it() method defines a code example. The string passed to it describes the specific behaviour we're interested in specifying about that facet (should have a balance of zero). The block holds the example code that exercises the subject code and sets expectations about its behaviour.

Using strings like this instead of legal Ruby class names and method names provides a lot of flexibility. Here's an example from RSpec's own code examples:

```
it "should match when value < (target + delta)" do
  be_close(5.0, 0.5).matches?(5.49).should be_true
end
```

This is an example of the behaviour of code, so the intended audience is someone who can read code. In Test::Unit, we might name the method test_should_match_when_value_is_less_than_target_plus_delta, which is pretty readable, but the ability to use non-alpha-numeric characters makes the name of this example more expressive.[1]

To get a better sense of how you can unleash this expressiveness, let's take a closer look at the describe() and it() methods.

The describe() method

The describe() method takes an arbitrary number of arguments and an optional block, and returns a subclass of Spec::Example::ExampleGroup.[2] We generally only use one or two arguments, which represent the facet of behaviour that we wish to describe. They might describe an object, perhaps in a pre-defined state, or perhaps a subset of the behaviour we can expect from that object. Let's look at a few examples, with the output they produce so we can get an idea of how the arguments relate to each other.

```
describe "A User" { ... }
=> A User

describe User { ... }
=> User

describe User, "with no roles assigned" { ... }
=> User with no roles assigned

describe User, "should require password length between 5 and 40" { ... }
=> User should require password length between 5 and 40
```

The first argument can be either a reference to a Class or Module, or a String. The second argument is optional, and should be a String. Using the class/module for the first argument provides an interesting benefit: when we wrap the ExampleGroup in a module, we'll see that module's name in the output. For example, if User is in the Authentication module, we could do something like this:

```
module Authentication
  describe User, "with no roles assigned" do
```

1. activesupport-2.2 introduced support for test "a string" do...end syntax, so you can get the basic benefit of strings out of the box in rails-2.2 or later.
2. As you'll see later in Chapter 17, *Extending RSpec*, on page 285, you can coerce the describe() method to return your own custom ExampleGroup subclass.

The resulting report would look like this:

```
Authentication::User with no roles assigned
```

So by wrapping the ExampleGroup in a Module, we see the fully qualified name Authentication::User, followed by the contents of the second argument. Together, they form a descriptive string, and we get the fully qualified name for free. This is a nice way to help RSpec help *us* to understand where things live as we're looking at the output.

You can also nest example groups, which can be a very nice way of expressing things in both input and output. For example, we can nest the input like this:

```
describe User do
  describe "with no roles assigned" do
    it "should not be allowed to view protected content" do
```

This produces output like this:

```
User with no roles assigned
- should not be allowed to view protected content
```

Or, with the --format nested option on the command line, the output looks like this:

```
User
  with no roles assigned
    should not be allowed to view protected content
```

To understand this example better, let's explore describe()'s yang, the it() method.

What's it() all about?

Similar to describe(), the it() method takes a single String, an optional Hash and an optional block. The String should be a sentence that, when prefixed with "it," represents the detail that will be expressed in code within the block. Here's an example specifying a stack:

```
describe Stack do
  before(:each) do
    @stack = Stack.new
    @stack.push :item
  end

  describe "#peek" do
    it "should return the top element" do
      @stack.peek.should == :item
    end
```

```
    it "should not remove the top element" do
      @stack.peek
      @stack.size.should == 1
    end
  end

  describe "#pop" do
    it "should return the top element" do
      @stack.pop.should == :item
    end

    it "should remove the top element" do
      @stack.pop
      @stack.size.should == 0
    end
  end
end
```

This is also exploiting RSpec's nested example groups feature to group the examples of pop() separately from the examples of peek().

When run with the --format nested command line option, this would produce the following output.

```
Stack
  #peek
    should return the top element
    should not remove the top element
  #pop
    should return the top element
    should remove the top element
```

Looks a bit like a specification, doesn't it? In fact, if we reword the example names without the word "should" in them, we can get output that looks even more like documentation:

```
Stack
  #peek
    returns the top element
    does not remove the top element
  #pop
    returns the top element
    removes the top element
```

What? No "should?" Remember, the goal here is readable sentences. "Should" was the tool that Dan used to get people writing sentences, but is not itself essential to the goal.

The ability to pass free text to the it() method allows us to name and organize examples in meaningful ways. As with describe(), the String can even include punctuation. This is a good thing, especially when we're dealing with code-level concepts in which symbols have important meaning that can help us to understand the intent of the example.

12.2 Pending Examples

In *Test Driven Development: By Example* [Bec02], Kent Beck suggests keeping a list of tests that you have yet to write for the object you're working on, crossing items off the list as you get tests passing, and adding new tests to the list as you think of them.

With RSpec, you can do this right in the code by calling the it() method with no block. Let's say that we're in the middle of describing the behaviour of a Newspaper:

```
describe Newspaper do
  it "should be black" do
    Newspaper.new.colors.should include('black')
  end

  it "should be white" do
    Newspaper.new.colors.should include('white')
  end

  it "should be read all over"
end
```

RSpec will consider the example with no block to be pending. Running these examples produces the following output

```
Newspaper
- should be black
- should be white
- should be read all over (PENDING: Not Yet Implemented)

Pending:
Newspaper should be read all over (Not Yet Implemented)
  Called from newspaper.rb:20

Finished in 0.006682 seconds

3 examples, 0 failures, 1 pending
```

As you add code to existing pending examples and add new ones, each time you run all the examples RSpec will remind you how many pending examples you have, so you always know how close you are to being done!

Another case for marking an example pending is when you're in the middle of driving out an object, you've got some examples passing and you add a new failing example. You look at the code, see the change you want to make and realize that the design really doesn't support what you want to do to make this example pass.

There are a couple of different paths people choose at this juncture. One is to comment out the failing example so you can refactor *in the green*, and then uncomment the example and continue on. This works great until you're interrupted in the middle of this near the end of the day on Friday, and 3 months later you look back at that file and find examples you commented out three months ago.

Instead of commenting the example out, you can mark it pending like this:

```
describe "onion rings" do
  it "should not be mixed with french fries" do
    pending "cleaning out the fryer"
    fryer_with(:onion_rings).should_not include(:french_fry)
  end
end
```

In this case, even though the example block gets executed, it stops execution on the line with the pending() declaration. The subsequent code is not run, there is no failure, and the example is listed as pending in the output, so it stays on your radar. When you've finished refactoring you can remove the pending declaration to execute the code example as normal. This is, clearly, much better than commenting out failing examples and having them get lost in the shuffle.

The third way to indicate a pending example can be quite helpful in handling bug reports. Let's say you get a bug report and the reporter is kind enough to provide a failing example. Or you create a failing example yourself to prove the bug exists. You don't plan to fix it this minute, but you want to keep the code handy. Rather than commenting the code, you could use the pending() method to keep the failing example from being executed.

You can also, however, wrap the example code in a block and pass that to the pending method, like this:

```
describe "an empty array" do
  it "should be empty" do
    pending("bug report 18976") do
      [].should be_empty
    end
```

```
  end
end
```

When RSpec encounters this block it actually executes the block. If the block fails or raises an error, RSpec proceeds as with any other pending example.

If, however, the code executes without incident, RSpec raises a PendingExampleFixedError, letting you know that you've got an example that is pending for no reason:

```
an empty array
- should be empty (ERROR - 1)

1)
'an empty array should be empty' FIXED
Expected pending 'bug report 18976' to fail. No Error was raised.
pending_fixed.rb:6:
pending_fixed.rb:4:

Finished in 0.007687 seconds

1 example, 1 failure
```

The next step is to remove the pending wrapper, and re-run the examples with your formerly-pending, newly-passing example added to the total of passing examples.

So now you know three ways to identify pending examples, each of which can be helpful in your process in different ways:

- add pending examples as you think of new examples that you want to write
- disable examples without losing track of them (rather than commenting them out)
- wrap failing examples when you want to be notified that changes to the system cause them to pass

So now that you know how to postpone writing examples, let's talk about what happens when you actually write some!

12.3 Before and After

If we were developing a Stack, we'd want to describe how a Stack behaves when it is empty, almost empty, almost full, and full. And we'd want to describe how the push(), pop(), and peek() methods behave under each of those conditions.

If we multiply the 4 states by the 3 methods, we're going to be describing 12 different scenarios that we'll want to group together by either state or method. We'll talk about grouping by method later this chapter. Right now, let's talk about grouping things by *Initial State*, using RSpec's before() method.

before(:each)

To group examples by initial state, or *context*, RSpec provides a before() method that can run either one time before :all the examples in an example group or once before :each of the examples. In general, it's better to use before(:each) because that re-creates the context before each example and keeps state from leaking from example to example. Here's how this might look for the Stack examples:

Download describeit/stack.rb

```
describe Stack, "when empty" do
  before(:each) do
    @stack = Stack.new
  end
end

describe Stack, "when almost empty (with one element)" do
  before(:each) do
    @stack = Stack.new
    @stack.push 1
  end
end

describe Stack, "when almost full (with one element less than capacity)" do
  before(:each) do
    @stack = Stack.new
    (1..9).each { |n| @stack.push n }
  end
end

describe Stack, "when full" do
  before(:each) do
    @stack = Stack.new
    (1..10).each { |n| @stack.push n }
  end
end
```

As we add examples to each of these example groups, the code in the block passed to before(:each) will be executed before each example is executed, putting the environment in the same known starting state before each example in that group.

before(:all)

In addition to before(:each), we can also say before(:all). This gets run once and only once in its own instance of Object, but its instance variables get copied to each instance in which the examples are run. A word of caution in using this: in general, we want to have each example run in complete isolation from one another. As soon as we start sharing state across examples, unexpected things begin to happen.

Consider a stack. The pop() method removes the top item from a stack, which means that the second example that uses the same stack *instance* is starting off with a stack that has one less item than in the before(:all) block. When that example fails, this fact is going to make it more challenging to understand the failure.

Even if it seems to you that sharing state won't be a problem right now in any given example, this is sure to change over time. Problems created by sharing state across examples are notoriously difficult to find. If we have to be debugging at all, the last thing we want to be debugging is the examples.

So what is before(:all) actually good for? One example might be opening a network connection of some sort. Generally, this is something we wouldn't be doing in the isolated examples that RSpec is really aimed at. If we're using RSpec to drive higher level examples, however, then this might be a good case for using before(:all).

after(:each)

Following the execution of each example, before(:each)'s counterpart after(:each) is executed. This is rarely necessary because each example runs in its own scope and the instance variables consequently go out of scope after each example.

There are cases, however, when after(:each) can be quite useful. If you're dealing with a system that maintains some global state that you want to modify just for one example, a common idiom for this is to set aside the global state in an instance variable in before(:each) and then restore it in after(:each), like this:

```
before(:each) do
  @original_global_value = $some_global_value
  $some_global_value = temporary_value
```


this copy is (B12.0 printing, December 3, 2009)

```
end

after(:each) do
  $some_global_value = @original_global_value
end
```

after(:each) is guaranteed to run after each example, even if there are failures or errors in any before blocks or examples, so this is a safe approach to restoring global state.

after(:all)

We can also define some code to be executed after(:all) of the examples in an example group. This is even more rare than after(:each), but there are cases in which it is justified. Examples include closing down browsers, closing database connections, closing sockets, etc. Basically, any resources that we want to ensure get shut down, but not after every example.

So we've now explored before and after :each and before and after :all. These methods are very useful in helping to organize our examples by removing duplication—not just for the sake of removing duplication but with the express purpose of improving clarity and thereby making the examples easier to understand.

But sometimes we want to share things across a wider scope. The next two sections will address that problem by introducing Helper Methods and Shared Examples.

12.4 Helper Methods

Another approach to cleaning up our examples is to use Helper Methods that we define right in the example group, which are then accessible from all of the examples in that group. Imagine that we have several examples in one example group, and at one point in each example we need to perform some action that is somewhat verbose.

```
describe Thing do
  it "should do something when ok" do
    thing = Thing.new
    thing.set_status('ok')
    thing.do_fancy_stuff(1, true, :move => 'left', :obstacles => nil)
    ...
  end

  it "should do something else when not so good" do
```

```
    thing = Thing.new
    thing.set_status('not so good')
    thing.do_fancy_stuff(1, true, :move => 'left', :obstacles => nil)
    ...
  end
end
```

Both examples need to create a new Thing and assign it a status. This can be extracted out to a helper like this:

```
describe Thing do
  def create_thing(options)
    thing = Thing.new
    thing.set_status(options[:status])
    thing
  end

  it "should do something when ok" do
    thing = create_thing(:status => 'ok')
    thing.do_fancy_stuff(1, true, :move => 'left', :obstacles => nil)
    ...
  end

  it "should do something else when not so good" do
    thing = create_thing(:status => 'not so good')
    thing.do_fancy_stuff(1, true, :move => 'left', :obstacles => nil)
    ...
  end
end
```

One idiom you can apply to clean this up even more is to yield self from initializers in your objects. Assuming that Thing's initialize() method does this, and set_status() does as well, you can write the above like this:

```
describe Thing do
  def given_thing_with(options)
    yield Thing.new do |thing|
      thing.set_status(options[:status])
    end
  end

  it "should do something when ok" do
    given_thing_with(:status => 'ok') do |thing|
      thing.do_fancy_stuff(1, true, :move => 'left', :obstacles => nil)
      ...
    end
  end

  it "should do something else when not so good" do
    given_thing_with(:status => 'not so good') do |thing|
      thing.do_fancy_stuff(1, true, :move => 'left', :obstacles => nil)
      ...
```

```
    end
  end
end
```

Obviously, this is a matter of personal taste, but you can see that this cleans things up nicely, reducing the noise level in each of the examples. Of course, with almost all benefits come drawbacks. In this case, the drawback is that we have to look elsewhere to understand the meaning of given_thing_with. This sort of indirection can make understanding failures quite painful when overused.

A good guideline to follow is to keep things consistent within each code base. If all of the code examples in your system look like the one above, even your new team mates who might not be familiar with these idioms will quickly learn and adapt. If there is only one example like this in the entire codebase, then that might be a bit more confusing. So as you strive to keep things clean, be sure to keep them consistent as well.

Sharing Helper Methods

If we have helper methods that we wish to share across example groups, we can define them in one or more modules and then include the modules in the example groups we want to have access to them.

```
module UserExampleHelpers
  def create_valid_user
    User.new(:email => 'e@mail.com', :password => 'shhhhh')
  end

  def create_invalid_user
    User.new(:password => 'shhhhh')
  end
end

describe User do
  include UserExampleHelpers

  it "does something when it is valid" do
    user = create_valid_user
    # do stuff
  end

  it "does something when it is not valid" do
    user = create_invalid_user
    # do stuff
  end
```

If we have a module of helper methods that we'd like available in all of our example groups, we can include the module in the configuration (see Section 17.1, *Global Configuration*, on page 285 for more information):

```
Spec::Runner.configure do |config|
  config.include(UserExampleHelpers)
end
```

So now that we can share helper methods across example groups, how about sharing *examples*?

12.5 Shared Examples

When we have a situation in which more than one class should behave in *exactly* the same way, we can use a shared example group to describe it once, and then include that example group in other example groups. We declare a shared example group with the shared_examples_for() method.

```
shared_examples_for "Any Pizza" do
  it "should taste really good" do
    @pizza.should taste_really_good
  end
  it "should be available by the slice" do
    @pizza.should be_available_by_the_slice
  end
end
```

Once a shared example group is declared, we can include it in other example groups with the it_should_behave_like() method.

```
describe "New York style thin crust pizza" do
  it_should_behave_like "Any Pizza"

  before(:each) do
    @pizza = Pizza.new(:region => 'New York', :style => 'thin crust')
  end

  it "should have a really great sauce" do
    @pizza.should have_a_really_great_sauce
  end
end

describe "Chicago style stuffed pizza" do
  it_should_behave_like "Any Pizza"

  before(:each) do
    @pizza = Pizza.new(:region => 'Chicago', :style => 'stuffed')
  end

  it "should have a ton of cheese" do
    @pizza.should have_a_ton_of_cheese
```

```
  end
end
```

which produces:

```
New York style thin crust pizza
- should taste really good
- should be available by the slice
- should have a really great sauce

Chicago style stuffed pizza
- should taste really good
- should be available by the slice
- should have a ton of cheese
```

This report does not include "Any Pizza", but the "Any Pizza" examples, "should taste really good" and "should be available by the slice" do appear in both of the other example groups. Also, @pizza is referenced in the shared examples before they get included in the others. Here's why that works. At runtime, the shared examples are stored in a collection and then copied into each example group that uses them. They aren't actually executed until the example group that uses them gets executed, but that happens after before(:each) happens.

This example also hints at a couple of other features that RSpec brings us to help make the examples as expressive as possible: Custom Expectation Matchers and Arbitrary Predicate Matchers. These will be explained in detail in later chapters, so if you haven't skipped ahead to read about them yet, consider yourself teased.

Sharing Examples in a Module

In addition to share_examples_for() and it_should_behave_like(), you can also use the share_as method, which assigns the group to a constant so you can include it using Ruby's include method, like this:

```
share_as :AnyPizza do
  ...
end

describe "New York style thin crust pizza" do
  include AnyPizza
  ...
end

describe "Chicago style stuffed pizza" do
  include AnyPizza
  ...
end
```

This leads to the same result as share_examples_for() and it_should_behave_like(), but allows you to use the familiar Ruby syntax instead.

Even with both of these approaches, shared examples are very limited in nature. Because the examples are run in the same scope in which they are included, the only way to share state between them and other examples in the including group is through instance variables. You can't just pass state to the group via the it_should_behave_like method.

Because of this constraint, shared examples are really only useful for a limited set of circumstances. When you want something more robust, we recommend that you create custom macros, which we'll discuss at length in Chapter 17, *Extending RSpec*, on page 285.

12.6 Nested Example Groups

Nesting example groups is a great way to organize your examples within one spec. Here's a simple example:

```
describe "outer" do
  describe "inner" do
  end
end
```

As we discussed earlier in this chapter, the outer group is a subclass of ExampleGroup. In this example, the inner group is a *subclass of the outer group*. This means that any helper methods and/or before and after declarations, included modules, etc declared in the outer group are available in the inner group.

If you declare before and after blocks in both the inner and outer groups, they'll be run as follows:

1. outer before
2. inner before
3. example
4. inner after
5. outer after

To demonstrate this, copy this into a ruby file:

```
describe "outer" do
  before(:each) { puts "first" }
  describe "inner" do
```

```
    before(:each) { puts "second" }
    it { puts "third"}
    after(:each) { puts "fourth" }
  end
  after(:each) { puts "fifth" }
end
```

If you run that with the spec command, you should see output like this:

```
first
second
third
fourth
fifth
```

Because they are all run in the context of the same object, you can share state across the before blocks and examples. This allows you to do a progressive setup. For example, let's say you want to express a given in the outer group, an event (or *when*) in the inner group, and the expected outcome in the examples themselves. You could do something like this:

```
describe Stack do
  before(:each) do
    @stack = Stack.new(:capacity => 10)
  end
  describe "when full" do
    before(:each) do
      (1..10).each {|n| @stack.push n}
    end
    describe "when it receives push" do
      it "should raise an error" do
        lambda { @stack.push 11 }.should raise_error(StackOverflowError)
      end
    end
  end
  describe "when almost full (one less than capacity)"
    before(:each) do
      (1..9).each {|n| @stack.push n}
    end
    describe "when it receives push" do
      it "should be full" do
        @stack.push 10
        @stack.should be_full
      end
    end
  end
end
```

Now, I can imagine some of you thinking "w00t! Now *that* is DRY!" while others think "Oh my god, it's so complicated!" I, personally, sit in the latter camp, and tend to avoid structures like this, as they can make it very difficult to understand failures. But in the end you have to find what works for you, and this structure is one option that is available to you. Handle with care.

I *do*, however, use nested example groups all the time. I just tend to use them to organize concepts rather than build up state. So I'd probably write the example above like this:

```
describe Stack do
  describe "when full" do
    before(:each) do
      @stack = Stack.new(:capacity => 10)
      (1..10).each {|n| @stack.push n}
    end
    describe "when it receives push" do
      it "should raise an error" do
        lambda { @stack.push 11 }.should raise_error(StackOverflowError)
      end
    end
  end
  describe "when almost full (one less than capacity)"
    before(:each) do
      @stack = Stack.new(:capacity => 10)
      (1..9).each {|n| @stack.push n}
    end
    describe "when it receives push" do
      it "should be full" do
        @stack.push 10
        @stack.should be_full
      end
    end
  end
end
```

In fact, there are many who argue that you should never use the before blocks to build up context at all. Here's the same example:

```
describe Stack do
  describe "when full" do
    describe "when it receives push" do
      it "should raise an error" do
        stack = Stack.new(:capacity => 10)
        (1..10).each {|n| stack.push n}
        lambda { stack.push 11 }.should raise_error(StackOverflowError)
      end
    end
  end
  describe "when almost full (one less than capacity)"
    describe "when it receives push" do
      it "should be full" do
```

```
        stack = Stack.new(:capacity => 10)
        (1..9).each {|n| stack.push n}
        stack.push 10
        stack.should be_full
      end
    end
  end
end
```

Now this is probably the most readable of all three examples. The nested describe blocks provide documentation and conceptual cohesion, and each example contains all of the code it needs. The great thing about this approach is that if you have a failure in one of these examples, you don't have to look anywhere else to understand it. It's all right there.

On the flip side, this is the least DRY of all three examples. If we change the Stack's constructor, we'll have to change it in two places here, and many more in a complete example. So you need to balance these concerns. Sadly, there's no one true way. And if there were, we'd all be looking for new careers, so let's be glad for the absence of the silver bullet.

What you've learned

In this chapter we covered quite a bit about the approach RSpec takes to structuring and organizing executable code examples. You learned that you can:

- Define an example group using the describe() method
- Define an example using the it() method
- Identify an example as *pending* by either omiting the block or using the pending() method inside the block
- Share state across examples using the before() method
- Define helper methods within an example group that are available to each example in that group
- Share examples across multiple groups
- Nest example groups for cohesive organization

But what about the stuff that goes inside the examples? We've used a couple of expectations in this chapter but we haven't really discussed them. The next chapters will address these lower level details, as well as introduce some of the peripheral tooling that is available to help you nurture your inner BDD child and evolve into a BDD ninja.

Chapter 13

Spec::Expectations

A major goal of BDD is *getting the words right*. We're trying to derive language, practices, and processes that support communication between all members of a team, regardless of each person's understanding of things technical. This is why we like to use non-technical words like *Given*, *When* and *Then*.

We also like to talk about *expectations* instead of *assertions*. The dictionary defines the verb "to assert" as "to state a fact or belief confidently and forcefully." This is something we do in a courtroom. We assert that it was *Miss Peacock* in the *kitchen* with a *rope* because that's what we believe to be true.

In executable code examples, we are describing an expectation of what *should* happen rather than what *will* happen, so we choose the word *should*.[1] Having chosen "should", we have another problem to solve: where do we put it? Consider the following assertion from test/unit.

```
assert_equal 5, result
```

In this example, assert_equal() accepts the expected value followed by the actual value. Now read that aloud: "Assert equal five result." A little bit cryptic, no? So now do what we normally do when reading code out loud and insert the missing words: "Assert that five equals the result." That's a bit better, but now that we're speaking in English, we see another problem. We don't really want to "assert that five equals result." We want to "assert that the result equals five!" The arguments are backwards!

1. See Chapter 11, *Writing software that matters*, on page 169 for more on the motivations behind *should*.

RSpec addresses the resulting confusion by exploiting Ruby's metaprogramming facilities to provide a syntax that speaks the way we do. What we want to say is that "the result should equal five," which is how we say it in English. Here's how we say it in RSpec:

```
result.should equal(5)
```

Read that out loud. In fact, climb up on the roof and cry out to the whole town!!! Satisfying, isn't it?

This is an example of an RSpec *expectation*, a statement which expresses that at a specific point in the execution of a code example, some thing should be in some state. Here are some other expectations that come with RSpec:

```
message.should match(/on Sunday/)
team.should have(11).players
lambda { do_something_risky }.should raise_error(
  RuntimeError, "sometimes risks pay off ... but not this time"
)
```

Don't worry about understanding them fully right now. In this chapter you'll learn about all of RSpec's built-in expectations. You'll also learn about the simple framework that RSpec uses to express expectations, which you can then use to extend RSpec with your own domain-specific expectations. With little effort, you'll be able to express things like:

```
judge.should disqualify(participant)
registration.should notify_applicant("person@domain.com", /Dear Person/)
```

Custom expectations like these can make your examples far more readable and feel more like descriptions of behaviour than tests. Of course, don't forget to balance readability with clarity of purpose. If an example with notify_applicant() fails, you'll want to understand the implications of that failure without having to go study a custom matcher. Always consider your team-mates when creating constructs like this, and strive for consistency within any code base (including its code examples).

With the proper balance, you'll find that this makes it much easier to understand what the examples are describing when looking back at them days, weeks, or even months later. Easier understanding saves time, and saving time saves money. This can help to reduce the cost of change later on in the life of an application. This is what Agile is all about.

To better understand RSpec's expectations, let's get familiar with their different parts. We'll start off by taking a closer look at the should()

and should_not() methods, followed by a detailed discussion of various types of *expression matchers*. As you'll see, RSpec supports expression matchers for common operations that you might expect, like equality, and some more unusual expressions as well.

13.1 should and should_not

RSpec achieves a high level of expressiveness and readability by exploiting open classes in Ruby to add the methods should() and should_not() to the Object class, and consequently every object in the system. Both methods accept either an *expression matcher* or a Ruby expression using a specific subset of Ruby operators. An Expression Matcher is an object that does exactly what its name suggests: it matches an expression.

Let's take a look at an example using the Equal Expression Matcher, which you can access through the method equal(expected). This is one of the many expression matchers that ships with RSpec.

```
result.should equal(5)
```

Seems simple enough, doesn't it? Well let's take a closer look. First, let's add parentheses as a visual aid:

```
result.should(equal(5))
```

Now take a look at Figure 13.1, on the next page.

When the Ruby interpreter encounters this line, it begins by evaluating equal(5), which returns a new instance of the Equal class, initialized with the value 5. This object is the expression matcher we use for this Expectation. This instance of Equal is then passed to result.should.

Next, should() calls matcher.matches?(self). Here matcher is the instance of Equal we just passed to should() and self is the result object. Because should() is added to every object, it can be ANY object. Similarly, the matcher can be ANY object that responds to matches?(target). This is a beautiful example of how dynamic languages make it so much easier to write truly Object Oriented code.

If matches?(self) returns true, then the Expectation is considered met, and execution moves on to the next line in the example. If it returns false, then an ExpectationNotMetException is raised with a message returned by matcher.failure_message_for_should().

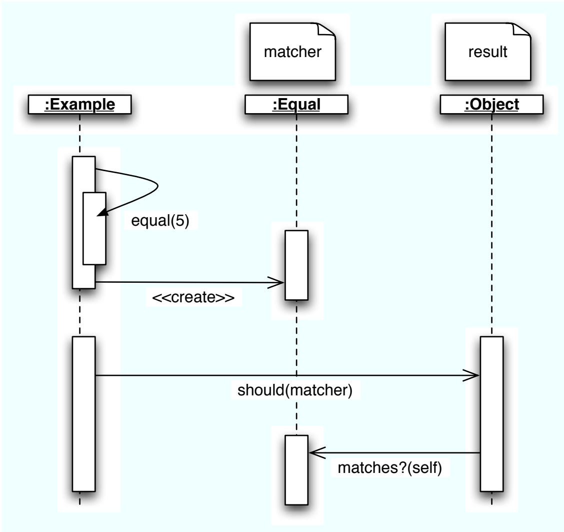

Figure 13.1: Should/Matcher Interaction Diagram

should_not() works the opposite way. If matches?(self) returns false, then the Expectation is considered met and execution moves on to the next line in the example. If it returns true, then an ExpectationNotMetException is raised with a message returned by matcher.failure_message_for_should_not. Note that should() uses failure_message_for_should, while should_not() uses failure_message_for_should_not, allowing the Matcher to provide meaningful messages in either situation. Clear, meaningful feedback is one of RSpec's primary goals.

The should() and should_not() methods can also take any of several operators such as == and =~. You can read more about those in Section 13.5, *Operator Expressions*, on page 220. Right now, let's take a closer look at RSpec's built-in matchers.

13.2 Built-In Matchers

RSpec ships with several built-in matchers with obvious names that you can use in your examples. In addition to equal(expected), others include:

```
include(item)
respond_to(message)
```

Matchers

The idea of a *Matcher* is not unique to RSpec. In fact, when I first pointed out to Dan North that we were using these, I referred to them as *Expectations*. Given Dan's penchant for "Getting The Words Right", he corrected me, gently, saying that "while should eat_cheese is an Expectation, the eat_cheese part is a Matcher", citing jMock2 (http://jmock.org) and Hamcrest (http://code.google.com/p/hamcrest/) as examples.

jMock and Hamcrest are "A Lightweight Mock Object Library" and a "library of matchers for building test expressions," respectively, and it turns out that jMock2 actually uses Hamcrest's matchers as Mock Argument Constraints. Seeing that inspired me to have RSpec share matchers across Spec::Expectations and Spec::Mocks as well. Since they are serving as both Mock Argument Constraint Matchers and Expectation Matchers, we'll refer to them henceforth as expression matchers.

```
raise_error(type)
```

By themselves, they seem a bit odd, but in context they make a bit more sense:

```
prime_numbers.should_not include(8)
list.should respond_to(:length)
lambda { Object.new.explode! }.should raise_error(NameError)
```

We'll cover each of RSpec's built-in matchers, starting with those related to equality.

Equality: Object Equivalence and Object Identity

Although we're focused on behaviour, many of the expectations we want to set are about the state of the environment after some event occurs. The two most common ways of dealing with post-event state are to specify that an object should have values that match our expectations (object equivalence) and to specify that an object *is* the very same object we are expecting (object identity).

Most xUnit frameworks support something like assert_equal to mean that two objects are equivalent and assert_same to mean that two objects are really the same object (object identity). This comes from languages like Java, in which there are really only two constructs that deal with equality: the == operator, which, in Java, means the two references point to the same object in memory, and the equals method, which defaults to the same meaning as ==, but is normally overridden to mean equivalence.

Note that you have to do a mental mapping with assertEqual and assertSame. In Java, assertEqual means equal, assertSame means ==. This is OK in languages with only two equality constructs, but Ruby is bit more complex than that. Ruby has four constructs that deal with equality.

```
a == b
a === b
a.eql?(b)
a.equal?(b)
```

Each of these has different semantics, sometimes differing further in different contexts, and can be quite confusing.[2] So rather than forcing you to make a mental mapping from expectations to the methods they represent, RSpec lets you express the exact method you mean to express.

```
a.should == b
a.should === b
a.should eql(b)
a.should equal(b)
```

The most common of these is should ==, as the majority of the time we're concerned with value equality, not object identity. Here are some examples:

```
(3 * 5).should == 15

person = Person.new(:given_name => "Yukihiro", :family_name => "Matsumoto")
person.full_name.should == "Yukihiro Matsumoto"
person.nickname.should == "Matz"
```

In these examples, we're only interested in the correct values. Sometimes, however, we'll want to specify that an object is the exact object that we're expecting.

```
person = Person.create!(:name => "David")
Person.find_by_name("David").should equal(person)
```

Note that this puts a tighter constraint on the value returned by find_by_name(), that it must be the exact same object as the one returned by create!(). While this may be appropriate when expecting some sort of caching

2. See http://www.ruby-doc.org/core/classes/Object.html#M001057 for the official documentation about equality in Ruby.

behaviour, the tighter the constraint, the more brittle the expectation. If caching is not a real requirement in this example, then saying Person.find_by_name("David").should == person is good enough and means that this example is less likely to fail later when things get refactored.

Do not use !=

While RSpec supports

```
actual.should == expected
```

it does *not* support

```
# unsupported
actual.should != expected
```

For the negative, you should use

```
actual.should_not == expected
```

The reason for this is that == is a method in Ruby, just like to_s(), push(), or any other method named with alphanumeric characters. The result is that

```
actual.should == expected
```

is interpreted as

```
actual.should.==(expected)
```

This is not true for !=. Ruby interprets

```
actual.should != expected
```

as

```
!(actual.should.==(expected))
```

This means that object returned by should() receives == whether the example uses == or !=. And *that* means that short of doing a text analysis of each example, which would slow things down considerably, RSpec can not know that the example really means != when it receives ==. And because RSpec doesn't know, it won't tell you, which means you'll be getting false responses. So, stay away from != in examples.

Floating Point Calculations

Floating point math can be a pain in the neck when it comes to setting expectations about the results of a calculation. And there's little more frustrating than seeing "expected 5.25, got 5.251" in a failure message, especially when you're only looking for two decimal places of precision.

To solve this problem, RSpec offers a be_close matcher that accepts an expected value *and* an acceptable delta. So if you're looking for precision of two decimal places, you can say:

```
result.should be_close(5.25, 0.005)
```

This will pass as long as the given value is within .005 of 5.25.

Multiline Text

Imagine developing an object that generates a statement. You could have one big example that compares the entire generated statement to an expected statement. Something like this:

```
expected = File.open('expected_statement.txt','r') do |f|
  f.read
end
account.statement.should == expected
```

This approach of reading in a file that contains text that has been reviewed and approved, and then comparing generated results to that text, is known as the "Golden Master" technique and is described in detail in J.B. Rainsberger's *JUnit Recipes* [Rai04].

This serves very well as a high level code example, but when we want more granular examples, this can sometimes feel a bit like brute force, and it can make it harder to isolate a problem when the wheels fall off.

Also, there are times that we don't really care about the entire string, just a subset of it. Sometimes we only care that it is formatted a specfic way, but don't care about the details. Sometimes we care about a few details but not the format.

In any of these cases we can expect a matching regular expression using either of the following patterns:

```
result.should match(/this expression/)
result.should =~ /this expression/
```

In the statement example, we might do something like this:

```
statement.should =~ /Total Due: \$37\.42/m
```

One benefit of this approach is that each example is, by itself, less brittle, less prone to fail due to unrelated changes. RSpec's own code examples are filled with expectations like this related to error messages, where we want to specify certain things are in place but don't want the expectations to fail due to inconsequential formatting changes.

Arrays and Hashes

As is the case with text, sometimes we want to set expectations about an entire Array or Hash, and sometimes just a subset. Because RSpec delegates == to Ruby, we can use that any time we want to expect an entire Array or Hash, with semantics we should all be familiar with.

```
[1,2,3].should == [1,2,3]
[1,2,3].should_not == [1,2,3,4]
{'this' => 'hash'}.should == {'this' => 'hash'}
{'this' => 'hash'}.should_not == {'that' => 'hash'}
```

But sometimes we just want to expect that 2 is in the Array [1,2,3]. To support that, RSpec includes an include() method that invokes a matcher that will do just that:

```
[1,2,3].should include(2)
{'a' => 1, 'b' => 2}.should include('b' => 2)
{'a' => 1}.should_not include('a' => 2)
```

Sometimes we don't need that much detail, and we just want to expect an Array with 37 elements, or a Hash with 42 key/value pairs. You could express that using the equality matchers, like this:

```
array.length.should == 37
hash.keys.length.should == 42
```

That's perfectly clear and is perfectly acceptable, but lacks the DSL feel that we get from so many of RSpec's matchers. For those of you who prefer that, we can use the have matcher, which you'll learn about in more detail later in this chapter in Section 13.4, *Have Whatever You Like*, on page 216. For an Array of players on a baseball field, you can do this:

```
team.should have(9).players_on_the_field
```

For a hash with 42 key/value pairs:

```
hash.should have(42).key_value_pairs
```

In these examples, the players_on_the_field() and key_value_pairs() methods are actually there as pure syntactic sugar, and are not even evaluated. Admittedly, some people get confused and even angered by this magic, and they have a valid argument when suggesting that this violates the principle of least surprise. So use this approach if you like the way it reads and use the more explicit and less magical, but equally effective array.length.should == 37 if that works better for you and your development team.

Ch, ch, ch, ch, changes

Ruby on Rails extends test/unit with some rails-specific assertions. One such assertion is assert_difference(), which is most commonly used to express that some event adds a record to a database table, like this:

```
assert_difference 'User.admins.count', 1 do
  User.create!(:role => "admin")
end
```

This asserts that the value of User.admins.count will increase by 1 when you execute the block. In an effort to maintain parity with the rails assertions, RSpec offers this alternative:

```
lambda {
  User.create!(:role => "admin")
}.should change{ User.admins.count }
```

You can also make that much more explicit if you want by chaining calls to by(), to() and from().

```
lambda {
  User.create!(:role => "admin")
}.should change{ User.admins.count }.by(1)

lambda {
  User.create!(:role => "admin")
}.should change{ User.admins.count }.to(1)

lambda {
  User.create!(:role => "admin")
}.should change{ User.admins.count }.from(0).to(1)
```

This does not only work with Rails. You can use it for any situation in which you want to express a side effect of some event. Let's say you want to specify that a real estate agent gets a $7,500 commission on a $250,000 sale:

```
lambda {
  seller.accept Offer.new(250_000)
}.should change{agent.commission}.by(7_500)
```

Now you could express the change by explicitly stating the expected starting and ending values, like this:

```
agent.commission.should == 0
seller.accept Offer.new(250_000)
agent.commission.should == 7_500
```

This is pretty straightforward and might even be easier to understand at first glance. Using should change, however, does a nice job of identifying what is the event and what is the expected outcome. It also functions as a wrapper for more than one expectation if you use the from() and to() methods, as in the examples above.

So which approach should you choose? It really comes down to a matter of personal taste and style. If you're working solo, it's up to you. If you're working on a team, have a group discussion about the relative merits of each approach.

Expecting Errors

When I first started learning Ruby I was very impressed with how well the language read my mind! I learned about Arrays before I learned about Hashes, so I already knew about Ruby's iterators when I encountered a problem that involved a Hash, and I wanted to iterate through its key/value pairs. Before using ri or typing puts hash.methods, I typed hash.each_pair |k,v| just to see if it would work. Of course, it did. And I was happy.

Ruby is filled with examples of great, intuitive APIs like this, and it seems that developers who write their own code in Ruby strive for the same level of *obvious*, inspired by the beauty of the language. We all want to provide that same feeling of happiness to developers that they get just from using the Ruby language directly.

Well, if we care about making developers happy, we should also care about providing meaningful feedback when the wheels fall off. We want to provide error classes and messages that provide context that will make it easier to understand what went wrong.

Here's a great example from the Ruby library itself:

```
$ irb
irb(main):001:0> 1/0
ZeroDivisionError: divided by 0
  from (irb):1:in `/'
  from (irb):1
```

The fact that the error is named ZeroDivisionError probably tells you everything you need to know to understand what went wrong. The message "divided by 0" reinforces that. RSpec supports the development of informative error classes and messages with the raise_error() matcher.

If a checking account has no overdraft support, then it should let us know:

```
account = Account.new 50, :dollars
lambda {
  account.withdraw 75, :dollars
```

```
}.should raise_error(
  InsufficientFundsError,
  /attempted to withdraw 75 dollars from an account with 50 dollars/
)
```

The raise_error() matcher will accept 0, 1 or 2 arguments. If you want to keep things generic, you can pass 0 arguments and the example will pass as long as any subclass of Exception is raised.

```
lambda { do_something_risky }.should raise_error
```

The first argument can be any of a String message, a Regexp that should match an actual message, or the class of the expected error.

```
lambda {
  account.withdraw 75, :dollars
}.should raise_error(
  "attempted to withdraw 75 dollars from an account with 50 dollars"
)

lambda {
  account.withdraw 75, :dollars
}.should raise_error(/attempted to withdraw 75 dollars/)

lambda {
  account.withdraw 75, :dollars
}.should raise_error(InsufficientFundsError)
```

When the first argument is an error class, it can be followed by a second argument that is either a String message or a Regexp that should match an actual message.

```
lambda {
  account.withdraw 75, :dollars
}.should raise_error(
  InsufficientFundsError,
  "attempted to withdraw 75 dollars from an account with 50 dollars"
)

lambda {
  account.withdraw 75, :dollars
}.should raise_error(
  InsufficientFundsError,
  /attempted to withdraw 75 dollars/
)
```

Which of these formats you choose depends on how specific you want to get about the type and the message. Sometimes you'll find it pragmatic to have just a few code examples that get into details about messages, while others may just specify the type. If you look through RSpec's own code examples, you'll see many that look like this:

```
lambda {
  @mock.rspec_verify
}.should raise_error(MockExpectationError)
```

Since there are plenty of other examples that specify details about the error messages raised by message expectation failures, this example only cares that a MockExpectationError is raised.

Expecting a Throw

A less often used, but very valuable construct in Ruby is the throw/catch block. Like raise() and rescue(), throw() and catch() allow you to stop execution within a given scope based on some condition. The main difference is that throw/catch expresses expected circumstances as opposed to exceptional circumstances. It is most commonly used (within its rarity) to break out of nested loops.

For example, let's say we want to know if anybody on our team has worked over 50 hours in one week in the last month. We're going to have a nested loop:

```
re_read_the_bit_about :sustainable_pace if working_too_hard?

def working_too_hard?
  weeks.each do |week|
    people.each do |person|
      return true if person.hours_for(week) > 50
    end
  end
end
```

This seems perfectly sound, but what if we want to optimize it so it short circuits as soon as working_too_hard == true? This is a perfect case for using throw/catch:

```
def working_too_hard?
  catch :working_too_hard do
    weeks.each do |week|
      people.each do |person|
        throw :working_too_hard, true if person.hours_for(week) > 50
      end
    end
  end
end
```

To set an expectation that a symbol is thrown, we wrap up the code in a proc and set the expectation on the proc:

```
lambda {
  team.working_too_hard?
```

```
}.should throw_symbol(:working_too_hard)
```

Like the raise_error() matcher, the throw_symbol() matcher will accept 0, 1 or 2 arguments. If you want to keep things generic, you can pass 0 arguments and the example will pass as long as anything is thrown.

The first (optional) argument to throw_symbol() must be a Symbol, as shown in the example above.

The second argument, also optional, can be anything, and the matcher will pass only if both the symbol and the thrown object are caught. In our current example, that might look like this:

```
lambda {
  team.working_too_hard?
}.should throw_symbol(:working_too_hard, true)

# or ...

lambda {
  team.working_too_hard?
}.should throw_symbol(:working_too_hard, false)
```

13.3 Predicate Matchers

A Ruby predicate method is one whose name ends with a "?" and returns a boolean response. One example built right into the language is array.empty?. This is a simple, elegant construct that allows us to write code like this:

```
do_something_with(array) unless array.empty?
```

When we want to set an expectation that a predicate should return a specific result, however, the code isn't quite as pretty.

```
array.empty?.should == true
```

While that does express what our intention, it doesn't read that well. What we really want to say is that the "array should be empty", right? Well, say it then!

```
array.should be_empty
```

Believe it or not, that will work as you expect. The expectation will be met and the example will pass if the array has an empty? method that returns true. If array does not respond to empty?, then we get a NoMethodError. If it does respond to empty? but returns false, then we get an ExpectationNotMetError.

This feature will work for any Ruby predicate. It will even work for predicates that accept arguments, such as:

```
user.should be_in_role("admin")
```

This will pass as long as user.in_role?("admin") returns true.

How They Work

RSpec overrides method_missing to provide this nice little bit of syntactic sugar. If the missing method begins with "be_", RSpec strips off the "be_", appends a "?", and sends the resulting message to the given object.

Taking this a step further, there are some predicates that don't read as fluidly as we might like when prefixed with "be_". instance_of?(type), for example, becomes be_instance_of. To make these a bit more readable, RSpec also looks for things prefixed with "be_a_" and "be_an_". So we also get to write be_a_kind_of(Player) or be_an_instance_of(Pitcher).

Even with all of this support for prefixing arbitrary predicates, there will still be cases in which the predicate just doesn't fit quite right. For example, you wouldn't want to say parser.should be_can_parse("some text"), would you? Well, we wouldn't want to have to say anything quite so ridiculous, so RSpec supports writing custom matchers with a simple DSL that you'll read about in Section 17.3, *Custom Matchers*, on page 290.

Up until now we've been discussing expectations about the state of an object. The object should be_in_some_state. But what about when the state we're interested in is not in the object itself, but in an object that it owns?

13.4 Have Whatever You Like

A hockey team should have 5 skaters on the ice under normal conditions. The word "character" should have 9 characters in it. Perhaps a Hash should have a specific key. We *could* say Hash.has_key?(:foo).should be_true, but what we really want to say is Hash.should have_key(:foo).

RSpec combines expression matchers with a bit more method_missing goodness to solve these problems for us. Let's first look at RSpec's use of method_missing. Imagine that we've got a simple RequestParameters class that converts request parameters to a hash. We might have an example like this:

```
request_parameters.has_key?(:id).should == true
```

This expression makes sense, but it just doesn't read all that well. To solve this, RSpec uses method_missing to convert anything that begins with have_ to a predicate on the target object beginning with has_. In this case, we can say:

```
request_parameters.should have_key(:id)
```

In addition to the resulting code being more expressive, the feedback that we get when there is a failure is more expressive as well. The feedback from the first example would look like this:

```
expected true, got false
```

Whereas the have_key example reports this:

```
expected #has_key?(:id) to return true, got false
```

This will work for absolutely any predicate method that begins with "has_". But what about collections? We'll take a look at them next.

Owned Collections

Let's say we're writing a fantasy baseball application. When our app sends a message to the home team to take the field, we want to specify that it sends 9 players out to the field. How can we specify that? Here's one option:

```
field.players.select {|p| p.team == home_team }.length.should == 9
```

If you're an experienced rubyist, this might make sense right away, but compare that to this expression:

```
home_team.should have(9).players_on(field)
```

Here, the object returned by have() is a matcher, which does not respond to players_on(). When it receives a message it doesn't understand (like players_on()), it delegates it to the target object, in this case the home_team.

This expression reads like a requirement and, like arbitrary predicates, encourages useful methods like players_on().

At any step, if the target object or its collection doesn't respond to the expected messages, a meaningful error gets raised. If there is no players_on method on home_team, you'll get a NoMethodError. If the result of that method doesn't respond to length or size, you'll get an error saying so. If the collection's size does not match the expected size, you'll get a failed expectation rather than an error.

Un-owned Collections

In addition to setting expectations about owned collections, there are going to be times when the object you're describing *is* itself a collection. RSpec lets us use have to express this as well:

```
collection.should have(37).items
```

In this case, items is pure syntactic sugar. What's happening to support this is safe, but a bit sneaky, so it is helpful for you to understand what is happening under the hood, lest you be surprised by any unexpected behaviour. We'll discuss the inner workings of have a bit later in this section.

Strings

Strings are collections too! Not quite like Arrays and Hashes, but they do respond to a lot of the same messages as collections do. Because Strings respond to length and size, you can also use have to expect a string of a specific length.

```
"this string".should have(11).characters
```

As in unowned collections, characters is pure syntactic sugar in this example.

Precision in Collection Expectations

In addition to being able to express an expectation that a collection should have some number of members, you can also say that it should have *exactly* that number, *at least* that number or *at most* that number:

```
day.should have_exactly(24).hours
dozen_bagels.should have_at_least(12).bagels
internet.should have_at_most(2037).killer_social_networking_apps
```

have_exactly is just an alias for have. The others should be self explanatory. These three will work for all of the applications of have described in the previous sections.

How It Works

The have method can handle a few different scenarios. The object returned by have is an instance of Spec::Matchers::Have, which gets initialized with the expected number of elements in a collection. So the expression:

```
result.should have(3).things
```

is the equivalent of the expression:

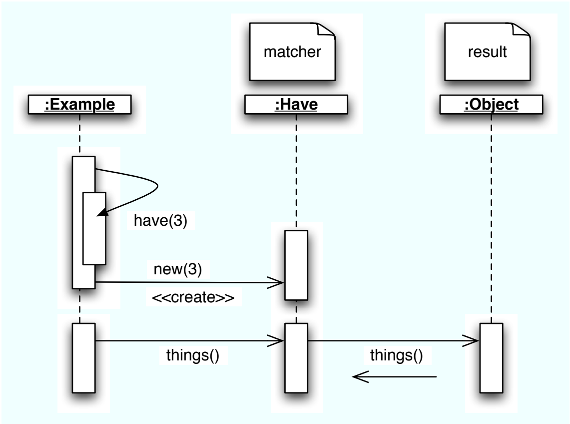

Figure 13.2: Have Matcher Sequence

```
result.should(Have.new(3).things)
```

Figure 13.2 shows how this all ties together. The first thing to get evaluated is Have.new(3), which creates a new instance of Have, initializing it with a value of 3. At this point, the Have object stores that number as the expected value.

Next, the Ruby interpreter sends things to the Have object. method_missing is then invoked because Have doesn't respond to things. Have overrides method_missing to store the message name (in this case things) for later use and then returns self. So the result of have(3).things is an instance of Have that knows the name of the collection you are looking for and how many elements should be in that collection.

The Ruby interpreter passes the result of have(3).things to should(), which, in turn, sends matches?(self) to the matcher. It's the matches? method in which all the magic happens.

First, it asks the target object (result) if it responds to the message that it stored when method_missing was invoked (things). If so, it sends that message and, assuming that the result is a collection, interrogates the result for its length or its size (whichever it responds to, checking for length first). If the object does not respond to either length or size, then you get an informative error message. Otherwise the actual length or size is compared to the expected size and the example passes or fails based the outcome of that comparison.

If the target object does not respond to the message stored in method_missing, then Have tries something else. It asks the target object if it, itself, can respond to length or size. If it will, it assumes that you are actually interested in the size of the target object, and not a collection that it owns. In this case, the message stored in method_missing is ignored and the size of the target object is compared to the expected size and, again, the example passes or fails based the outcome of that comparison.

Note that the target object can be anything that responds to length or size, not just a collection. As explained in our discussion of Strings, this allows you to express expectations like "this string".should have(11).characters.

In the event that the target object does not respond to the message stored in method_missing, length or size, then Have will send the message to the target object and let the resulting NoMethodError bubble up to the example.

As you can see, there is a lot of magic involved. RSpec tries to cover all the things that can go wrong and give you useful messages in each case, but there are still some potential pitfalls. If you're using a custom collection in which length and size have different meanings, you might get unexpected results. But these cases are rare, and as long as you are aware of the way this all works, you should certainly take advantage of its expressiveness.

13.5 Operator Expressions

Generally, we want to be very precise about our expectations. We would want to say that "2 + 2 should equal 4," not that "2 + 2 should be greater than 3." There are exceptions to this, however. Writing a random generator for numbers between 1 and 10, we would want to make sure that 1 appears roughly 1000 in 10,000 tries. So we set some level of tolerance, say 2%, which results in something like "count for 1's should be greater than or equal to 980 and less than or equal to 1020."

An example like that might look like this:

```
it "should generate a 1 10% of the time (plus/minus 2%)" do
  result.occurrences_of(1).should be_greater_than_or_equal_to(980)
  result.occurrences_of(1).should be_less_than_or_equal_to(1020)
end
```

Certainly it reads like English, but it's just a bit verbose. Wouldn't it be nice if, instead, we could use commonly understood operators like >= instead of be_greater_than_or_equal_to? As it turns out, we can!

Thanks to some magic that we get for free from the Ruby language, RSpec is able to support the following expectations using standard Ruby operators:

```
result.should == 3
result.should =~ /some regexp/
result.should be < 7
result.should be <= 7
result.should be >= 7
result.should be > 7
```

RSpec can do this because Ruby interprets these expressions like this:

```
result.should.==(3)
result.should.=~(/some regexp/)
result.should(be.<(7))
result.should(be.<=(7))
result.should(be.>=(7))
result.should(be.>(7))
```

RSpec exploits that interpretation by defining == and =~ on the object returned by should() and <, <=, >, and >= on the object returned by be.

13.6 Generated Descriptions

Sometimes we end up with a an example docstring which is nearly an exact duplication of the expectation expressed in the example. For example:

```
describe "A new chess board" do
  before(:each) do
    @board = Chess::Board.new
  end

  it "should have 32 pieces" do
    @board.should have(32).pieces
  end
end

Produces:
A new chess board
- should have 32 pieces
```

In this case, we can rely on RSpec's automatic example-name generation to produce the name you're looking for:

```
describe "A new chess board" do
  before(:each) { @board = Chess::Board.new }
  specify { @board.should have(32).pieces }
end
```

```
Produces:
A new chess board
- should have 32 pieces
```

This example uses the specify() method instead of it() because specify is more readable when there is no docstring. Both it() and specify() are actually aliases of the example() method, which creates an example.

Each of RSpec's matchers generates a description of itself, which gets passed on to the example. If the example (or it, or specify) method does not receive a docstring, it uses the last of these descriptions that it receives. In this example, there is only one: "should have 32 pieces."

It turns out that it is somewhat rare that the auto-generated names express exactly what you would want to express in the descriptive string passed to example. Our advice is to always start by writing exactly what you want to say and only resort to using the generated descriptions when you actually see that the string and the expectation line up precisely. Here's an example in which it might be more clear to leave the string in place:

```
it "should be eligible to vote at the age of 18" do
  @voter.birthdate = 18.years.ago
  @voter.should be_eligible_to_vote
end
```

Even though the auto-generated description would read "should be eligible to vote," the fact that he is 18 today is very important to the requirement being expressed. Whereas, consider this example:

```
describe RSpecUser do
  before(:each) do
    @rspec_user = RSpecUser.new
  end
  it "should be happy" do
    @rspec_user.should be_happy
  end
end
```

This Expectation would produce a string identical to the one that is being passed to it, so this is a good candidate for taking advantage of auto-generated descriptions.

13.7 Subject-ivity

The *subject* of an example is the object being described. In the happy RSpecUser example, the subject is an instance of RSpecUser, instantiated in the before block.

RSpec offers an alternative to setting up instance variables in before blocks like this, in the form of the subject() method. You can use this method in a few different ways, ranging from explicit, and consequently verbose, to implicit access which can make things more concise. First let's discuss explicit interaction with the subject.

Explicit Subject

In an example group, you can use the subject() method to define an explicit subject by passing it a block, like this:

```
describe Person do
  subject { Person.new(:birthdate => 19.years.ago) }
end
```

Then you can interact with that subject like this:

```
describe Person do
  subject { Person.new(:birthdate => 19.years.ago) }
  specify { subject.should be_eligible_to_vote }
end
```

Delegation to Subject

Once a subject is declared, the example will delegate should() and should_not() to that subject, allowing you to clean that up even more:

```
describe Person do
  subject { Person.new(:birthdate => 19.years.ago) }
  it { should be_eligible_to_vote }
end
```

Here the should() method has no explicit receiver, so it is received by the example itself. The example then calls subject() and delegates should() to it. Note that we used it() in this case, rather than specify(). Read that aloud and compare it to the previous example and you'll see why.

The previous example reads "specify subject should be eligible to vote," whereas this example reads "it should be eligible to vote." Getting more concise, yes? It turns out that, in some cases, we can make things even more concise using an implicit subject.

Implicit Subject

In the happy RSpecUser example, we created the subject by calling new on the RSpecUser class without any arguments. In cases like this, we can leave out the explicit subject declaration and RSpec will create an *implicit subject* for us:

```
describe RSpecUser do
  it { should be_happy }
end
```

Now *that* is concise! Can't get much more concise than this. Here, the subject() method used internally by the example returns a new instance of RSpecUser.

Of course this only works when all the pieces fit. The describe() method has to receive a class that can be instantiated safely without any arguments to new(), and the resulting instance has to be in the correct state.

One word of caution: seeing things so concise like this breeds a desire to make everything else concise. Be careful to *not* let the goal of keeping things concise get in the way of expressing what you really want to express. Delegating to an implicit subject takes a lot for granted, and it should only be used when all the pieces really fit, rather than coercing the pieces to fit.

Beyond Expectations

In this chapter, we've covered:

- should() and should_not()
- RSpec's built-in matchers
- Predicate matchers
- Operator expressions
- Generated descriptions
- Declaring an explicit subject()
- Using the implicit subject()

For most projects, you'll probably find that you can express what you want to using just the tools that come along with RSpec. But what about those cases where you think to yourself "if only RSpec had this one additional matcher"? We'll address that question in Chapter 17, *Extending RSpec*, on page 285, along with a number of other techniques for extending RSpec and tuning its DSL towards your specific projects.

In the meantime, there's still quite a bit more material to cover without extending things at all. In the next chapter we'll introduce you to RSpec's built-in mock objects framework, a significant key to thinking in terms of behaviour.

Chapter 14

Spec::Mocks

BDD developers specify what code *does*, not what it *is*. We do this from the outside-in, starting with Cucumber features to specify how an application should behave when viewed from the outside. We write step definitions that interact with objects that sit at the surface of the app, and set expectations about the responses they get back from those same objects.[1]

In all but the most trivial applications, these surface-level objects delegate work to other objects below the surface. Those sub-surface objects then delegate some or all of the work to other objects, and they to more objects, etc, etc.

From a design standpoint, this all makes perfect sense. We all understand the value of separation of concerns and its impact on the maintainability of an application. But this does present a bit of a chicken and egg problem from a development standpoint. We want to progress in small, verifiable steps, but how can we know that an individual object is properly executing its role if an object it delegates work to doesn't exist yet?

Enter *Test Doubles*.

A test double stands in for a collaborator in an example. If we want the CheckingAccount object to log messages somewhere but we have yet to develop a logger, we can use a double in its place.

1. You learned about step definitions in Section 4.2, *Steps and Step Definitions*, on page 52, and can read more about them in the (as yet) unwritten *chp.cucumber*

We hear doubles referred to as mocks, stubs, fakes, imposters, or any number of other names depending on how they are used, and there is quite a lot of literature describing different names and patterns and the differences between them. When we boil it all down, however, we end up with just a few underlying concepts.

- Test Doubles
- Test-Specific Extensions
- Method Stubs
- Message Expectations

Method stubs and messsage expectations are method-level concepts that we can apply to either test doubles or test-specific extensions, which are both object-level concepts. We'll explore each of these in depth, and talk about how and when we use them.

14.1 Test Doubles

A Test Double is an object that stands in for another object in an example. We often refer to them by names like Mock Objects, Test Stubs, Fakes, etc. In fact, this chapter is called Spec::Mocks because that's the name of the RSpec library that we use to generate test doubles. In spite of the fact that all of these names have different implications, they tend to get used somewhat interchangeably because the behaviour that makes an object a Mock as opposed to a Stub is *expressed at the method level*. See the sidebar on the following page for more on this.

To create a double, just use the double() method, like this:

```
thingamajig_double = double('thing-a-ma-jig')
```

The string argument is optional, but highly recommended as it is used in failure messages. There are also stub() and mock() methods, which produce the same kind of object:

```
stub_thingamajig = stub('thing-a-ma-jig')
mock_thingamajig = mock('thing-a-ma-jig')
```

We can use those to make the spec more clear when appropriate. We'll discuss what that means a bit later. For now, just know that all three methods provide an instance of the Spec::Mocks::Mock class, which provides facilities for generating Method Stubs and Message Expectations.

Test Double Nomenclature

The terminology around test doubles has evolved over the years, and there is quite a lot of overlap and it can be confusing. Some folks in the London XP community had been experimenting with the idea of self-verifying expectations back in 1999. They needed a name for it and coined the term "mock object." Over time we've tended to use mock to mean any sort of test double regardless of whether we're using it to verify expectations.

Gerard Meszaros introduced the term *Test Double* in his book *XUnit Test Patterns* (Mes07), in which he also identified a number of test double patterns, including Mock Objects, Test Stubs, Fakes, Spies, etc, etc. All of the patterns supported by RSpec can be found in Meszaros' writing.

As you learn about test doubles, mocks, stubs, fakes, spies, etc, etc, keep in mind that we're usually talking about methods rather than objects, and there are generally only two kinds of objects we use: test doubles and test-specific extensions.*

All of the other patterns we'll talk about and you'll read about elsewhere are *usually* variations of method stubs and method expectations and can be applied to either test doubles or test-specific extensions.

*. See Section 14.4, *Test-Specific Extensions*, on page 232

14.2 Method Stubs

A *Method Stub* is a method that we can program to return pre-defined responses during the execution of a code example. Consider the following:

```
describe Statement do
  it "uses the customer's name in the header" do
    customer = double('customer')
    customer.stub(:name).and_return('Aslak')
    statement = Statement.new(customer)
    statement.generate.should =~ /^Statement for Aslak/
  end
end
```

This example specifies that a statement uses its customer's name to generate part of the statement. The customer double stands in for a

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real Customer. Thanks to Ruby's dynamic typing, the customer can be of any class, as long as it responds to the right methods.

We create a Test Double using the double() method on line 3. On line 4, we create a Method Stub using the stub() method. It takes a single argument: a symbol representing the name of the method that we want to stub. We follow that with a call to and_return(), which tells the double to return 'Aslak' in response to the name() message.[2]

Here is a simple implementation that will pass this example:

```
class Statement
  def initialize(customer)
    @customer = customer
  end

  def generate
    "Statement for #{@customer.name}"
  end
end
```

When the example is executed, the code on line 6 in the example sends the generate() message to the Statement object. This is the object in development, and is a real Statement.

When the Statement executes the generate() method, it asks the @customer for its name(). The customer is not the focus of this example. It is an immediate collaborator of the Statement, and we're using a test double to stand in for a real Customer in order to control the data in the example. We programmed it to return 'Aslak', so the result is "Statement for Aslak" and the example passes.

Of course, we could also implement the generate() method like this:

```
def generate
  "Statement for Aslak"
end
```

That is, after all, the simplest thing we could do to get the example to pass. This is what traditional TDD instructs us to do first. What it instructs us to do next varies from practicioner to practicioner. One approach is to triangulate: add another example that uses a different value, forcing the implementation to generalize the value in order to pass both examples.

2. This sort of method chaining is called a *fluent interface*, and is quite common in all of Ruby's most common test double frameworks. In fact, earlier versions of RSpec used fluent interfaces to set expectations like result.should.equal(4).

Another approach is to view the 'Aslak' in the implementation as duplication with the 'Aslak' in the example. Following the DRY principle, we remove that duplication by generalizing the implementation.

Neither of these approaches is ideal. Triangulation requires an extra example that specifies the same essential behaviour. DRY is certainly a worthy justification, but it requires that we take that extra step. Experience shows that this approach will periodically result in hard-coded values remaining in implementation code. There is, however, a third option!

14.3 Message Expectations

A message expectation, a.k.a. mock expectation, is a method stub that will raise an error if it is never called. In RSpec, we create a message expectation using the should_receive() method, like this:

```
describe Statement do
  it "uses the customer's name in the header" do
    customer = double('customer')
►   customer.should_receive(:name).and_return('Aslak')
    statement = Statement.new(customer)
    statement.generate.should =~ /^Statement for Aslak/
  end
end
```

Using should_receive() instead of stub() sets an expectation that the customer double should receive the name() message. The subsequent and_return() works just like before: it is an instruction to return a specific value in response to name().

In this example, if the generate() method fails to ask the customer double for its name, the example will fail with Double "customer" expected :name with (any args) once, but received it 0 times. If the generate() method calls customer.name(), then the customer double returns the programmed value, execution continues on, and the example passes.

Tight Coupling

Clearly, this example is highly coupled to the implementation, but this coupling is easily justified. We're specifying that the statement uses the customer's name! If that is the requirement that we are expressing in this example, then setting a message expectation is perfectly reasonable.

On the flip side, we want to avoid setting message expectations that are not meaningful in the context of an example. Generally speaking, we only want to use message expectations to express the intent of the example. To explain what we mean, let's look at an example that uses both a method stub and a method expectation.

Mixing Method Stubs and Message Expectations

Extending the statement examples, let's add a requirement that any time a statement is generated, a log entry gets created. Here's one way we might express that:

```ruby
describe Statement do
  it "logs a message on generate()" do
    customer = stub('customer')
    customer.stub(:name).and_return('Aslak')
    logger   = mock('logger')
    statement = Statement.new(customer, logger)

    logger.should_receive(:log).with(/Statement generated for Aslak/)

    statement.generate
  end
end
```

Now we have three participants in the example: the statement, which is the subject of the example, the logger, which is the primary collaborator, and the customer, which is a secondary collaborator. The logger is the primary collaborator because the example's docstring states that the Statement logs a message on generate().

By using the mock() method to generate the logger double and the stub() method to generate the customer double, we're helping to express that these objects are playing different roles in the example. This is a wonderful technique, embedding intent right in the code in the example.

Given, Then, When?

The logger.should_receive() statement is the only expectation in the example, and it comes *before* the event; the When. The resulting flow is a bit different from the Given, When, Then flow that we're accustomed to seeing. Here it's Given, Then, When: Given a statement constructed with a customer and logger, Then the logger should receive log() When the statement receives generate().

This change in flow can be a bit jarring for those experienced in writing code examples, yet new to message expectations. So much so that some in the community are beginning to solve the problem with new libraries that take different approaches. See the sidebar on the following page for more on this.

Of course, what we don't see is that there is an automatic and implicit verification step that happens at the end of each example. This is facilitated by the test double framework hooking into the lifecycle of the examples, listening for the end of each example, and then verifying that any expectations set in the example were met. So the flow is really Given, Expect, When, Then, but since we never see the Then, it is admittedly a bit magical.

Thus far we've only talked about setting method stubs and message expectations on test double objects. This is a very useful technique when the collaborators we need either don't exist yet, or are very expensive to set up or use in a code example. But sometimes the collaborator we need already exists, requires little or no setup, and exposes only trivial behaviour. For cases like this, we can add support for method stubs and message expectations directly to the real object using a technique called *Test-Specific Extensions*.

14.4 Test-Specific Extensions

As the name suggests, a Test-Specific Extension is an extension of an object that is specific to a particular test, or *example* in our case. We call them Test-Specific Extensions because it is very similar to the *Test-Specific Subclass* pattern described by Meszaros, in which a subclass of a real class is used to extend instances to support test-double-like behaviour.

Thanks to Ruby's metaprogramming model, we can get the same result by extending existing objects. And because the resulting object is partially the original object and partially a test double, we commonly refer to this technique as *Partial Mocking and Stubbing*.

Partial Stubbing

Consider a case in Ruby on Rails where we want to disconnect the system we are working on from the database. We can use real objects but stub the find() and save() methods that we expect to be invoked. For example:

```
describe WidgetsController do
  describe "PUT update with valid attributes"
```

Given, When, Then with Test Spies

Libraries like RR and the ironically named not-a-mock use the Test Spy pattern to provide a means of expressing message expectations in the past tense, thereby maintaining the flow of expectations at the end of an example.* As of this writing, Spec::Mocks does not support Test Spies, but, luckily, both not-a-mock and RR plug right into RSpec and can be used instead of Spec::Mocks if spies are what you're after.

Here's what our statement, customer, logger example might look like using not-a-mock:†

```
describe Statement do
  it "logs a message when on generate()" do
    customer = stub('customer')
    customer.stub(:name)
    logger   = mock('logger')
    logger.stub(:log)
    statement = Statement.new(customer, logger)

    statement.generate

    logger.should have_received(:log)
  end
end
```

And here with RR:‡

```
describe Statement do
  it "logs a message when on generate()" do
    customer = Object.new
    stub(customer).name
    logger   = Object.new
    stub(logger).log
    statement = Statement.new(customer, logger)

    statement.generate

    logger.should have_received.log
  end
end
```

*. http://xunitpatterns.com/Test%20Spy.html
†. http://github.com/notahat/not_a_mock
‡. http://github.com/btakita/rr

```
    it "redirects to the list of widgets"
      widget = Widget.new()
      Widget.stub!(:find).and_return(widget)
      widget.stub!(:update_attributes).and_return(true)
      put :update, :id => 37
      response.should redirect_to(widgets_path)
    end
  end
end
```

There are a few things going on in this example:

1. We stub the class level find method to return a known value: in this case, the Widget object created on the previous line.
2. We stub the update_attributes method of the widget object, programming it to return true.
3. We invoke the put() method from the Rails functional testing API.[3]
4. We set an expectation that the response object should redirect to the list of widgets.

This example specifies exactly what the description suggests: WidgetsController PUT update with valid attributes redirects to the list of widgets. That the attributes are valid is a *given* in this example, and we don't really need to know what constitutes *valid attributes* in order to specify the controller's behaviour in response to them. We just program the Widget to pretend it has valid attributes.

This means that changes to the Widget's validation rules will not have any impact on this example. As long as the controller's responsibility does not change, this example won't need to change, nor will the controller itself.

There is also no dependency on the database in this example. Well, no explicit dependency. Rails will try to load up the schema for the widgets table the first time it loads widget.rb, but that is the only db interaction. There are no additional db interactions as a result of this example. If we use a Rails plugin like NullDB,[4] we can completely disconnect from the database and this example will still run.

3. As you'll learn about in Chapter 24, *Rails Controllers*, on page 385, the rspec-rails library provides rspec flavored wrappers around Rails' built-in testing facilities.
4. http://avdi.org/projects/nulldb/

Partial Mocking

In the WidgetsController example, it is possible to get it to pass without ever actually finding a widget, or updating its attributes. As long as the controller method redirects to the widgets_path, that example passes. For this reason, and for the purposes of documentation, we may want separate examples that specify these details. For these examples, we can set message expectations on the Widget class and instance instead of method stubs. This is called partial mocking.

Here's what this might look like:

```
describe WidgetsController do
  describe "PUT update with valid attributes"
    it "finds the widget"
      widget = Widget.new()
      widget.stub!(:update_attributes).and_return(true)

      Widget.should_receive(:find).with("37").and_return(widget)

      put :update, :id => 37
    end

    it "updates the widget's attributes" do
      widget = Widget.new()
      Widget.stub!(:find).and_return(widget)

      widget.should_receive(:update_attributes).and_return(true)

      put :update, :id => 37
    end
  end
end
```

Note how we mix method stubs and message expectations in these examples. The first example specifies that the WidgetsController finds the widget, so we set an expectation that the Widget class should receive the find() method. We need to program the widget to return true for update_attributes(), but we're not specifying that it is called in this example, so we just use a method stub.

Message expectations on the real model objects allow us to specify how the controller interacts with them, rather than a specific outcome. These two examples, combined with the redirect example in which we used only method stubs on the model objects, produce the following output:

```
WidgetsController
  PUT update with valid attributes
```

```
finds the widget
updates the widget's attributes
redirects to the list of widgets
```

As you can see just from the output, these techniques help us to specify what the WidgetsController *does*. And by using different techniques in different examples, we are able to keep each example focused on a specific granular facet of the behaviour.

Partial stubbing/mocking isn't risk free. We must take care not to replace too much of the real objects with stub/mock methods. This is especially important for the subject of the example, because we end up not working with the object we thought we were. So keep partial mocking to an absolute minimum.

14.5 More on Method Stubs

The examples we've looked at before only touch the surface of the API for test doubles. In this section and the next we'll take a deeper look at the utilities supported by Spec::Mocks.

One Line Shortcut

Most of the time we use method stubs we simply return a stubbed value. For these cases, RSpec offers a simple shortcut:

```
customer = double('customer', :name => 'Bryan')
```

The double(), mock(), and stub() methods each accept a hash after the optional name. Each key/value pair in the hash is converted to a stub using the key as the method name and the value as the return value. The example above is a shortcut for this:

```
customer = double('customer')
customer.stub(:name).and_return('Bryan')
```

The hash can be of any length, so if we have more than one method we wish to stub, we just add key/value pairs for each method:

```
customer = double('customer',
  :name => 'Bryan',
  :open_source_projects => ['Webrat','Rack::Test']
)
```

Implementation Injection

From time to time we might stub a method that ends up getting called more than once in an example and we want to supply different return values for it based on the arguments. One way to handle this is to supply a block to the stub() method, like this:

```
ages = double('ages')
ages.stub(:age_for) do |what|
  if what == 'drinking'
    21
  elsif what == 'voting'
    18
  end
end
```

This is essentially what Meszaros calls the Fake pattern, in which a real method is replaced by a lightweight implementation. We're just injecting the implementation with a block, rather than defining a method directly on the object.

This is especially useful in cases in which we want to define the stub in a before() block and use it several examples. The downside of this is that we separate the data and calculation from the example, so we recommend only using that approach for cases in which the returned value (21, 18, or nil in this case) is not part of what's being specified in the examples.

Stub Chain

Let's say we're building an educational website with Ruby on Rails, and we need a database query that finds all of the published articles written in the last week by a particular author. Using a custom DSL built on ActiveRecord named scopes, we can express that query like so:

```
Article.recent.published.authored_by(params[:author_id])
```

Now let's say that we want to stub the return value of authored_by() for an example. Using standard stubbing, we might come up with something like this:

```
recent      = double()
published   = double()
authored_by = double()
article     = double()
Article.stub(:recent).and_return(recent)
recent.stub(:published).and_return(published)
published.stub(:authored_by).and_return(article)
```

That's a *lot* of stubs! Instead of revealing intent it does a great job of hiding it. It's complex, confusing, and if we should ever decide to change any part of the chain we're in for some pain changing this. For these reasons, many people simply avoid writing stubs when they'd otherwise want to. Those people don't know about RSpec's stub_chain() method, which allows us to write this:

```
article = double()
Article.stub_chain(:recent, :published, :authored_by).and_return(article)
```

Much nicer! Now this is still quite coupled to the implementation, but it's also quite a bit easier to see what's going on and map this to any changes we might make in the implementation.

14.6 More on Message Expectations

Message expectations tend to be more tightly bound to implementation details of the method in development than method stubs. In the logger example, if the customer fails to log a message the example fails. Had we only stubbed the log() method we would not get a failure.

RSpec offers a number of utilities we can use to specify more focused aspects of implementation. Keep in mind that all of these utilities we're about to discuss increase the coupling between the spec and the object in development, which increases the likelihood that subsequent changes to the object in development will force changes in the specs. We recommend, therefore, that these only be used to express specific requirements.

Counts

Test doubles often stand in for objects with expensive operations like database and network calls. When we're optimizing, we may want to specify that a given message is not sent to the double any more times than is necessary for the operation. By default, should_receive() sets an expectation that a message should be received once, and only once. We can set this expectation explicitly like this:

```
mock_account.should_receive(:withdraw).exactly(1).times
```

Using the same syntax, we can specify any number:

```
mock_account.should_receive(:withdraw).exactly(5).times
```

Sometimes we may want to make sure that an operation is repeated no more than some number of times. Consider a double that is standing in for a collaborator that establishes network connections. If it can't get a connection, we want it to retry it five times, but no more. In this case, we can set an upper bound:

```
network_double.should_receive(:open_connection).at_most(5).times
```

Similarly, we can set a lower bound for a situation in which we want to specify that a call is made at least some number of times:

```
network_double.should_receive(:open_connection).at_least(2).times
```

RSpec includes a couple of convenience methods to handle the cases where the count is one or two. This reads a bit better than exactly(1).times, and is recommended approach:

```
account_double.should_receive(:withdraw).once
account_double.should_receive(:deposit).twice
```

Negative Expectation

Sometimes we want to specify that a specific message is *never* received during an example. Imagine a requirement that we only try to make connections after pinging a server. Here's one way we can express that requirement:

```
network_double.stub(:ping).and_return(false)
network_double.should_not_receive(:open_connection)
```

If the network_double receives open_connection(), the example will fail. Here are two more ways to express that a message should not be received:

```
network_double.should_receive(:open_connection).never
network_double.should_receive(:open_connection).exactly(0).times
```

These both work fine, but should_not_receive() is the most commonly used.

Specifying Expected Arguments

In cases in which we expect specific arguments, we can use the with method to constrain the expectation. For literal values, we can just pass them directly to the with() method:

```
account_double.should_receive(:withdraw).with(50)
```

If the account_double receives the withdraw() method with any value besides 50, it will raise an error saying it was expecting 50 but got the other value instead. We can pass any number of arguments to with(), and it will fail if any of the received arguments fail to match the expection arguments:

```
checking_account.should_receive(:transfer).with(50, savings_account)
```

This example will only pass if the checking_account receives transfer() with arguments matching 50 and savings_account in the correct order.

The arguments are evaluated using ==(), so in this example they have to ==(50) and ==(savings_account).

Argument Matchers

Sometimes we don't care about the specific values of all of the arguments. When specifying a transfer operation as in the example above, we might have separate examples for the two different arguments. In the example focused on the account, we need the second argument in the example, or the double would raise an error saying it only got one argument. But we don't care what that argument is, since this example is focused on the first argument.

instance_of()

We can address this using an *Argument Matcher*: a method which returns an object that can match against the real arguments received during the example. In this case, we want the second argument to be an instance of Fixnum, but we don't care what it is. We can use the instance_of() argument matcher to address this:

```
Line 1  describe Transfer do
     -    it "passes the target account to the source account" do
     -      source_account = double()
     -      target_account = double()
     5      transfer = Transfer.new(
     -        :source_account => source_account,
     -        :target_account => target_account,
     -        :amount         => 50
     -      )
    10      source_account.should_receive(:transfer).
     -        with(target_account, instance_of(Fixnum))
     -      transfer.execute()
     -    end
     -  end
```

On line 11, we specify that the first argument should ==(target_account) and that the second argument can be any Fixnum. Of course we know it's going to be 50, because that is what is supplied on line 8, but we don't *care* about that in this example.

When we do this, we're coupling the example to a specific type, which is usually *not* recommended. Remember, these facilities are available, but we want to use them only when they help express the intent of the example.

anything()

When we want to specify that an argument is received, but we really don't care what it is, we can use the anything() matcher, like this:

```
describe Transfer do
  it "passes the submitted amount to the source account" do
    source_account = stub()
    target_account = stub()
    transfer = Transfer.new(
      :source_account => source_account,
      :target_account => target_account,
      :amount         => 50
    )
    source_account.should_receive(:transfer).
      with(anything(), 50)
    transfer.execute()
  end
end
```

any_args()

As mentioned earlier, a message expectation without the with() method will accept any arguments. If you wish, you can use the any_args() method to explicitly specify that any arguments are acceptable:

```
source_account.should_receive(:transfer).
  with(any_args())
```

no_args()

Now imagine we have an API that can accept zero or more arguments, and we want to specify that under certain conditions it should receive a message with no arguments. We can do that too, using the no_args() argument matcher:

```
collaborator.should_receive(:message).
  with(no_args())
```

hash_including()

If the expected argument is a Hash, we can specify the expected key/value pairs like this:

```
mock_account.should_receive(:add_payment_accounts).
             with(hash_including('Electric' => '123', 'Gas' => '234'))
```

hash_not_including()

The hash argument in this example is expected to include keys for 'Electric' and 'Gas' with the corresponding values 123 and 234 respectively.

We can also specify that those values should *not* be in the hash like this:

```
mock_account.should_receive(:add_payment_accounts).
             with(hash_not_including('Electric' => '123', 'Gas' => '234'))
```

In this case, an acceptable argument value would be a hash that does not have the specified key-value pairs.

Regular Expressions

For String arguments, we can expect just a part of the string using a Regexp that will be matched against it, like this:

```
mock_atm.should_receive(:login).with(/.* User/)
```

As you can see, RSpec comes with a range of useful argument matchers built in, but sometimes we need to express more specfic constraints. In these cases it's easy to extend RSpec with our own.

Custom Argument Matchers

Let's say we want to be able to expect a Fixnum argument that is greater than three. With a custom argument matcher, we can express this expectation something like this:

```
calculator.should_receive(:add).with(greater_than_3)
```

An argument matcher is simply an object supporting a specific interface. The only method that is required is ==(actual), which acts as a match operation (not equality). It should return true if the actual argument matches (or conforms to) the matcher.

```
class GreaterThanThreeMatcher
  def ==(actual)
    actual > 3
  end
end
```

We can return an instance of GreaterThanThreeMatcher from a greater_than_3() method, like this:

```
def greater_than_3
  GreaterThanThreeMatcher.new
end
```

Using an argument matcher like this, the should_receive() method will give you failure messages like:

```
Mock 'calculator' expected :add with (#<Spec::Mocks::ArgumentMatchers::
   GreaterThanThreeMatcher:0x5e7af4>) but received it with (3)
```

We can improve on that message by adding a description method to the matcher:

```
def description
  "a number greater than 3"
end
```

Now, the message will be:

```
Mock 'subject' expected :msg with (a number greater than 3)
  but received it with (2)
```

We can generalize this a bit by parameterizing the method and the matcher object like this:

```
class GreaterThanMatcher

  def initialize(expected)
    @expected = expected
  end

  def description
    "a number greater than #{@expected}"
  end

  def ==(actual)
    actual > @expected
  end
end

def greater_than(floor)
  GreaterThanMatcher.new(floor)
end
```

Now we can use this matcher for any situation in which we expect a number greater than some other number:

```
calculator.should_receive(:add).with(greater_than(37))
```

Returning Consecutive Values

Sometimes we want the subject to send the same message to the collaborator more than once, and we want to set up different return values each time in order to trigger a particular behaviour in the subject.

Consider a gateway_client, which depends on a network object to connect to the real gateway. We want to specify that the gateway client will ask the network to try to open a connection up to three times before it gives up. Here are a few examples we might write to specify this:

```
describe GatewayClient, "#connect" do
  before(:each) do
```

```
-       @network = stub()
-       @gateway_client = GatewayClient.new(@network)
5     end
-
-     it "returns true if network returns connection on first attempt" do
-       @network.should_receive(:open_connection).
-         and_return(Connection.new)
10      @gateway_client.connect.should be_true
-     end
-
-     it "returns true if network returns connection on third attempt" do
-       @network.should_receive(:open_connection).
15        and_return(nil, nil, Connection.new)
-       @gateway_client.connect.should be_true
-     end
-
-     it "returns false if network fails to return connection in 3 attempts" do
20      @network.should_receive(:open_connection).
-         and_return(nil, nil, nil)
-       @gateway_client.connect.should be_false
-     end
-
25  end
```

On line 9 in the first example, we program the @network to return a Connection the first time open_connection() is called. This is how we normally set return values for a method stub or message expectation.

The second example is a bit different. On line 15, we program the @network to expect open_connection(), returning nil the first two times, and a Connection the third. We do so by passing nil, nil, and Connection.new to the and_return() method. With three arguments passed to and_return(), we're implicitly telling the @network to expect open_connection() three times.

The third example programs open_connection() to return nil three times in a row. Again, we're implicitly telling @network to expect open_connection() three times. We could get the same behaviour by explictly telling the @network to expect open_connection() three times and return nil, like this:

```
it "returns false if network fails to return connection in 3 attempts" do
  @network.should_receive(:open_connection).
    exactly(3).times.
    and_return(nil)
  @gateway_client.connect.should be_false
end
```

In that variation, we only pass nil (once) to and_return() because we're already telling the @network to expect open_connection() three times on line 3. The @network in each of these variations behave in exactly the same way.

Throwing or Raising

To specify an object's behaviour in response to errors, we want to have our collaborator throw a symbol or raise an error in response to a specific message. Spec::Mocks provides several ways to do this. The most common approach is to simply raise an exception:

```
account_double.should_receive(:withdraw).and_raise
```

With no arguments, the and_raise() method tells the account_double to raise an instance of Exception when it receives the withdraw() message. To raise a specific type of exception, we can pass and_raise an exception class, like this:

```
account_double.should_receive(:withdraw).and_raise(InsufficientFunds)
```

RSpec will create an instance of InsufficientFunds by calling InsufficientFunds.new. If the exception class we need requires any arguments to its constructor, we can create an instance in the example and pass that in instead:

```
the_exception = InsufficientFunds.new(:reason => :on_hold)
account_double.should_receive(:withdraw).and_raise(the_exception)
```

We can also throw symbols instead of raising errors. As you might expect, this is done with the and_throw() method instead of and_raise:

```
account_double.should_receive(:withdraw).and_throw(:insufficient_funds)
```

Yielding

```
account_double.should_receive(:balance).and_yield(args)
```

Ordering

When specifying interactions with a test double, the order of the calls is rarely important. In fact, the ideal situation is to specify only a single call. But sometimes, we need to specify that messages are sent in a specific order.

Consider an implementation of a database-backed class roster in which we want the roster to ask the database for the count of students registered for a given class before adding any new students for that class. We can specify this using the ordered() method, and specifying the message expectations in the order in which we expect them:

```
describe Roster do
  it "asks database for count before adding" do
    database = double()
    student  = double()
    database.should_receive(:count).with('Roster', :course_id => 37).ordered
    database.should_receive(:add).with(student).ordered

    roster = Roster.new(37, database)
    roster.register(student)
  end
end
```

This example will only pass if the count() and add() messages are sent with the correct arguments and *in the same order*. Here is a possible implementation:

Download mocking/ordering.rb

```
class Roster
  def initialize(id, database)
    @id = id
    @database = database
  end

  def register(student)
    @database.count('Roster', :course_id => @id)
    @database.add(student)
  end

end
```

Note that ordering has effect only within the context of a single object. You can specify ordering of expectations for multiple objects in an example, but the order is *not enforced across objects*.

Also note that ordering ignores any messages besides the ones assigned as ordered. For example, the following implementation would still pass the example above, provided that we told the database double to act as_null_object().

Download mocking/ordering.rb

```
def register(student)
  @database.count('Roster', :course_id => @id)
  @database.begin
  @database.add(student)
  @database.commit
end
```

The fact that the database receives begin() and commit() is ignored by the ordering mechanism. As long as the ordered messages are received in the correct order, the example will pass.

Overriding method stubs

In the statement examples earlier this chapter, we looked at examples specifying that the statement uses the customer's name in the header, and that it logs a message on generate(). We never really looked at those together at the point that the statement supports both. Here's what that looks like without any refactoring.

```
describe Statement do
  it "uses the customer's name in the header" do
    customer = stub('customer')
    customer.stub(:name).and_return('Aslak')
    logger   = mock('logger')
    logger.stub(:log)
    statement = Statement.new(customer, logger)

    statement.generate.should =~ /^Statement for Aslak/
  end

  it "logs a message on generate()" do
    customer = stub('customer')
    customer.stub(:name).and_return('Aslak')
    logger   = mock('logger')
    statement = Statement.new(customer, logger)

    logger.should_receive(:log).with(/Statement generated for Aslak/)

    statement.generate
  end
end
```

As you can see there is a lot of noise and a lot of duplication. We can reduce this significantly by exploiting the fact that message expectations can override stubs:

```
describe Statement do
  before(:each) do
    @customer = double('customer')
    @logger   = double('log', :log => nil)
    @statement = Statement.new(@customer, @logger)
  end

  it "uses the customer's name in the header" do
    @customer.should_receive(:name).and_return('Aslak')
    @statement.generate.should =~ /^Statement for Aslak/
  end
```

```
  it "logs a message on generate()" do
    @customer.stub(:name).and_return('Aslak')
    @logger.should_receive(:log).with(/Statement generated for Aslak/)
    @statement.generate
  end
end
```

Now the code in each example is very well aligned with their docstrings, with no unnecessary noise. By setting the log() stub on the @logger double in the before() block, we don't need to set that stub in the first example. In the second example, we override that stub with the expectation. Once the expectation is met, any subsequent calls to log() are caught by the stub, and essentially ignored.

14.7 When to Use Test Doubles and Test-Specific Extensions

Now that we know how to use test doubles and test-specific extensions, the next question is *when* to use them! There are a lot of opinions about this, and we're not going to be able to cover every topic (this could easily fill an entire book), but let's look at some guidelines that can help you navigate your way.

Isolation from Dependencies

Even the most highly decoupled code has some dependencies. Sometimes they are on objects which are cheap and easy to construct and have no complex state. These generally don't present a problem, so there is no need to create stubs for them.

The problematic dependencies are the ones that are expensive to construct, involve external systems (network, servers, even the file system), have dependencies on other expensive objects, or function slowly. We want to isolate our examples from these dependencies because they complicate setup, slow down run times, and increase potential points of failure.

Consider the system depicted in Figure 14.1, on the following page with dependencies on a database and a network connection. We can replace the dependencies with test doubles as shown in Figure 14.2, on the next page, thereby removing the real dependencies from the process. Now we are free of any side effects arising from external systems.

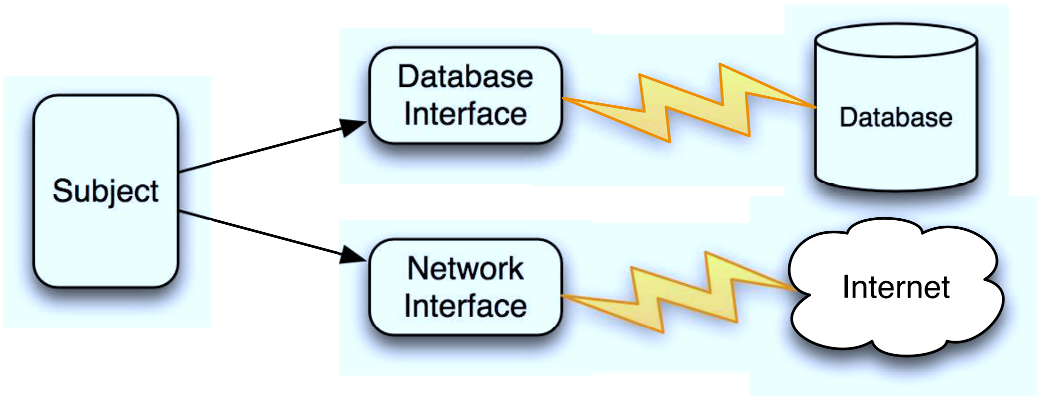

Figure 14.1: External Dependencies

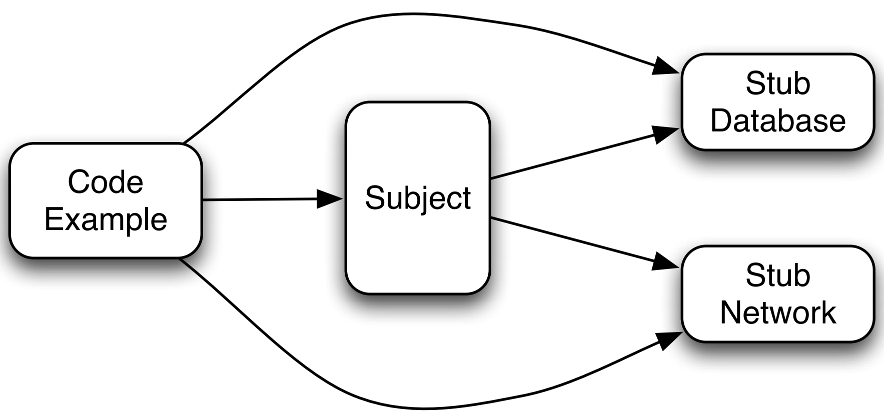

Figure 14.2: Stubbed Dependencies

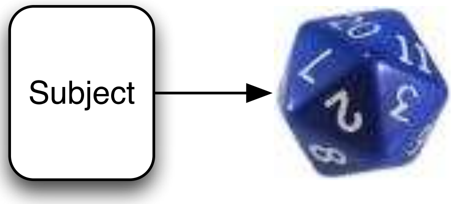

Figure 14.3: Dependency on a random generator

Isolation from Non-Determinism

Depending on external systems can also be a source of non-determinism. When we depend on components with non-deterministic characteristics, we may find that files get corrupted, disks fail, networks time out, and servers go down in the middle of running specs. As these are things that we have no control over, they can lead to inconsistent and surprising results when we run our specs.

Doubles can disconnect our examples from real implementations of these dependencies, allowing us to specify things in a controlled environment. They help us to focus on the behaviour of one object at a time without fear that another might behave differently from run to run.

Non-determinism can also be local. A random generator may well be local, but is clearly a source of non-determinism. We would want to replace the real random generator with stable sequences to specify different responses from our code. Each example can have a pseudo-random sequence tailored for the behaviour being specified.

Consider a system that uses a die, like the one shown Figure 14.3. Because a die is a random generator, there is no way to use it to write a deterministic example. Any specifications would have to be statistical in nature, and that can get quite complicated. Statistical specs are useful when we're specifying the random generators directly, but when we're specifying their clients, all that extra noise takes focus away from the behaviour of the object we should be focused on.

If we replace the die with something that generates a repeatable sequence, as shown in Figure 14.4, on the next page, then we can write examples

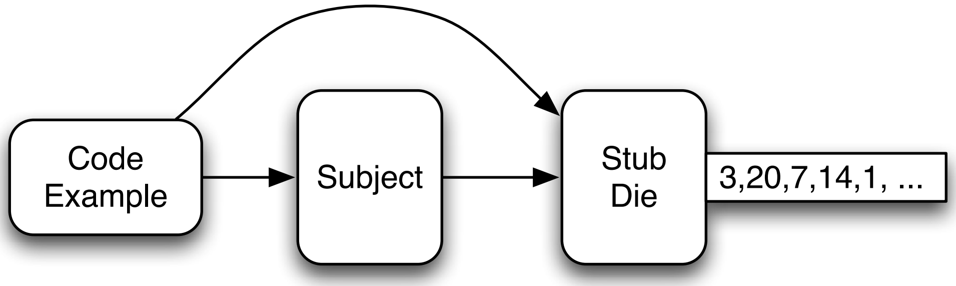

Figure 14.4: Dependency on a repeatable sequence

that illustrate the system's behaviour based on that sequence. A stub is perfect for this, because each example can specify a different sequence.

Making Progress Without Implemented Dependencies

Sometimes we are specifying an object whose collaborators haven't been implemented yet. Even if we've already designed their APIs, they might be on another team's task list and they just haven't gotten to it yet.

Rather than break focus on the object we're specifying to implement that dependency, we can use a test double to make the example work. This not only keeps us focused on the task at hand, but it also provides an opportunity to explore that dependency and possible alternative APIs before it is committed to code.

Interface Discovery

When we're implementing the behaviour of one object, we often discover that it needs some service from another object that may not yet exist. Sometimes it's an existing interface with existing implementations, but it's missing the method that the object we're specifying really wants to use. Other times, the interface doesn't even exist at all yet. This process is known as *Interface Discovery*, and is the cornerstone of mock objects.

In cases like these we can introduce a mock object, which we can program to behave as the object we are currently specifying expects. This is a very powerful approach to writing Object Oriented software, as it allows us to design new interfaces as they are needed, making decisions about them as late as possible, when we have the most information about how they will be used.

Focus on Role

In 2004, Steve Freeman, Nat Pryce, Tim Mackinnon, and Joe Walnes presented a paper entitled Mock Roles, not Objects.[5] The basic premise is that we should think of *roles* rather than specific objects when we're using mocks to discover interfaces.

In the logging example in Section 14.3, *Mixing Method Stubs and Message Expectations*, on page 231, the logger could be called a Logger, or a Messenger, a Recorder, a Reporter, etc, etc. What the object is doesn't matter in that example. The only thing that matters is that it represents an object that will act out the *role* of a logger at runtime. Based on that example, in order to act like a logger, the object has to respond to the log() method.

Focusing on roles rather than objects frees us up to assign roles to different objects as they come into existence. This not only allows for very loose coupling between objects at runtime, it provides loose coupling between concepts as well.

Focus on Interaction Rather Than State

Object Oriented systems are all about interfaces and interactions. An object's internal state is an implementation detail, and not part of its observable behaviour. As such it is more subject to change than the object's interface. We can therefore keep specs more flexible and less brittle by avoiding reference to the internal state of an object.

Even if we already have a well designed API up front, mocks still provide value because they focus on interactions between objects rather than side-effects on the internal state of any individual object.

This may seem to contradict the idea that we want to avoid implementation detail in code examples. Isn't that what we're doing when we specify what messages an object sends? In some cases, this is a perfectly valid observation. Consider this example with a method stub:

```
describe Statement do
  it "uses the customer's name in the header (with a stub)" do
```

5. http://mockobjects.com/files/mockrolesnotobjects.pdf

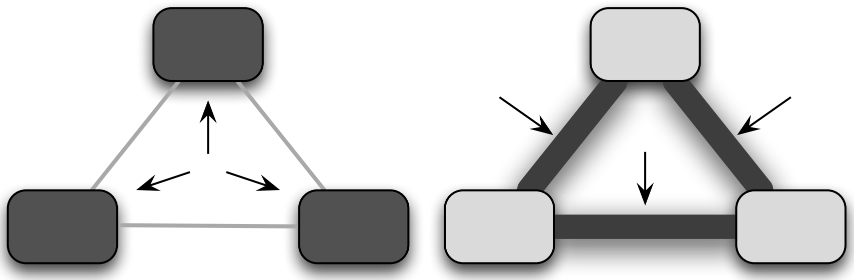

Figure 14.5: Focus on State vs Interaction

```
    customer = stub("customer", :name => "Dave Astels")
    statement = Statement.new(customer)
    statement.header.should == "Statement for Dave Astels"
  end
end
```

Now compare that with the same example using a message expectation instead:

```
describe Statement do
  it "uses the consumer's name in the header (with a mock)" do
    customer = mock("customer")
    customer.should_receive(:name).and_return("Dave Astels")
    statement = Statement.new(customer)
    statement.header.should == "Statement for Dave Astels"
  end
end
```

In this case, there is not much value added by using a message expectation in the second example instead of the method stub in the first example. The code in the second example is more verbose, and more tightly bound to the underlying implementation of the header() method. Fair enough. But consider the logger example earlier this chapter. That is a perfect case for a message expectation, because we're specifying an interaction with a collaborator, not an outcome.

A nice way to visualize this is to compare the left and right diagrams in Figure 14.5. When we focus on state, we design objects. When we focus on interaction, we design behaviour. There is a time and place for each approach, but when we choose the latter, mock objects make it much easier to achieve.

14.8 Risks and Trade-Offs

In this section we'll look at some of the common pitfalls of mocking and stubbing, things that we should avoid, and things that can alert us to design problems.

Over-specification

Mock objects should make it easy to set up the context for our examples. If we need a bunch of mocks in one example, we end up with a long and confusing set up.

Specify only what is absolutely necessary for the current example. If that turns out to be a lot, it's time to re-evaluate the design... it may be more coupled than previously thought.

Nested Doubles

Doubles should not only be simple to set up, they should be shallow as well. While not all methods that we specify on doubles need to return values, many do. When they do it's generally best if the return value is a simple value: a language primitive or a value object.

One exception to this guideline is when we want to introduce a double through a query, as we demonstrated in Section 14.4, *Test-Specific Extensions*, on page 232. In this case, we can stub the query method to return the double.

When we do find it necessary to nest doubles, it's quite often a sign that we're working with a pre-existing design that may have some coupling problems. A general rule of thumb is that if the code is hard to use in examples, it's going to be hard to use everywhere else.

Absence of Coverage

One goal of BDD (and TDD) is to develop confidence in the system by taking small, verifiable steps, and building up a suite of regression tests as we go. When we're using mock objects in dynamic languages like Ruby, it is possible to change an object's API and forget to change the examples that mock that same API.

The result can be that all of our examples pass, yet when we start up the application, the wheels fall off right away because one object is sending the wrong message to another. There is little that can knock our confidence in our system more than finding such a gaping hole in our regression test suite.

One remedy for this situation is to have some higher level of automated testing in place. In BDD, we start with automated acceptance criteria before we even start developing objects, so this should not be an issue. Even if we forget to change the API on a mock, the automated scenarios should catch any problems we've introduced very shortly after we introduce them.

But, to the extent that we do *not* follow this practice, we also increase the risk of getting false-positive feedback from our specs.

Brittle examples

The biggest pitfall of over-use of mocks is that examples can become brittle. The more we specify about interactions with dependencies in an example, the more likely that example will be impacted by changes to other code in the system. This is the same impact that any highly coupled code has on a system.

This brittleness is more likely to emerge when back-filling examples onto existing code that is already highly coupled. Mocks can be helpful in this situation if we listen to them. If mocks are painful to set up, it's a red flag that the design might be too highly coupled.

When we're using mocks as intended, to discover new roles and APIs, there is a natural tendency for them to be simple and usable because we're working from the client perspective. This becomes somewhat of a self-fulfilling prophecy. We want our mocks to be simple to set up, and so they are. And when they are simple to set up, the resulting code is generally more highly decoupled.

14.9 Choosing other Test Double Frameworks

In RSpec's early days, we felt that including a test double framework was crucial. There were other frameworks we could have used, but they were all still young and we wanted to experiment with our own ideas.

Fast forward four years, and the landscape has changed. As RSpec's user base grew, so did the range of preferences. The existing test double frameworks matured, and new ones appeared, and their maintainers were all willing to support RSpec's runner as well as that of Test::Unit.

Built-In Support

RSpec uses its own test double framework unless we tell it otherwise. We can, however, choose any other framework provided that it has an adapter for RSpec's runner. RSpec ships with adapters for Mocha, Flexmock and RR, three of the most popular Ruby test double frameworks. To select one of those frameworks, we just add a little bit of configuration.

```
Spec::Runner.configure do |config|
  config.mock_with <framework id>
end
```

The framework id is one of :rspec, :mocha, :flexmock, or :rr. RSpec's own framework is used unless you specify something else, but you can set it explicity if you choose to.

Custom Adapters

To use a mock framework that doesn't have built in support, we need to write a custom adapter. Assuming that the framework has the necessary extension points, this is a trivial exercise. As an example, here is the built-in adapter we use for Flexmock:

```
Line 1  require 'flexmock/rspec'
     -
     -  module Spec
     -    module Adapters
     5      module MockFramework
     -        include FlexMock::MockContainer
     -        def setup_mocks_for_rspec
     -          # No setup required
     -        end
    10        def verify_mocks_for_rspec
     -          flexmock_verify
     -        end
     -        def teardown_mocks_for_rspec
     -          flexmock_close
    15        end
     -      end
     -    end
     -  end
```

The setup_mocks_for_rspec() method on line 7 is called before each example is run. Flexmock doesn't have anything to set up, so in this case it's a no-op. Other frameworks do things like attach behaviour to Object to support transparent access to test-specific extensions, or simply create a global storage area to record test double activity.

At the end of each example, RSpec calls verify_mocks_for_rspec() on line 10. In the FlexMock adapter, this delegates to flexmock_verify(), which verifies any message expectations.

The teardown_mocks_for_rspec() on line 13 is guaranteed to be called, even in the event of a failure or error. In this example, it delegates to FlexMock's flexmock_close() method, which removes test double extensions from any classes or other global objects, restoring them to their state before the example.

That's all there is to writing an adapter. Once we have one to use, we can pass it's module name directly to the mock_with() method, like this:

```
Spec::Runner.configure do |config|
  config.mock_with MyMockFrameworkAdapter
end
```

We encourage you to explore the other frameworks. The concepts that we've discussed in this chapter can generally be applied to any test double framework, each of which has its own personality and, in some cases, offers additional behaviour that Spec::Mocks does not support, like test spies in RR.

One at a Time

The one caveat for using the other frameworks is that you can only use one framework in a suite of examples. We enforce this to avoid collisions. RSpec and Mocha both expose the mock() and stub() methods to each example. Also, both frameworks add behaviour to Object, and even with RSpec enforcing one test-double framework per suite, we have seen cases in which Spec::Mocks was being used, but failure messages were coming from Mocha because another library involved was implicitly using Mocha if it happened to be loaded.

This *is* something we plan to improve in the future. For the time being, however, you can still get a lot of flexibility by using different test double frameworks in different suites.

14.10 What We've Learned

In this chapter we explored method stubs and message expectations on test doubles and test-specific extensions of real objects. We learned that there are a lot of different names for test doubles, but we can usually use the same kind of object to enact several different patterns.

We took a look at some of the risks involved with method stubs and message expectations, and pitfalls that we can keep our eyes out for. We also looked at some of the underlying motivations for method stubs and message expectations, including:

- Focus on roles
- Focus on interaction
- Interface discovery
- Making progress without implemented dependencies
- Isolation from dependencies
- Isolation from non-determinism

We've now covered the three libraries that ship with RSpec. In the remaining chapters in this section, we'll explore the RSpec ecosystem including peripheral tooling, techniques for extending RSpec, and integration with TextMate and Test::Unit.

Chapter 15

RSpec and Test::Unit

Are you working on a Ruby project that already uses Test::Unit? Are you considering migrating over to RSpec?

Migrating from Test::Unit to RSpec is a straightforward, but manual process. It involves a series of refactorings to your tests and, as with all refactorings, you should rerun them between each refactoring. That way if any changes you make cause things to go awry, you'll always know what caused the problem because it's the last change you made before you ran the tests.

While you're in the middle of this refactoring, your tests will look like half tests and half RSpec code examples because you'll be mixing the two styles. This is not pretty, but it's extremely important as it allows you to rerun everything after each refactoring. As you'll see, RSpec and Test::Unit are completely interoperable, but the reason for this is to make migration easier. We recommend you don't use this interoperability to leave your tests (or specs) in the hybrid state, as it will just lead to confusion later on.

The migration work essentially consists of refactoring the following Test::Unit elements to RSpec:

- `class SomeClassTest < Test::Unit::TestCase` becomes `describe SomeClass`
- `def test_something` becomes `it "should do something descriptive"`
- `def setup` becomes `before(:each)`
- `def teardown` becomes `after(:each)`
- `assert_equal 4, array.length` becomes `array.length.should == 4`

Before we jump in and start with these refactorings, let's get you set up so that you can run the tests between each refactoring using RSpec's runner.

15.1 Running Test::Unit tests with the RSpec runner

There are several ways to run tests written with Test::Unit. You can use rake to run one or more test files, run them directly with the ruby interpreter, or you can use the testrb script that comes with your Ruby distribution. We'll use the TestTask that ships with Rake for our example.

Let's start with a very minimal project that has one library file, one test file, a test_helper.rb, and a Rakefile with a TestTask defined.

Download testunit/lib/person.rb

```
class Person
  def self.unregister(person)
  end

  def initialize(first_name, last_name)
    @first_name, @last_name = first_name, last_name
  end

  def full_name
    "#{@first_name} #{@last_name}"
  end

  def initials
    "#{@first_name[0..0]}#{@last_name[0..1]}"
  end
end
```

Download testunit/test/test_helper.rb

```
$:.unshift File.join(File.dirname(__FILE__), *%w[.. lib])

require 'person'
```

Download testunit/test/person_test.rb

```
require File.join(File.dirname(__FILE__), "/test_helper.rb")
require 'test/unit'

class PersonTest < Test::Unit::TestCase

  def setup
    @person = Person.new('Dave','Astels')
  end

  def test_full_name
```

```
    assert_equal 'Dave Astels', @person.full_name
  end

  def test_initials
    assert_equal 'DA', @person.initials
  end

  def teardown
    Person.unregister(@person)
  end

end
```

Download testunit/Rakefile

```
require 'rake/testtask'
Rake::TestTask.new do |t|
  t.test_files = FileList['test/person_test.rb']
end
```

This PersonTest has a setup and teardown, one passing test and one failing test. We're including a failing test to give you a better picture of the enhanced output you get from RSpec. Go ahead and run rake test, and you should see the following output:

```
Started
.F
Finished in 0.00903 seconds.

  1) Failure:
test_initials(PersonTest) [./test/person_test.rb:15]:
<"DA"> expected but was
<"DAs">.

2 tests, 2 assertions, 1 failures, 0 errors
```

If you've been using Test::Unit this should be quite familiar to you. After the word "Started" we get a text-based progress bar with a "." for each passing test and an "F" for each failure.

The progress bar is followed by the details of each failure, including a reference to the line in the test file that contains the failed assertion, and an explanation of the failure.

Lastly we have a summary listing how many test methods were run, how many assertions were evaluated, the number of logical failures (failed assertions) and the number of errors.

To get started transforming the PersonTest to a Person spec, add an RSpec Rake task that will run the same tests:

Download testunit/Rakefile

```
require 'rubygems'
require 'spec/rake/spectask'

Spec::Rake::SpecTask.new do |t|
  t.ruby_opts = ['-r test/unit']
  t.spec_files = FileList['test/person_test.rb']
end
```

When RSpec gets loaded, it checks whether Test::Unit has been loaded and, if it has, enables the bridge between RSpec and Test::Unit that supports running tests with RSpec. By passing -r test/unit to the Ruby interpreter, Test::Unit will be loaded before RSpec.

For now no other changes are needed, so run the tests with rake spec and you should see output like this:

```
.F

1)
Test::Unit::AssertionFailedError in 'PersonTest test_initials'
<"DA"> expected but was
<"DAs">.
./test/person_test.rb:15:in `test_initials'

Finished in 0.028264 seconds

2 examples, 1 failure
```

At this point, RSpec's output is almost identical to that which we get from Test::Unit, but the summary is different. It sums up *code examples* instead of tests, and it doesn't discriminate between logical failures and execution errors. If something goes wrong we've got to fix it. It doesn't really matter if it's a failure or an error, and we'll know all we need to know as soon as we look closely at the detailed messages.

Enabling RSpec's Test::Unit bridge from Rake is an easy way to start when you want to get all your tests running through RSpec, but if you want to run individual test cases from an editor like TextMate, or straight from the command line using the ruby command, you'll need to modify the require 'test/unit' statements wherever they appear.

If you're using rspec-1.2 or later, change require 'test/unit' to require 'spec/test/unit'. With rspec-1.1.12 or earlier, use require 'spec/interop/test'. In either case, you may also need to require 'rubygems' first. Here's what you'll end up with:

this copy is (B12.0 printing, December 3, 2009)

Generating RSpec HTML reports from Test::Unit tests

You saw how easy it was to make RSpec run your Test::Unit tests. Once you've successfully done that, try to output a HTML report for your tests. Just add --format html:result.html to RSpec's command line.

If you're using Rake to run your tests it's just a matter of adding the following line inside your SpecTask:

```
t.spec_opts = ['--format', 'html:result.html']
```

Then just open up result.html in a browser and enjoy the view!

Download testunit/test/person_test_with_rspec_required.rb

```
require File.join(File.dirname(__FILE__), "/test_helper.rb")
require 'rubygems'
require 'spec/test/unit'
```

Once you have done this, you no longer need the -r test/unit in the Rakefile, so you can remove it:

Download testunit/Rakefile

```
Spec::Rake::SpecTask.new do |t|
  t.spec_files = FileList['test/person_test.rb']
end
```

Now run the test again with rake spec and you should get the same output:

```
.F

1)
Test::Unit::AssertionFailedError in 'PersonTest test_initials'
<"DA"> expected but was
<"DAs">.
test/person_test_with_rspec_required.rb:19:in `test_initials'
test/person_test_with_rspec_required.rb:22:

Finished in 0.016624 seconds

2 examples, 1 failure
```

That's all it takes to run Test::Unit tests with RSpec. And with that, you've also taken the first step towards migrating to RSpec. You can now start to refactor the tests themselves, and after every refactoring you'll be able to run all the tests to ensure that your refactorings are ok.

15.2 Refactoring Test::Unit Tests to RSpec Code Examples

Although you haven't seen it yet, by loading RSpec's Test::Unit bridge, we have also snuck RSpec in the back door. All of RSpec's API is now available and ready to be used within this TestCase, and the refactorings in this section will help you gradually change your tests to specs.

Describing Test::Unit::TestCases

The first step we'll take is to add a describe() declaration to the TestCase, as shown on line 6 in the code that follows:

Download testunit/test/person_test_with_describe.rb

```
Line 1   require File.join(File.dirname(__FILE__), "/test_helper.rb")
-        require 'rubygems'
-        require 'spec/test/unit'
-
5        class PersonTest < Test::Unit::TestCase
-          describe('A Person')
-
-          def setup
-            @person = Person.new('Dave','Astels')
10         end
-
-          def test_full_name
-            assert_equal 'Dave Astels', @person.full_name
-          end
15
-          def test_initials
-            assert_equal 'DA', @person.initials
-          end
-
20         def teardown
-            Person.unregister(@person)
-          end
-
-        end
```

This not only embeds intent right in the code, but it also adds documentation to the output. Go ahead and run rake spec and you should get output like this:

```
.F

1)
Test::Unit::AssertionFailedError in 'A Person test_initials'
```

```
<"DA"> expected but was
<"DAs">.
test/person_test_with_describe.rb:18:in `test_initials'
test/person_test_with_describe.rb:21:

Finished in 0.018498 seconds

2 examples, 1 failure
```

The String passed to describe() gets included in the failure message, providing more context in which to understand the failure. Of course, since we've only described the context, but haven't migrated the tests to code examples, the resulting "A Person test_initials" is a bit odd. But that's just temporary.

We can take this a step further and just use the describe() method to generate RSpec's counterpart to a TestCase, the Spec::ExampleGroup:

Download testunit/test/person_spec_with_setup_and_tests.rb

```
require File.join(File.dirname(__FILE__), "/test_helper.rb")
require 'rubygems'
require 'spec/test/unit'

describe('A Person') do

  def setup
    @person = Person.new('Dave','Astels')
  end

  def test_full_name
    assert_equal 'Dave Astels', @person.full_name
  end

  def test_initials
    assert_equal 'DA', @person.initials
  end

  def teardown
    Person.unregister(@person)
  end

end
```

This not only provides similar internal documentation, but it also reduces the noise of the creation of the class, focusing on the DSL of describing the behaviour of objects and making the code more readable. If you run rake spec you should see the same output that was generated when we added describe() to the TestCase.

So now we've got setup, teardown and test methods with assertions wrapped inside the RSpec DSL. This is the hybrid you were warned about earlier in this chapter, so let's keep working our way from the outside-in—time to get rid of those nasty tests!

test methods to examples

Now that we've replaced the concept of a TestCase with a group of examples, let's continue inward and replace the tests with examples. We create examples using the it() method within an example group. Here's what our Person examples look like in RSpec:

Download testunit/test/person_spec_with_examples.rb

```
require File.join(File.dirname(__FILE__), "/test_helper.rb")
require 'rubygems'
require 'spec/test/unit'

describe('A Person') do

  def setup
    @person = Person.new('Dave','Astels')
  end

  it "should include the first and last name in #full_name" do
    assert_equal 'Dave Astels', @person.full_name
  end

  it "should include the first and last initials in #initials" do
    assert_equal 'DA', @person.initials
  end

  def teardown
    Person.unregister(@person)
  end

end
```

Using strings passed to it() instead of method names that start with "test" provides a much more fluid alternative to expressing the intent of the example.

Running this with rake spec provides this output:

```
.F

1)
Test::Unit::AssertionFailedError in \
      'A Person should include the first and last initials in #initials'
<"DA"> expected but was
<"DAs">.
```

```
test/person_spec_with_examples.rb:17:
test/person_spec_with_examples.rb:6:

Finished in 0.020142 seconds

2 examples, 1 failure
```

Look how much more expressive that is! “A Person should include the first and last initials in #initials” actually tells you something you can tell your grandmother.

Two refactorings down, two to go. Next up, setup() and teardown().

before and after

RSpec runs the block passed to before(:each) before each example is run. This is RSpec’s replacement for Test::Unit’s test-centric setup() method.

RSpec also runs the block passed to after(:each) after each example is run, replacing Test::Unit’s teardown().

So the next step is to simply replace setup() and teardown() with before() and after():

Download testunit/test/person_spec_with_before_and_after.rb

```
require File.join(File.dirname(__FILE__), "/test_helper.rb")
require 'rubygems'
require 'spec/test/unit'

describe('A Person') do

  before(:each) do
    @person = Person.new('Dave','Astels')
  end

  it "should include the first and last name in #full_name" do
    assert_equal 'Dave Astels', @person.full_name
  end

  it "should include the first and last initials in #initials" do
    assert_equal 'DA', @person.initials
  end

  after(:each) do
    Person.unregister(@person)
  end

end
```

This time, the output from rake spec should be exactly the same as when setup() and teardown() were in place. We're almost done with this refactoring now. There's only one step left—converting assertions to RSpec expectations.

should and should_not

The last step in refactoring from tests to RSpec code examples is replacing assertions with RSpec expectations using should() and should_not().

Go ahead and replace the assert_equal with a should ==.

Download testunit/test/person_spec_with_should.rb

```
require File.join(File.dirname(__FILE__), "/test_helper.rb")
require 'rubygems'
require 'spec/test/unit'

describe('A Person') do

  before(:each) do
    @person = Person.new('Dave','Astels')
  end

  it "should include the first and last name in #full_name" do
    @person.full_name.should == 'Dave Astels'
  end

  it "should include the first and last initials in #initials" do
    @person.initials.should == 'DA'
  end

  after(:each) do
    Person.unregister(@person)
  end

end
```

This will produce the following output:

```
.F

1)
'A Person should include the first and last initials in #initials' FAILED
expected: "DA",
     got: "DAs" (using ==)
test/person_spec_with_should.rb:17:
test/person_spec_with_should.rb:6:

Finished in 0.007005 seconds

2 examples, 1 failure
```

As you see, the error messages from should failures are a little different that the assert failures. We still have one passing and one failing example, but the class name is gone. At this point, we've replaced the class name and test name with the example group string (passed to describe()) and the example string (passed to it()).

One last step

At this point it appears that the TestCase has been completely migrated over to an RSpec ExampleGroup, but appearances can be deceiving. The object returned by describe() is *still* a TestCase. You can see this by adding puts self to the describe() block:

Download testunit/test/person_spec_with_puts.rb

```
describe('A Person') do
  puts self
```

Run rake spec again and you should see Test::Unit::TestCase::Subclass_1 in the output. So now, as the final step in the conversion, remove 'test/unit' from require 'spec/test/unit', so you just have require 'spec', and run rake spec again. This time you'll see Spec::Example::ExampleGroup::Subclass_1 instead, thus completing the migration.

15.3 What We Just Did

In this chapter we showed you how to refactor from tests to specs with a series of refactorings that allow you to run all your tests/examples between each step.

- Convert TestCase classes to RSpec example groups with the describe() method.
- Convert test_xxx() methods to RSpec code examples using the it() method.
- Convert setup() and teardown() to before() and after().
- Convert Test::Unit assertions to RSpec expectations using should() and should_not().
-

While the order does seem logical, you can do these refactorings in any order. In fact, there is no technical reason that you can't mix test methods with RSpec expectations and RSpec code examples with assertions all living happily side by side. The aesthetic reasons for avoiding this are clear, but this does mean that you can use Test::Unit extensions in your specs. Most notable are the Test::Unit assertions that ship with Ruby on Rails, any of which can be called from within an RSpec example.

Chapter 16

Tools And Integration

In the Codebreaker tutorial in Part I, you used the spec command to run specs from a command line shell. In this chapter, we'll show you a number of command line options that you may not have tried out yet, as well as how RSpec integrates with other command line tools like Rake and autotest, and GUI editors like TextMate.

16.1 The spec Command

The spec command is installed when you install the rspec gem, and provides a number of options that let you customize how RSpec works. You can print a list of all these options by asking for help:

```
spec --help
```

Most of the options have a long form using two dashes and a shorthand form using one dash. The help option, for example, can be invoked with -h in addition to --help. We recommend you use the long form if you put it in a script such as a Rakefile (for clarity) and the short form when you run it directly from the command line (for brevity).

All of the command line options are also available when you run individual spec files directly with the ruby command.

Running One Spec File

Running a single file is a snap. You can use the spec command or even just the ruby command. For example, enter the following into simple_math_spec.rb:

```
require 'rubygems'
require 'spec'
```

```
describe "simple math" do
  it "should provide a sum of two numbers" do
    (1 + 2).should == 3
  end
end
```

Now run that file with the spec command:

```
spec simple_math_spec.rb
```

You should see output like this:

```
.

Finished in 0.00621 seconds

1 example, 0 failures
```

This is RSpec's default output format, the *progress bar* format. It prints out a dot for every code example that is executed and passes (only one in this case). If an example fails, it prints an F. If an example is pending it prints a *. These dots, F's and *'s are printed after each example is run, so when you have many examples you can actually see the progress of the run, hence the name "progress bar."

After the progress bar, it prints out the time it took to run and then a summary of what was run. In this case, we ran one example and it passed, so there are no failures.

Now try running it with the ruby command instead:

```
ruby simple_math_spec.rb
```

You should see the same output. When executing individual spec files, the spec and ruby commands are somewhat interchangeable. We do, however, get some added value from the spec command when running more than just one file.

Running Several Specs at Once

Running specs directly is handy if you just want to run one single file, but in most cases you really want to run many of them in one go. The simplest way to do this is to just pass the directory containing your spec files to the spec command. So if your spec files are in the spec directory (they are, aren't they?), you can just do this:

```
spec spec
```

...or if you're in a Rails project:

```
script/spec spec
```

In either case, the spec command will load all of the spec files in the spec directory and its sub-directories. By default, the spec command only loads files ending with _spec.rb. As you'll see later in this chapter, while this pattern is the convention, you can configure RSpec to load files based on any pattern you choose.

Being able to execute the files is only the tip of the iceberg. The spec command offers quite a few options, so let's take a closer look at them.

Diff output with --diff

One of the most common expectations in code examples is that an object should match an expected value. For example, comparing two strings:

Download tools/command_line/diff_spec.rb

```
    bill.to_text.should == <<-EOF
From: MegaCorp
To: Bob Doe
Ref: 9887386
Note: Please pay imminently
EOF
```

The *here doc* defines the expected result, and it is compared to the actual result of the to_text() method. If the to_text() method returns a different string the example will fail, and if the difference is subtle it can be hard to spot. Let's assume we goofed the implementation by forgetting to add the last name and hardcoded a silly message because we were irritated and working overtime. Without the --diff option the output would be:

```
expected: "From: MegaCorp\nTo: Bob Doe\nRef: 9887386\nNote: Please pay ...
     got: "From: MegaCorp\nTo: Bob\nRef: 9887386\nNote: We want our money ...
```

It's not exactly easy to spot where the difference is. Now, let's add the --diff option to the command line and run it again. This time we'll see:

```
Diff:

@@ -1,5 +1,5 @@
 From: MegaCorp
-To: Bob
+To: Bob Doe
 Ref: 9887386
-Note: We want our money!
+Note: Please pay imminently
```

The diff format shows the difference of each line. It uses Austin Ziegler's excellent diff-lcs Ruby gem, which you can install with:

```
gem install diff-lcs
```

Diffing is useful for more than strings. If you compare two objects that are not strings, their #inspect representation will be used to create the diff.

Tweaking the output with --format

By default, RSpec will report the results to the console's standard output by printing something like ...F......F.... followed by a backtrace for each failure. This is fine most of the time, but sometimes you'll want a more expressive form of output. RSpec has several built-in formatters that provide a variety of output formats. You can see a full list of all the built-in formatters with RSpec's --help option.

For example, the specdoc formatter can be used to print out the results as specdoc. The specdoc format is inspired from TestDox (see the sidebar).

You activate it simply by telling the spec command:

```
spec path/to/my/specs --format specdoc
```

The output will look something like the following:

```
Stack (empty)
- should be empty
- should not be full
- should add to the top when sent #push
- should complain when sent #peek
- should complain when sent #pop

Stack (with one item)
- should not be empty
- should return the top item when sent #peek
- should NOT remove the top item when sent #peek
- should return the top item when sent #pop
- should remove the top item when sent #pop
- should not be full
- should add to the top when sent #push
```

If you use nested example groups, like this:

```
describe Stack do
  context "when empty" do
    it "should be empty" do
```

Then you can use the *nested* format, like this:

TestDox

In 2003, Chris Stevenson, who was working with Aslak in ThoughtWorks at the time, created a little Java tool called TestDox (http://agiledox.sourceforge.net/). What it did was simple: It scanned Java source code with JUnit tests and produced textual documentation from it. The following Java source code...

```
public class AccountDepositTest extends TestCase {
    public void testAddsTheDepositedAmountToTheBalance() { ... }
}
```

...would produce the following text:

```
Account Deposit
- adds the deposited amount to the balance
```

It was a simplistic tool, but it had a profound effect on the teams that were introduced to it. They started publishing the TestDox reports for everyone to see, encouraging the programmers to write real sentences in their tests, lest the TestDox report should look like gibberish.

Having real sentences in their tests, the programmers started to think about behaviour, what the code should do, and the BDD snowball started to roll...

```
spec path/to/my/specs --format nested
```

and generate output like this:

```
Stack
  when empty
    should be empty
    should not be full
    should add to the top when sent #push
    should complain when sent #peek
    should complain when sent #pop
  with one item
    should not be empty
    should return the top item when sent #peek
    should NOT remove the top item when sent #peek
    should return the top item when sent #pop
    should remove the top item when sent #pop
    should not be full
    should add to the top when sent #push
```

Several formatters?

RSpec lets you specify several formatters simultaneously by using several --format options on the command line. Now why would anyone want to do that? Maybe you're using a continuous integration (CI) environment to build your code on every checkin. If both you and the CI use the same Rake tasks to run RSpec, it can be convenient to have one progress formatter that goes to standard output, and one HTML formatter that goes to a file.

This way you can see the CI RSpec result in HTML and your own in your console—and share the Rake task to run your specs.

RSpec also bundles a formatter that can output the results as HTML. You probably don't want to look at the HTML in a console, so you should tell RSpec to output the HTML to a file:

```
spec path/to/my/specs --format html:path/to/my/report.html
```

For all of the formatters, RSpec will treat whatever comes after the colon as a file, and write the output there. Of course, you can omit the colon and the path, and redirect the output to a file with >, but using the --format flag supports output of multiple formats simultaneously to multiple files, like so:

```
spec path/to/my/specs --format progress \
                      --format nested:path/to/my/report.txt \
                      --format html:path/to/my/report.html
```

After you have done this and opened the resulting HTML file in a browser, you should see something like Figure 16.1, on the next page.

Finally, the profile formatter works just like the default progress formatter, except that it also outputs the 10 slowest examples. We really recommend using this to constantly improve the speed of your code examples and application code.

Loading extensions with --require

If you're developing your own extensions to RSpec, such as a custom --formatter or maybe even a custom --runner, you must use the --require option to load the code containing your extension.

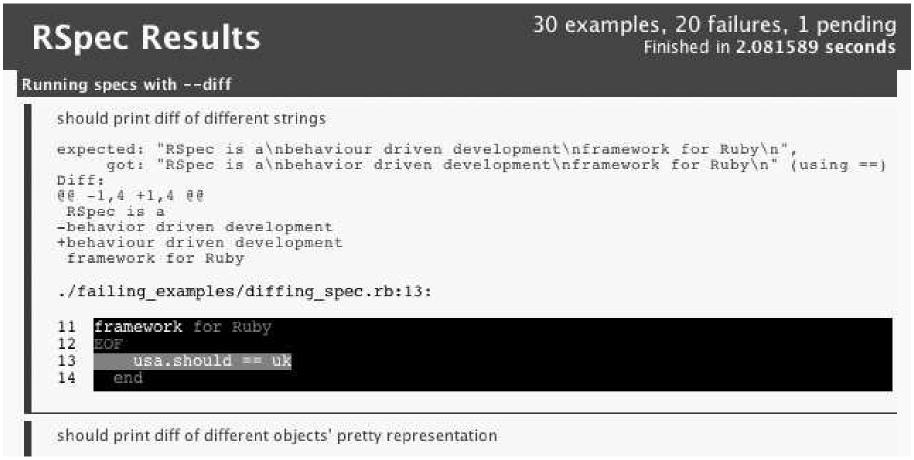

Figure 16.1: HTML Report

The reason you can't do this in the spec files themselves is that when they get loaded, it's already too late to hook in an RSpec plugin, as RSpec is already running.

Getting the noise back with --backtrace

Have you ever seen a backtrace from a failing test in an xUnit tool? It usually starts with a line in your test or the code being tested, and then further down you'll see ten furlongs of stack frames from the testing tool itself. All the way to where the main thread started.

Most of the time, most of the backtrace is just noise, so with RSpec you'll only see the frames from *your* code. The entire backtrace can be useful from time to time, such as when you think you may have found a bug in RSpec, or when you just want to see the whole picture of why something is failing. You can get the full backtrace with the --backtrace flag:

```
spec spec --backtrace
```

Colorize Output with --color

If you're running the specs all the time (you are, aren't you?), it requires some focus to notice the difference between the command line output from one run and the next. One thing that can make it easier on the eyes is to colorize the output, like this:

```
spec spec --color
```

With this option, passing examples are indicated by a green dot (.), failing examples by a red F, and pending examples by a yellow asterisk (*). Error reports for any failing examples are red.

The summary line is green if there are no pending examples and all examples pass. If there are any failures it is red. If there are no failures, but there are pending examples, it is yellow. This makes it much easier to see what's going on by just looking at the summary.

Invoke With Options Stored in a File with --options

You can store any combination of these options in a file and tell the spec command where to find it. For example, you can add this to spec/spec.opts:

```
--color
--format specdoc
```

You can list as many options as you want, with one or more words per line. As long as there is a space, tab or newline between each word, they will all be parsed and loaded. Then you can run the code examples with this command:

```
spec spec --options spec/spec.opts
```

That will invoke the options listed in the file.

Generate an Options File with --generate-options

The --generate-options option is a nice little shortcut for generating the options file referenced in the previous section. Let's say that we want to generate spec/spec.opts with --color and --format html:examples.html. Here's what the command would look like:

```
spec --generate-options spec/spec.opts \
  --color \
  --format html:examples.html
```

Then you can run the specs using the –options option:

```
spec spec --options spec/spec.opts
```

16.2 TextMate

The RSpec Development Team maintains a TextMate bundle which provides a number of useful commands and snippets. The bundle has been relatively stable for some time now, but when we add new features to

RSpec, they are sometimes accompanied with an addition or a change to the TextMate bundle.

We maintain the bundle in two different locations: in the official TextMate Bundle subversion repository at http://svn.textmate.org/trunk/Bundles/RubyRSpec.tmbundle and our development source repository at http://github.com/dchelimsky/rspec-tmbundle.

We update the subversion repository with each rspec release, so if you prefer to stick with rspec releases, the official TextMate repository is a simple and clean option. Just follow the bundle maintenance instructions on the TextMate website at http://manual.macromates.com/en/bundles.

If, however, you're an early adopter who likes to keep a local copy of rspec's git repository and update it regularly to keep up with the latest changes, then you'll want to do the same with the TextMate bundle. Instructions for this can be found on the rspec-tmbundle github wiki at http://github.com/dchelimsky/rspec-tmbundle/wikis.

16.3 Autotest

Autotest is one of several tools that ship with Seattle.rb's ZenTest library.[1] The basic premise is that you open up a shell, fire up autotest, and it monitors changes to files in specific locations. Based on its default mappings, every time you save a test file, autotest will run that test file. And every time you save a library file, autotest will run the corresponding test file.

When you install the rspec gem, it installs an autospec command, which is a thin wrapper for autotest that lets you use autotest with projects developed with RSpec.

To try this out, open up a shell and cd to the codebreaker directory that you created back in Chapter 4, *Automating Features with Cucumber*, on page 50. If you use command line editors like vim or emacs, open up a second shell to the same directory, otherwise open the project in your favorite text editor.

In the first shell, type the autospec command. You should see it start up and execute a command which loads up some number of spec files and runs them. Now, go to one of the spec files and change one of the

1. [sudo] gem install ZenTest

code examples so it will fail and save the file. When you do, autotest will execute just that file and report the failure to you. Note that it only runs *that* file, not all of the code example files.

Now reverse the change you just made so the example will pass and save the file again. What autotest does now is quite clever. First it runs the one file, which is the one with failures from the last run, and sees that all the examples pass. Once it sees that the previous failures are now passing, it loads up the entire suite and runs all of the examples again.

I can tell you that when I first heard about autotest, I thought it sounded really interesting, but wasn't moved by it. Then I actually tried it. All I can say is *try it*.

By default, autotest maps files in the lib directory to corresponding files in the test directory. For example, if you have a lib/account.rb file and a test/test_account.rb file, each time you save either autotest will run test/test_account.rb.

These mappings are completely configurable, so if you prefer to name your test files account_test.rb instead of test_account.rb, you can configure autotest to pay attention to files ending with _test.rb rather than starting with test_. See the ZenTest rdoc for more information about configuring these mappings.

RSpec uses standard autotest hooks to modify the autotest mappings to cater to RSpec's conventions. So if you run autospec and you modify spec/codebreaker/game_spec.rb or lib/codebreaker/game.rb, autotest will run spec/codebreaker/game_spec.rb.

rspec-rails modifies the mappings even further, so when you save app/models/account.rb, its code examples in spec/models/account_spec.rb will be run automatically.

16.4 Heckle

Heckle is a *mutation testing* tool written by Ryan Davis and Kevin Clark. From heckle's rdoc:

> *Heckle is a mutation tester. It modifies your code and runs your tests to make sure they fail. The idea is that if code can be changed and your tests don't notice, either that code isn't being covered or it doesn't do anything.*

To run heckle against your specs, you have to install the heckle gem, and then identify the class you want to heckle on the command line. To heckle the Game class from the Codebreaker tutorial in Part I, you would do this:

```
spec spec/codebreaker/game_spec.rb --heckle Codebreaker::Game
```

Depending on how far you got in the tutorial, the output looks something like this:

```
1 **********************************************************************
2 ***  Codebreaker::Game#start loaded with 4 possible mutations
3 **********************************************************************
4
5 4 mutations remaining...
6 3 mutations remaining...
7 2 mutations remaining...
8 1 mutations remaining...
9 No mutants survived. Cool!
```

Line 2 indicates that heckle found four opportunities to mutate the code in the start() method. Heckle prints out 4 mutations remaining..., and mutates the code. Perhaps it changes the value of an argument to the method. Perhaps it changes a conditional expression to return true or false, rather than performing a calculation.

Heckle then runs the examples against the mutated code. If the mutation *survives*, meaning there are no failures, then the examples aren't really robust enough to fully cover all of the different paths through the code. It is, therefore, a good thing if the mutation does *not* survive.

"No mutants survived", on line 9, tells us that there were failures after each mutation, so our code examples are sufficiently robust.

You can run heckle against all of the classes in a module by naming just that module. This command would run all of the specs in the spec/ directory, and heckle every class it could find in the Codebreaker module.

```
spec spec --heckle Codebreaker
```

You can also run heckle against a single method, like so:

```
spec spec --heckle Codebreaker::Game#start
```

This would only heckle the start() method, ignoring the other methods defined in the Game class.

As of version 1.4.1, released back in 2007, heckle will only mutate instance methods, so this won't check your class methods or methods defined in a module, unless that module is included in a class that heckle can find.

16.5 Rake

Rake is a great automation tool for Ruby, and RSpec ships with custom tasks that let you use RSpec from Rake. You can use this to define one or several ways of running your examples. For example, rspec-rails ships with several different tasks:

```
rake spec             # Run all specs in spec directory (excluding plugin specs)
rake spec:controllers # Run the code examples in spec/controllers
rake spec:helpers     # Run the code examples in spec/helpers
rake spec:models      # Run the code examples in spec/models
rake spec:views       # Run the code examples in spec/views
```

This is only a partial list. To see the full list, cd into the root of any rails app you have using RSpec and type rake -T spec. All of these tasks are defined using the Spec::Rake::SpecTask.

Spec::Rake::SpecTask

The Spec::Rake::SpecTask class can be used in your Rakefile to define a task that lets you run your specs using Rake. The simplest way to use it is to put the following code in your Rakefile:

```
require 'spec/rake/spectask'

Spec::Rake::SpecTask.new
```

This will create a task named spec that will run all of the specs in the spec directory (relative to the directory rake is run from—typically the directory where Rakefile lives). Let's run the task from a command window:

```
rake spec
```

Now that's simple! But that's only the beginning. The SpecTask exposes a collection of useful configuration options that let you customize the way the command runs.

To begin with, you can declare any of the command line options. If you want to have the SpecTask colorize the output, for example, you would do this:

```
Spec::Rake::SpecTask.new do |t|
  t.spec_opts = ["--color"]
end
```

About Code Coverage

Code coverage is a very useful metric, but be careful, as it can be misleading. It is possible to have a suite of specs that execute 100% of your codebase without ever setting any expectations. Without expectations you'll know that the code will probably run, but you won't have any way of knowing if it behaves the way you expect it to.

So while low code coverage is a clear indicator that your specs need some work, high coverage does not necessarily indicate that everything is honky-dory.

spec_opts takes an Array of Strings, so if you also wanted to format the output with the specdoc format, you could do this:

```
Spec::Rake::SpecTask.new do |t|
  t.spec_opts = ["--color", "--format", "specdoc"]
end
```

Check the rdoc for Spec::Rake::SpecTask to see the full list of configuration options.

16.6 RCov

RCov is a code coverage tool. The idea is that you run your specs and rcov observes what code in your application is executed and what is not. It then provides a report listing all the lines of code that were never executed when you ran your specs, and a summary identifying the percentage of your codebase that is covered by specs.

There is no command line option to invoke rcov with RSpec, so you have to set up a rake task to do it. Here's an example (this would go in Rakefile):

```
require 'rake'
require 'spec/rake/spectask'

namespace :spec do
  desc "Run specs with RCov"
  Spec::Rake::SpecTask.new('rcov') do |t|
    t.spec_files = FileList['spec/**/*_spec.rb']
    t.rcov = true
    t.rcov_opts = ['--exclude', '\/Library\/Ruby']
```

```
  end
end
```

This is then invoked with rake spec:rcov and produces a report that excludes any file with /Library/Ruby as part of its path. This is useful if your library depends on other gems, because you don't want to include the code in those gems in the coverage report. See rcov's documentation for more info on the options it supports.

As you can see, RSpec's spec command offers you a lot of opportunities to customize how RSpec runs. Combine that with powerful tools like Rake, Autotest, and Heckle and you've got a great set of tools you can use to drive out code with code examples, and run metrics against your specs to make sure you've got good code coverage (with rcov) and good branch coverage (with heckle).

Chapter 17

Extending RSpec

RSpec provides a wealth of functionality out of the box, but sometimes we want to express things in more domain specific ways, or modify the output format to make it better serve as documentation for a specific audience. In this chapter, we'll explore the utilities and extension points that RSpec provides to satisfy these needs.

17.1 Global Configuration

RSpec exposes a configuration object that supports the definition of global before and after blocks, as well as hooks to include modules in examples, or extend example group classes. We can access it via the Spec::Runner module like this:

```
Spec::Runner.configure {|config| ... }
```

The config block argument is the configuration object, and it exposes the following methods:

before(scope = :each, options={}, &block) Though more commonly used, this is an alias for append_before.

append_before(scope = :each, options={}, &block) Appends the submitted block to the list of before blocks that get run by every example group. scope can be any of :each, :all, or :suite. If :each, the block is run before each example. If :all, the block is run once per group, before any examples have been run. If :suite, the block is run once before any example groups have run.

The only supported option is :type, which allows you to limit the inclusion of this before block to example groups of the specified type. For example, with rspec-rails, you might say something like:

```
config.before(:each, :type => :controller) do
  ...
end
```

This would cause the submitted block to be run before each controller example, but no other types of examples. See Section 17.2, *Custom Example Groups*, on the next page for more information.

prepend_before(scope = :each, options={}, &block) Just like append_before(), but adds the block to the beginning of the list instead of the end. This is rarely useful, as anything added to the global list is going to run before anything added in individual example groups and examples. If you're using another library that extends RSpec, however, and you really need your before block to run first, prepend_before() is your friend.

after(scope = :each, options={}, &block) Though more commonly used, this is an alias for prepend_after.

prepend_after(scope = :each, options={}, &block) Adds the submitted block to the beginning of the list of after blocks that get run by every example group. See append_before(), above, for notes about scope.

append_after(scope = :each, options={}, &block) Just like prepend_after(), but adds the block to the end of the list.

include(*modules, options={}) Includes the submitted module or modules in every example group. Methods defined in submitted modules are made available to every example.

Like the before() and after() methods, the options hash supports a :type option that lets you limit the inclusion of the module(s) to a specific type of example group.

extend(*modules, options={}) Extends every example group with the submitted module or modules. Methods defined in submitted modules are made available to every example group. This is the easiest way to make macros (see Section 17.4, *Macros*, on page 294) available to example groups.

mock_with(framework) By default, RSpec uses its own mocking framework. You can, however, choose any framework. framework can be a Symbol or a module reference. If it's a symbol, it can be any of :rspec (default), :mocha, :flexmock, and :rr. These all reference adapters that ship with RSpec.

If you use a different mock framework, or perhaps you've written your own, you can write an adapter module for it, and then pass that module to mock_with(). See Chapter 14, *Spec::Mocks*, on page 226 for more information about writing your own adapter.

Each of these methods supports extending example groups by including modules, extending them with modules, or adding to their lists of before and after blocks. While these are very useful ways of extending groups, sometimes we need something a bit more robust. For cases like this, we can write our own example group classes.

17.2 Custom Example Groups

In Michael Feathers' presentation at SD West 2007, API Design As If Unit Testing Mattered,[1] he suggested that API designers should not just test their own code, but they should test code that *uses their code*! He also suggested that they should ship the tools that they develop to do this with the software, so that developers using their APIs have an easy path to testing their own code.

If you've worked with Ruby on Rails' built-in testing support, you know well the result of doing this. Rails' ships with specialized subclasses of Test::Unit::TestCase that bring us domain-specific commands like get() and post(), and assertions like assert_template(). These extensions make tests for our rails apps a joy to write and a snap to read.

In the next part of the book, you'll learn about *rspec-rails*, the extension library that brings RSpec to Rails development. The rspec-rails gem ships with custom example groups that actually extend the Rails TestCase classes, providing developers with all of the utilities that ship with Rails, *plus* the additional facilities that come with RSpec.

In this section, we'll explore approaches to authoring custom example groups. Whether shipping a domain-specific spec framework with your library, or developing one for internal use, we think you'll find this quite simple and flexible.

1. http://www.objectmentor.com/resources/articles/as_if_unit_testing_mattered.pdf

Object Model

In order to understand how and when to write a custom example group class, let's explore RSpec's object model first. It is quite simple but, because it is hidden behind RSpec's DSL, it is not always easy to spot without some internal inspection. Here's an example for discussion:

```
describe Account do
  it "has a balance of zero when first created" do
    account = Account.new
    account.balance.should == Money.new(0)
  end
end
```

As you read in Section 12.1, *Describe It!*, on page 182, the describe() method creates a subclass of Spec::Example::ExampleGroup, and the it() method creates a method on that class. If you look at the code for Spec::Example::ExampleGroup, however, you'll only see this:

```
module Spec
  module Example
    class ExampleGroup
      extend  Spec::Example::ExampleGroupMethods
      include Spec::Example::ExampleMethods
    end
  end
end
```

Spec::Example::ExampleGroup is really just a wrapper for the ExampleGroupMethods and ExampleMethods modules that define the behaviour of an example group. This design lets RSpec use Spec::Example::ExampleGroup as a default example group base class, while also allowing us to choose an entirely different base class and add RSpec behaviour to it.

This is how RSpec supports interoperability with test/unit. We just reopen Test::Unit::TestCase, and add RSpec behaviour to it. Of course, in the case of test/unit it's not *quite* that simple because RSpec does some things that test/unit already does, so there is some monkey patching involved. But given that test/unit ships with Ruby 1.8, the risk of changes to test/unit impacting RSpec and, consequently, RSpec users, is very low.

So now we have three ways to write a custom example group base class. We can subclass Spec::Example::ExampleGroup, we can write our own from scratch, adding example group behaviour the same way that RSpec does in Spec::Example::ExampleGroup, or we can add the behaviour to a class from an entirely different library like test/unit, or minitest.

Registering a custom default example group class

Once we have a custom subclass, we need to tell RSpec to use it instead of its own ExampleGroup class. We do this by registering the class with RSpec's ExampleGroupFactory. Here's how we register a custom class as the default base class for example groups:

```
Spec::Example::ExampleGroupFactory.default(CustomExampleGroup)
```

This does two powerful things. First, the describe() method creates a subclass of CustomExampleGroup (in this example). Second, CustomExampleGroup is assigned to the constant, Spec::ExampleGroup, which is guaranteed to reference the default base class whether its RSpec's own Spec::Example::ExampleGroup or a custom class. If a library ships with its own default base class, end-users can still add facilities to it by simply re-opening Spec::ExampleGroup and add utilities to it, regardless of its class.

Named example group classes

Developing our own subclass is a nice first step, but sometimes we have different needs for different parts of our system. In rspec-rails, for example, we have different example groups for specifying models, controllers, views, and even helpers and routing. Each of these types of example groups has different needs.

Controller specs need methods like get() and post(), and expectations like should render_template(). Model specs don't need any of those facilities, but they do need a means of isolating database state from one example to the next.

In order to support different example group classes for different purposes within a single spec suite, RSpec's ExampleGroupFactory lets us register classes with keys to access them. Here's how rspec-rails does this with its ControllerExampleGroup:

```
Spec::Example::ExampleGroupFactory.register(:controller, self)
```

This code appears within the ControllerExampleGroup, so self is referencing that.

Once a class is registered, we can coerce RSpec into returning a subclass of the class we want in two different ways. The more obvious way is to explicitly name it in the describe() declaration, like this:

```
describe WidgetsController, :type => :controller do
  ...
end
```

When the ExampleGroupFactory receives this request (delegated from the call to describe()), it first looks to see if a :type is declared. If so, it returns a subclass of the class registered with that name.

If you're already an rspec-rails user, you very likely have not seen that options hash appended to calls to describe() before. That's because when the ExampleGroupFactory fails to find a :type key in the request, it then inspects the path to the file in which the group was declared. In the case of controller specs, they are conventionally stored in spec/controllers. The ExampleGroupFactory extracts "controllers" from that path, converts it from a string to a symbol, and looks to see if it has a class registered with :controllers as its key.

If there is no :type declaration and no subclass mapped to the path, then the ExampleGroupFactory creates a subclass of the default example group class.

Now that we have a means of separating behaviour for different needs in different example group classes, the next thing we'll talk about is how to develop custom matchers that *speak* in our domain.

17.3 Custom Matchers

RSpec's built-in matchers support most of the expectations we'd like to write in our examples out of the box. There are cases, however, in which a subtle change would allow us to express exactly what we want to say rather than *almost* exactly what we want to say. For those situations we can easily write our own custom matchers.

You're already using some of these if you're using the rspec-rails gem. render_template(), for example, is a Rails-domain-specific matcher for expecting that a specific template gets rendered by a controller action. Without that matcher, we'd write expectations such as:

```
response.rendered_template.should == "accounts/index"
```

With this custom matcher, we are able to write examples using language closer to the domain:

```
response.should render_template("accounts/index")
```

All of RSpec's built-in matchers follow a simple protocol, which we use to write our own custom matchers from scratch. We'll go over the protocol in a bit, but first let's take a look at RSpec's Matcher DSL for defining custom matchers in just a few lines of code.

Matcher DSL

RSpec's Matcher DSL makes defining custom matchers a snap.[2] Let's say we're working on a personnel application and we want to specify that joe.should report_to(beatrice).

To get there, we'd probably start off with something like joe.reports_to?(beatrice).should be_true. That's a good start, but it presents a couple of problems. If it fails, the failure message says expected true, got false. That's accurate, but not very helpful.

Another problem is that it just doesn't read as well as it could. We really want to say joe.should report_to(beatrice). And if it fails, we want the message to tell us we were expecting an employee who reports to beatrice.

We can solve the readability and feedback problems using RSpec's Matcher DSL to generate a report_to() method, like this:

```
Spec::Matchers.define :report_to do |boss|
  match do |employee|
    employee.reports_to?(boss)
  end
end
```

The define() method on Spec::Matchers defines a report_to() method that accepts a single argument. We can then call report_to(beatrice) to create an instance of Spec::Matchers::Matcher configured with beatrice as the boss, and the match declaration stored for later evaluation.

Now when we say that joe.should report_to(beatrice), the report_to method creates a in instance of Spec::Matchers::Matcher that will call the block with joe.

The match block should return a boolean value. True indicates a match, which will pass if we use should() and fail if we use should_not(). False indicates no match, which will do the reverse: fail if we use should() and pass if we use should_not().

In the event of a failure, the matcher generates a message from its name and the expected and actual values. In this example the message would be something like this:

```
expected <Employee: Joe> to report to <Employee: Beatrice>
```

2. The matcher DSL is based on suggestions from Yehuda Katz.

The representation of the employee objects depends on how to_s() is implemented on the Employee class, but the matcher gleans "report to" from the Symbol passed to define().

In the event of a failure using should_not(), the generated message would read like this:

```
expected <Employee: Joe> not to report to <Employee: Beatrice>
```

These default messages generally work well, but sometimes we'll want a bit of control over the failure messages. We can get that by overriding them, and the description, with blocks that return the messages we want.

```
Spec::Matchers.define :report_to do |boss|
  match do |employee|
    employee.reports_to?(boss)
  end

  failure_message_for_should do |employee|
    "expected the team run by #{boss} to include #{employee}"
  end

  failure_message_for_should_not do |employee|
    "expected the team run by #{boss} to exclude #{employee}"
  end

  description do
    "expected a member of the team run by #{boss}"
  end
end
```

The block passed to failure_message_for_should() will be called and the result displayed in the event of a should() failure. The block passed to failure_message_for_should_not() will be called and the result displayed in the event of a should_not() failure. The description() will be displayed when this matcher is used to generate its own description.

As with the stock matchers, RSpec's matcher DSL will probably cover 80% of the remaining 20%. Still, there are cases where you'll want even more control over certain types of things. As of this writing, for example, there is no support for passing a block to the matcher itself. RSpec's built-in change() matcher needs that ability to express expectations like this:

```
account = Account.new
lambda do
  account.deposit(Money.new(50, :USD))
end.should change{ account.balance }.by(Money.new(50, :USD))
```

We can't easily define a matcher that accepts a block with the DSL because Ruby won't let us pass one block to another without first packaging it as a Proc object. We probably could do it with some gymnastics, but in cases like this it is often simpler to just write some clear code using RSpec's Matcher Protocol.

Matcher Protocol

A matcher in RSpec is any object that responds to a specific set of messages. The simplest matchers only need to respond to these two:

matches? The should() and should_not() methods use this to decide if the expectation passes or fails. Return true for a passing expection; false for a failure.

failure_message_for_should The failure message to be used when you use should() and matches?() returns false.

Here's the report_to() matcher we used in Section 17.3, *Matcher DSL*, on page 291, written using these two methods:

```
class ReportTo
  def initialize(manager)
    @manager = manager
  end

  def matches?(employee)
    @employee = employee
    employee.reports_to?(@manager)
  end

  def failure_message_for_should
    "expected #{@employee} to report to #{@manager}"
  end
end

def report_to(manager)
  ReportTo.new(manager)
end
```

This is clearly more verbose than the Matcher DSL, as we have to define a class *and* a method. We also have to store state in order to generate the failure message, which is not necessary in the DSL because it delivers the actual and expected objects to the match and message declaration blocks. Still, if writing a matcher out this way is more expressive than using the DSL in a given circumstance, then a custom matcher from scratch is the way to go.

The following methods are also part of the protocol, supported by the should() and should_not() methods, but completely optional:

failure_message_for_should_not optional - the failure message to be used when you use should_not() and matches?() returns true.

description optional - the description to be displayed when you don't provide one for the example (i.e. it { ... } instead of it "should ... " do ... end)

does_not_match? optional - on rare occasions it can be useful for the matcher to know if it's being called by should() or should_not(). In these cases, we can implement a does_not_match?() method on the matcher.

The should_not() method will call does_not_match?() if it is implemented. When it does, it considers a response of true to be a success and false to be a failure.

If the matcher does not respond to does_not_match?(), should_not() will call match?() and consider a response of false to be a success and true to be a failure.

With just these few methods and the expressive support of the Ruby language, we can create some sophistocated matchers. While we recommend using the Matcher DSL first, this simple protocol offers a robust back-up plan.

17.4 Macros

Custom matchers can help us to build up domain-specific DSLs for specifying our code, but they still require a bit of repetitive ceremony. In rspec-rails, for example, it is quite common to see examples like this:

```
describe Widget do
  it "requires a name" do
    widget = Widget.new
    widget.valid?
    widget.should have(1).error_on(:name)
  end
end
```

With a custom matcher, we can clean that up a bit:

```
describe Widget do
  it "requires a name" do
    widget = Widget.new
    widget.should require_attribute(:name)
```

```
  end
end
```

We can even get more terse by taking advantage of the implicit subject, which you read about in Section 13.7, *Implicit Subject*, on page 224, like this:

```
describe Widget do
  it { should require_attribute(:name) }
end
```

Now that is terse, expressive, and complete all at the same time. But for the truly common cases like this, we can do even better. In 2006, the *shoulda* library emerged as an alternative to RSpec for writing more expressive tests.[3] One of the innovations that came from shoulda was *macros* to express the common, redundant things we want to express in tests. Here's the widget example with a shoulda macro instead of a custom matcher:

```
class WidgetTest < Test::Unit::TestCase
  should_require_attributes :name
end
```

In late 2007, Rick Olsen introduced his own rspec-rails extension library named *rspec_on_rails_on_crack*.[4], which added macros to rspec-rails. In rspec_on_rails_on_crack, the widget example looks like this:

```
describe Widget do
  it_validates_presence_of Widget, :name
end
```

Macros like this are great for the things that are ubiquitous in our applications, like Rails' model validations. They're a little bit like shared example groups, which you read about in Section 12.5, *Shared Examples*, on page 195, but they are more expressive because they have unique names, and, unlike shared examples, they can accept arguments.

Macros are also quite easy to add to RSpec. Let's explore a simple example. Here is some code that you might find in a typical controller spec.

```
describe ProjectsController do
  context "handling GET index" do
    it "should render the index template" do
      get :index
      controller.should render_template("index")
```

3. http://www.thoughtbot.com/projects/shoulda
4. http://github.com/technoweenie/rspec_on_rails_on_crack

```
    end

    it "should assign @projects => Project.all" do
      Project.should_receive(:all).and_return(['this array'])
      get :index
      assigns[:projects].should == ['this array']
    end
  end
end
```

This would produce output like this:

```
ProjectsController handling GET index
- should render the index template
- should assign @projects => Project.all
```

Using macros inspired by rspec_on_rails_on_crack and shoulda, we can express the same thing at a higher level and get the same output like this:

Download extending_rspec/macro_example/spec/controllers/projects_controller_spec.rb

```
describe ProjectsController do
  get :index do
    should_render "index"
    should_assign :projects => [Project, :all]
  end
end
```

The underlying code is quite simple for the experienced Rubyist:

Download extending_rspec/macro_example/spec/spec_helper.rb

```
module ControllerMacros
  def should_render(template)
    it "should render the #{template} template" do
      do_request
      response.should render_template(template)
    end
  end

  def should_assign(hash)
    variable_name = hash.keys.first
    model, method = hash[variable_name]
    model_access_method = [model, method].join('.')
    it "should assign @#{variable_name} => #{model_access_method}" do
      expected = "the value returned by #{model_access_method}"
      model.should_receive(method).and_return(expected)
      do_request
      assigns[variable_name].should == expected
    end
  end
```

```
  def get(action)
    define_method :do_request do
      get action
    end
    yield
  end
end

Spec::Runner.configure do |config|
  config.use_transactional_fixtures = true
  config.use_instantiated_fixtures  = false
  config.fixture_path = RAILS_ROOT + '/spec/fixtures/'
  config.extend(ControllerMacros, :type => :controller)
end
```

The get() method defines a method that is used internally within the macros named do_request(), and yields to the block that contains the other macros, giving them access to the do_request() method.

The should_assign() method seems a bit complex, but it goes out of its way to provide you nice feedback so when you're writing the examples first (as I trust you are), you'll get a failure message like this:

```
expected: "the value returned by Project.all",
     got: nil (using ==)
```

We exposed these macros to controller specs by extending all controller example groups with the ControllerMacros module in the last line of the configuration. If we didn't want them in all controller specs, we could also explicitly extend individual groups inline, like this:

```
describe ProjectsController do
  extend ControllerMacros
  ...
```

At this point we've explored a number of ways to make RSpec code examples more expressive, but all of these techniques apply only to the *input*: the code we write and read in our examples. This is great if you're a developer, but part of RSpec's value-add is its ability to customize output for different audiences. We'll explore how RSpec does this and how we can customize it in the next section.

17.5 Custom Formatters

RSpec uses message formatters to generate the output you see when running a suite of specs. These formatters receive notification of events, such as when an example group is about to be run, or an individual example fails.

RSpec ships with a number of built-in formatters designed to generate plain text output, an all-purpose html formatter, and a TextMate-specific html formatter as well. You're probably already familiar with the progress bar formatter, which is the default formatter when you run the `spec` command with no options. Run `spec --help` to see a full listing of all of the built-in formatters.

If none of the built-in formatters satisfy your specific reporting needs, you can easily create a *custom formatter*. This can be very useful for building out custom spec reports for co-workers or a client. And if you happen to be an IDE developer, custom formatters are definitely your friend.

In this section, we'll review the APIs for the various parts of the puzzle that RSpec uses to write all of its built-in formatters, and anybody can use to write a custom formatter.

Formatter API

The simplest way to write a custom formatter is to subclass `Spec::Runner::Formatter::BaseFormatter`, which implements all of the required methods as no-ops. This allows us to implement only the methods we care about, and reduces the risk that changes in future versions of RSpec will impact the formatter.

Here is a list of all the required methods as of this writing, but be sure to look at the documentation for `Spec::Runner::Formatter::BaseFormatter` to ensure that you have the latest information.

initialize(options, output) When formatters are initialized, they are handed an options struct with `color` and `dry_run` options to help determine how to format output.

The `output` is `STDOUT` by default, but can be overridden on the command line to be a filename, in which case a `File` object is passed to `initialize()`.

To handle either possibility, RSpec's built-in formatters write to the output object with `output << "text"`, which works for any `IO` object.

start(example_count) This is the first method that is called. `example_count` is the total count of examples that will be run.

example_group_started(example_group_proxy) Called as an example group is started. See Section 17.5, *ExampleGroupProxy*, on page 300 for more about `example_group_proxy`. There is no corresponding example_group_finished message because we have not found a use for one in any of RSpec's built-in formatters.

example_started(example_proxy) Called as an example is started. See below for more about the example_proxy.

example_pending(example_proxy, message) Called when an example is pending. The example_proxy is the same object that was passed to example_started(). The message is the message passed to the pending method, or a default message generated by RSpec (see Section 7.3, *Pending*, on page 104 for more information).

example_failed(example_proxy, counter, failure) Called when an example fails. The example_proxy is the same object that was passed to example_started(). The counter indicates the sequential number of this failure within the current run. So if there are seven failures, and this is the last, counter will be the number 7. See below for more information about the failure object.

example_passed(example_proxy) Called when an example passes. The example_proxy is the same object that was passed to example_started().

start_dump() Called after all of the code examples have been executed. The next method to be called will be dump_failure() if there are any failures.

dump_failure(counter, failure) Called once for each failure in a run. counter is the sequential number of this failure, and is the same as the counter passed to example_failed() for this example. See below for more information about the failure object.

dump_summary(duration, example_count, failure_count, pending_count) Called after any calls to dump_failure(). duration is the total time it took to run the suite. example_count is the total number of examples that were run. failure_count is the number of examples that failed. pending_count is the number of examples that are pending.

dump_pending() Called after dump_summary(), and is a trigger to output messages about pending examples. It is up to the formatter to collect information about pending examples and generate any output at this point.

close() Called once at the very end of the run, signaling the formatter to clean up any resources it still has open.

ExampleGroupProxy

An ExampleGroupProxy is a lightweight proxy for an example group. This is the object sent to the example_group_started() method, and it carries the following information that can be useful in formatters:

description This is the complete description string, built by concatenating the strings and objects passed to the describe() or context() method, and all of its parents in nested groups. For example, this code:

```
describe ParkingTicket do
  context "on my windshield"
```

would produce "ParkingTicket" when starting the outer group, and "ParkingTicket on my windshield" when starting the inner group.

nested_descriptions Similar to description, except the formatted strings for each group are not concatenated. In the ParkingTicket example, the nested_descriptions for the outer group would be ["ParkingTicket"], and the inner group would get ["ParkingTicket","on my windshield"].

This is used by RSpec's built-in nested formatter, which is invoked with --format nested on the command line.

examples An array of ExampleProxy objects for all of the examples in this group.

location The file and line number at which the proxied example group was declared. This is extracted from caller, and is therefore formatted as an individual line in a backtrace.

ExampleProxy

An ExampleProxy is a lightweight proxy for an individual example. This is the object sent to the example_started(), and then either example_passed(), example_failed(), or example_pending().

Note that the same ExampleProxy object is passed to both example_started() method *and* the appropriate method after the example is finished. This lets the formatter map the beginning and end of an example using object identity (equal?()). RSpec's profile formatter, invoked with --format profile, uses this feature to calculate the time it takes for each example to run.

Each ExampleProxy carries the following information:

description The description string passed to the it() method or any of its aliases. This is nil when the proxy is passed to example_started(), but has a non-nil value when passed to the other example_xxx() methods. The reason is that RSpec users can write examples like this:

```
describe MyCustomFormatter do
  it { should solve_all_my_reporting_needs }
end
```

In this case there is no string passed to the it() method, so the example doesn't know its own description until the solve_all_my_reporting_needs() matcher generates it, which won't happen until the example is run.

location The file and line number at which the proxied example was declared. This is extracted from caller, and is therefore formatted as an individual line in a backtrace.

Failure

The example_failed() and dump_failure() methods are each sent a Failure object, which contains the following information:

header Header messsage for reporting this failure, including the name of the example and an indicator of the type of failure. FAILED indicates a failed expectation. FIXED indicates a pending example that passes, and no longer needs to be pending. RuntimeError indicates that a RuntimeError occured.

exception This is the actual Exception object that was raised.

Invoking A Custom Formatter

Once we've put in all of the energy to write a formatter using the APIs we've discussed, we'll probably want to start using it! Invoking a custom formatter couldn't be much simpler. We just need to require the file in which it is defined, and then add its class to the command line.

Let's say we've got a PDF formatter that generates a PDF document that we can easily ship around to colleagues. Here is the command we'd use, assuming that it is named PdfFormatter and defined in formatters/pdf_formatter.rb:

```
spec spec --require formatters/pdf_formatter --format PdfFormatter:report.pdf
```

The structure of the --format argument is FORMAT[:WHERE]. FORMAT can be any of the built-in formatters, or the name of the class of a custom formatter. WHERE is STDOUT by default, or a filename. Either way, that's what gets submitted to the initialize method of the formatter.

17.6 What We've Learned

In this chapter we explored the utilities and extension points that RSpec provides to support extending RSpec to meet your specific needs. These include:

- **Global Configuration** lets us assign before and after blocks to every example group. We can also use it to add methods to example groups by *extending* them with custom modules, and add methods to individual examples by *including* custom modules.
- **Custom Example Group Classes** provide a logical home for custom behaviour. They are ideal for libraries that want to ship with spec'ing facilities for their end users.
- We can use **Custom Matchers** to build up a DSL for expressing code examples.
- **Macros** also support DSLs, but with a different flavor than the custom matchers. Because they generate code themselves, we can also use them to express groups of expectations in a single command.
- **Custom Formatters** let us control the output that RSpec provides so we can produce different spec reports for different purposes and audiences.

In practice, we find that the global configuration, custom matchers defined with the Matcher DSL, and macros tend to be the most common ways that we extend RSpec. There are already numerous matcher and macro libraries for RSpec that are targeted at Rails development. Custom formatters tend to be the domain of IDE developers that support RSpec, like NetBeans and RubyMine.

Chapter 18

Cucumber

Coming soon ...

Part IV

Behaviour Driven Rails

Chapter 19

BDD in Rails

Ruby on Rails lit the web development world on fire by putting developer happiness and productivity front and center. Concepts like convention over configuration, REST, declarative software, and the Don't Repeat Yourself principle are first class citizens in Rails, and have had a profound impact on the Ruby community and the wider web development community.

In the context of this book, the single most important concept expressed directly in Rails is that automated testing is a crucial component in the development of web applications. Rails was the first web development framework to ship with an integrated full-stack testing framework. This lowered the barrier to entry for those new to testing and, in doing so, raised the bar for the rest of us.

RSpec's extension library for Rails, rspec-rails, extends the Rails testing framework by offering separate classes for spec'ing Rails models, views, controllers and even helpers, in complete isolation from one another.[1] All of that isolation can be risky if not accompanied by automated end-to-end functional testing to make sure all the pieces work together. For that we use Cucumber and supporting tools like Webrat and Selenium.

While these tools are great additions to any web developer's arsenal of testing tools, in the end, tools are tools. While RSpec and Cucumber

1. Early versions of the rspec-rails plugin were built on ZenTest (http://www.zenspider.com/ZSS/Products/ZenTest/), which offered support for testing models, views, controllers and helpers separately. We later decided that we wanted more runtime component isolation than ZenTest provided, so we rolled our own, but we owe a debt of gratitude to ZenTest's author, Ryan Davis, for paving the way.

are optimized for BDD, using them doesn't automatically mean you're *doing* BDD.

In the chapters that follow, we'll show you how to use rspec-rails in conjunction with tools like Cucumber, Webrat, and Selenium, to drive application development from the Outside-In with a powerful BDD toolset and, much more importantly, a BDD *mindset*.

So what does that mean? What *is* the BDD mindset? And how do we apply it to developing Rails apps? To put this into some perspective, let's take a look at traditional Rails development.

19.1 Traditional Rails Development

Rails developers typically use an inside-out approach to developing applications. Design the schema and implement models first, then the controllers, and lastly the views and helpers.

This progression has you build things you *think* other parts of the system are going to need before those other parts exist. This approach moves quickly at first, but often leads to building things that won't be used in the way you imagined, or perhaps won't get used at all. When you realize that the models don't really do what you need, you'll need to either revisit what you've already built or make do. At this juncture, you might hear your conscience telling you to "do the simplest thing."

The Illusion of "simple" with Inside-Out
by Zach Dennis

I once worked on an application that had to display events to a user. Working inside-out, we had built several of the models that we felt accurately represented the application, including some custom search functionality that would find events based on a set of criteria from the user. When we got to implementing the views we realized that we needed to filter a list of events based on some additional criteria. Did an event belong to a user or to a group a user belonged to? Was the user an admin?

We had already set up associations for events belonging to users and groups. It *seemed* as though the simplest approach would be to take advantage of what we had already built, so we added those checks to the views rather than refactoring the model to support the additional filtering. Feeling guilty about logic in views, we refactored the view, extracting the checks to a method in a helper module. We felt good at the time about the decision. We were being pragmatic and doing the *simplest thing*.

> Over time, we were presented with similar situations and made similar decisions. Before long the application had all of this *simplicity* tucked away in places in which it was very difficult to re-use and work with. We needed to re-use some of this logic in other parts of the application, but it wasn't simple any longer. Now it felt like we had to choose the least of three evils: force some awkward way of accessing the logic for re-use, duplicate the logic, or go back and perform time-consuming surgery on the application to make it easier to work with.

Building from the models out to the views means writing code based on what you *think* you're going to need. Ironically, it's when you focus on the UI that you discover what is really needed from the models, and when you get to them there's already a body of supporting code developed, refactored, well tested, and ready to be used.

It turns out that we are more likely to build what we *really* need rather than what we *think* we need by working from the outside-in.

19.2 Outside-In Rails Development

Outside-in Rails development is like standing the traditional inside-out approach on its head. Instead of working from the models out to views, we work from the views in toward the models.

This approach lets customer-defined acceptance criteria drive development in a much more direct way. It puts us in a better position to discover objects and interfaces earlier on in the process and make design decisions based on real need.

The BDD cycle with Rails is the same Outside-In process we use with any other framework (or no framework), web, desktop, command line, or even an API. The cycle depicted in Figure 19.1, on the following page is the same cycle depicted in Figure 1.1, on page 24, but we've added some detail to help map it to Rails.

- Start with a scenario. Make sure you have a clear understanding of the scenario and how it is expected to work, including how the UI should support a user interacting with the app (see the sidebar on page 309).
- Execute the scenario with Cucumber. This reveals which steps are pending. Most, if not all of the steps will be pending at first.
- Write a step definition for the first step. Execute the scenario with Cucumber and watch it fail.

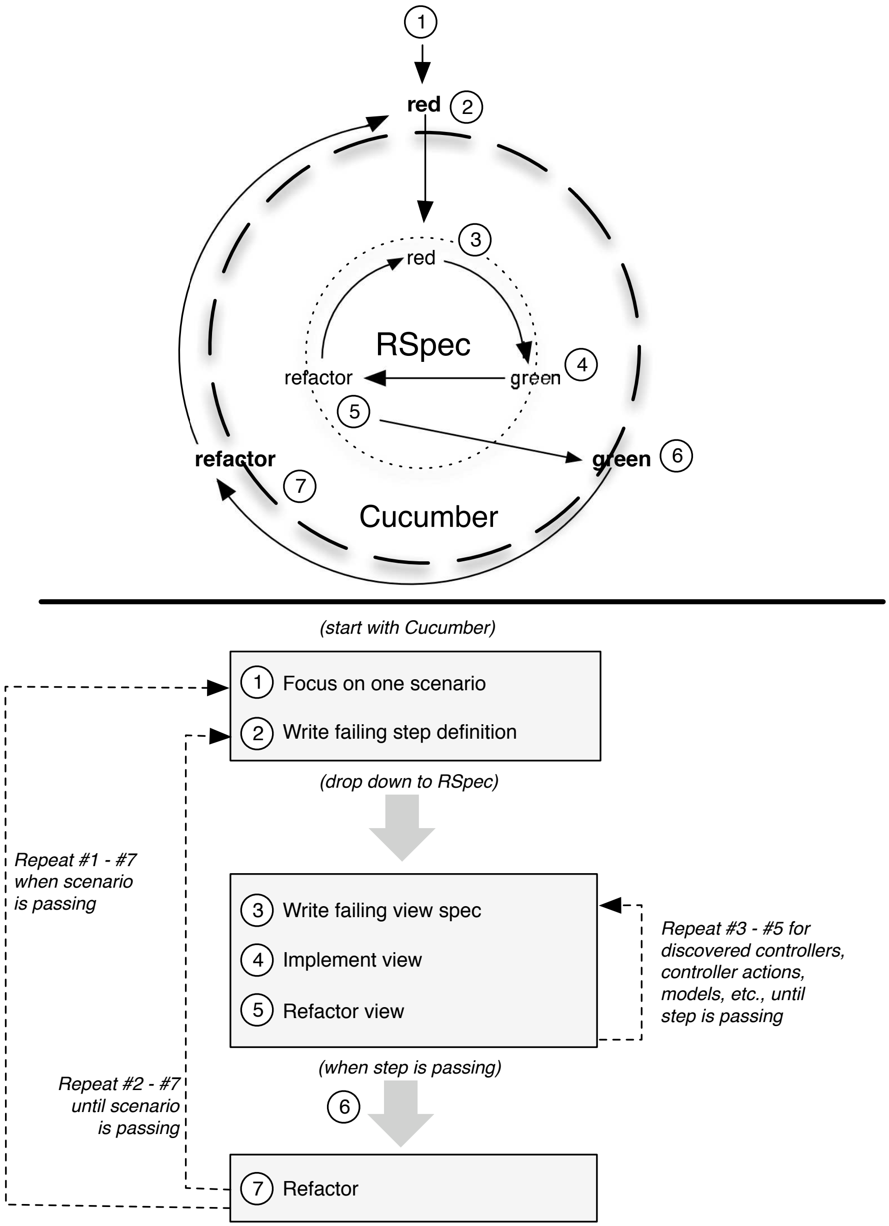

Figure 19.1: The BDD Cycle in Rails

Understanding application behaviour

The way in which a user expects to interact with a web app is going to influence the resulting implementation, both client and server-side. Ignoring this fact can lead to a design that supports the desired functionality, but with an implementation that is poorly aligned with the behaviour.

Outside-in guides us to focus first on the outermost point of a scenario, the UI, and then work our way in. This involves communicating with the customer using visual tools like whiteboards, wireframes, screen mockups, or other forms of visual aid. And if there are designers on the team, these communications should definitely involve them.

BDD is about *writing software that matters*. And little matters more to our customers than how people will interact with the application. Understanding user interaction first will go a long way toward understanding the underlying behaviour of the app.

- Drive out the view implementation using the red/green/refactor cycle with RSpec. You'll discover assigned instance variables, controllers, controller actions, and models that the view will need in order to do its job.
- Drive out the controller with RSpec, ensuring that the instance variables are properly assigned. With the controller in place you'll know what models it needs to do its job.
- Drive out those objects with RSpec, ensuring that they provide the methods needed by the view and the controller. This typically leads to generating the required migrations for fields in the database.
- Once you have implemented all of the objects and methods that you have discovered are needed, execute the scenario with Cucumber again to make sure the step is satisfied.

Once the step is passing, move on to the next unimplemented step and continue working outside-in. When a scenario is done, move on to the next scenario or, better yet, ask the nearest customer to validate that it's working as expected and *then* move on to the next scenario.

This is outside-in Rails development—implementing a scenario from its outermost-point down, building what we discover is needed to make it work.

Now that you have a high level view of the outside-in process in Rails, let's get started by setting up a Rails project with the necessary tools. This will let us explore ground zero in the following chapters.

19.3 Setting up a Rails project

To set up a Rails project for outside-in development, we need to install RSpec, rspec-rails, Cucumber, and Webrat. There are several installation methods to choose from, including system-wide gems, config.gem, vendor/gems, and vendor/plugins. We'll take a look at all of these approaches, starting with the simplest: system-wide gem installation.

System-wide gems

Installing the necessary libraries and tools is as simple as installing any other rubygems. When working with the latest stable releases this is a great route to take:

```
$ [sudo] gem install cucumber rspec-rails webrat
```

RSpec is a dependency of rspec-rails, so when you install rspec-rails you get RSpec for free.

Using Rails config.gem

To take advantage of Rails' built-in gem management, we recommend that you configure the gems in config/environments/test.rb:

```
config.gem 'rspec-rails', :lib => false
config.gem 'rspec',       :lib => false
config.gem 'cucumber'
config.gem 'webrat'
```

We use lib => false for rspec and rspec-rails because even though we may want rails' gem configuration to help us with installing and bundling gems, we want rspec-rails' rake tasks to control when they are loaded.

After saving this file you should be able to perform any of the following commands on each development machine:

```
# WINDOWS
set RAILS_ENV=test

# *nix, Mac OS X, and cygwin (Windows)
```

```
export RAILS_ENV=test

# see what gems are required in the test environment
rake gems

# install required gems to your system
rake gems:install

# unpack required gems from your system to the app's vendor/gems
rake gems:unpack

# unpack required dependencies for your app's gems
rake gems:unpack:dependencies
```

A few things to note:

- Use sudo if you normally use sudo to install gems.
- On *nix, Mac OS X, and cygwin, you can add RAILS_ENV=test to each command instead of exporting it to the shell. If you do, and you're also using sudo, be sure to put the RAILS_ENV before sudo, like this:

  ```
  RAILS_ENV=test sudo rake gems:install
  ```

- The rake tasks installed by older versions of rspec-rails cause some trouble in this process, so be sure to delete lib/tasks/rspec.rake before executing these commands if you're upgrading.

Bundling manually in vendor/gems

Rails supports loading gems found in vendor/gems/ before loading system-wide gems. After you've installed the system-wide gems you can unpack them into vendor/gems/:

```
$ cd vendor
$ mkdir gems
$ cd gems
$ gem unpack cucumber
$ gem unpack rspec
$ gem unpack rspec-rails
$ gem unpack webrat
```

This method allows you to store the gems your application relies on in version control. It also makes application development and deployment very simple since you don't have to worry about installing every required gem on every system—they're bundled with the app. The only time this doesn't work is when your app requires gems with native extensions. In that case you will have to install the gem so it compiles correctly for the target architecture.

Note that webrat depends on nokogiri, which has native extensions, so you won't want to unpack that dependency and store it in source control.

Bundling in vendor/plugins

Rails supports loading plugins found in vendor/plugins/ before loading gems found in vendor/gems. This is a great way to stay on the edge of development:

```
> cd RAILS_ROOT
> script/plugin install --force git://github.com/aslakhellesoy/cucumber.git
> script/plugin install --force git://github.com/dchelimsky/rspec.git
> script/plugin install --force git://github.com/dchelimsky/rspec-rails.git
> script/plugin install --force git://github.com/brynary/webrat.git
```

This method also allows you to store libraries your application relies on in version control and it shares the same benefits of development and deployment as the vendor/gems installation method. Again, don't unpack nokogiri (or any other dependencies of these four libraries that have native extensions).

Bootstrapping an app with RSpec and Cucumber

Once the RSpec and Cucumber gems are installed, we need to set up some files and configuration in order to use them. RSpec and Cucumber both ship with Rails generators that take care of most of the work. Just run these two commands to finish bootstrapping a Rails app for development with Cucumber and RSpec:

```
$ script/generate rspec
$ script/generate cucumber
```

That's it. Now if you run those, you'll see a bunch of directories and files getting set up. Let's take a closer look at the output of each command, beginning with RSpec.

```
$ ./script/generate rspec
    exists  lib/tasks
    create  lib/tasks/rspec.rake
    create  script/autospec
    create  script/spec
    create  spec
    create  spec/rcov.opts
    create  spec/spec.opts
    create  spec/spec_helper.rb
```

Here's a description of each file and directory that was generated:

- lib/tasks/rspec.rake: Adds a collection of rake spec tasks to your application. These tasks offer various ways of running your specs. Run rake -T spec to find out more about these tasks.
- script/autospec: A command that provides integration with autotest in your Rails project. [2]
- script/spec: A command to run spec files directly with the version of rspec the Rails app was configured for, e.g. system-wide rspec gem, a local rspec gem in vendor/gems, or rspec installed in vendor/plugins.
- spec: The directory where you place specs for your Rails app.
- spec/rcov.opts: Add options to this file that you want rcov to run with when running any of the rake spec tasks with rcov, e.g. rake spec:rcov.
- spec/spec.opts: Add options to this file that you want rspec to utilize when running any of the rake spec tasks.
- spec/spec_helper.rb: This file is used to load and configure rspec. It is also where you would require and configure any additional helpers or tools that your project utilizes when running specs.

And here's what we get from running the Cucumber generator:

```
$ ./script/generate cucumber
  create  features/step_definitions
  create  features/step_definitions/webrat_steps.rb
  create  config/environments/cucumber.rb
  create  features/support
  create  features/support/env.rb
  create  features/support/paths.rb
  exists  lib/tasks
  create  lib/tasks/cucumber.rake
  create  script/cucumber
```

- features/step_definitions: All of your step definitions will go in this directory.
- features/step_definitions/webrat_steps.rb: This is generated with commonly used Webrat step definitions. We'll learn more about this file in Chapter 21, *Simulating the Browser with Webrat*, on page 326.

2. See Section 16.3, *Autotest*, on page 279 for more information on rspec and autotest integration

- config/environments/cucumber.rb: Cucumber needs some settings that are different from the default test environment. You shouldn't need to modify this file at all.
- features/support: This directory holds any Ruby code that needs to be loaded to run your scenarios that are *not* step definitions, like helper methods shared between step definitions.
- features/support/env.rb: Bootstraps and configures the Cucumber runner environment.
- features/support/paths.rb: Support for mapping descriptive page names used in scenario steps to their URLs.
- lib/tasks/cucumber.rake: Adds the rake features task which prepares the test database and runs your application's feature suite.
- script/cucumber: The command line feature runner.

In addition to creating these files, the script/generate cucumber command adds a cucumber environment to config/database.yml for us. That's all we need to run Cucumber features in a Rails application. As we progress, we'll be adding files to three places (see Figure 19.2, on the next page):

- features: This is where we put each Cucumber *.feature file containing our scenarios.
- features/step_definitions: We'll add step definitions to implement the plain text scenarios here. Use one file for each domain concept, for example movie_steps.rb and checkout_steps.rb.
- features/support: This directory holds any supporting code or modules we extract from step definitions as we refactor.

Now we are ready for Outside-In, Behaviour Driven Development.

19.4 What We Just Learned

So far we've explored the high level of what it means to do BDD in Rails using outside-in development, and we've set up a Rails project with the recommended tools. In the next chapter, we'll take a look at how Cucumber and Rails can be used together to begin driving development from the outside. Turn the page and let's begin.

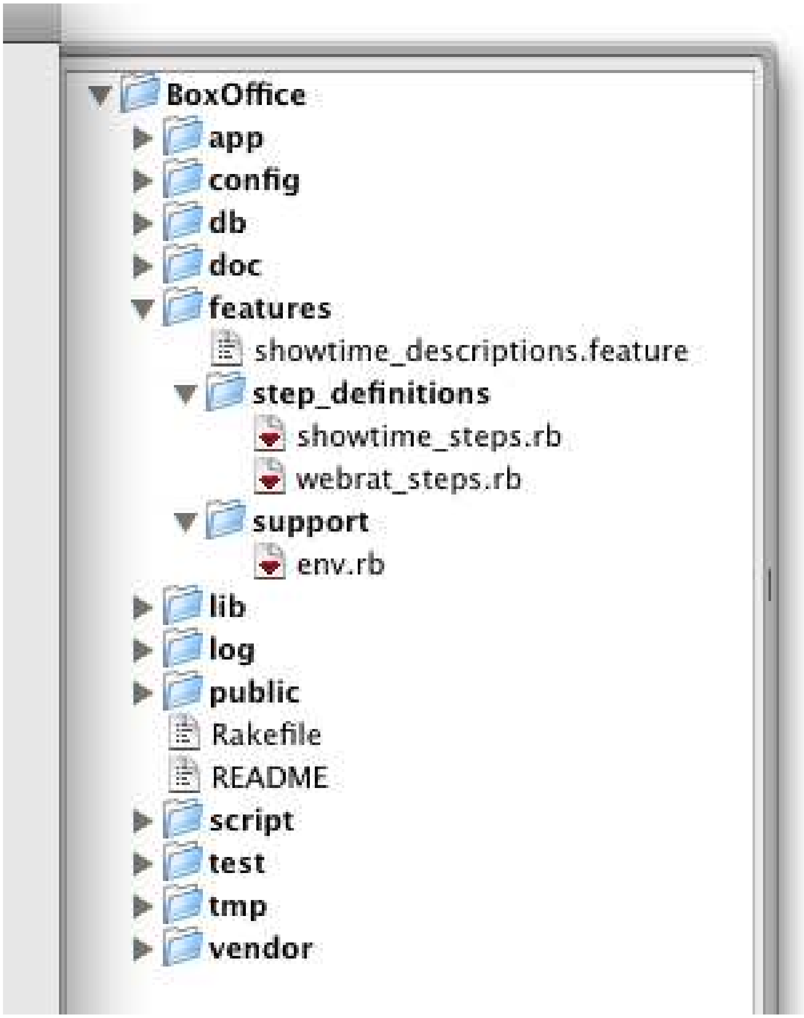

Figure 19.2: Rails Project Tree with Cucumber Features

Chapter 20

Cucumber with Rails

Cucumber supports collaboration between project stakeholders and application developers, with the goal of developing a common understanding of requirements and providing a backdrop for discussion. The result of that collaboration is a set of plain text descriptions of features and automated scenarios that application code must pass to be considered *done*. Once passing, the scenarios serve as regression tests as development continues.

As with any BDD project, we use Cucumber in a Rails project to describe application level behaviour. In this chapter we'll look at how Cucumber integrates with Rails, exploring a variety of approaches to setting up context, triggering events and specifying expected outcomes as we describe the features of our web application.

20.1 Step Definition Styles

Step definitions connect the natural language steps in a plain-text feature file to Ruby code that interacts directly with the application. Since Cucumber helps us describe behaviour in business terms, the steps shouldn't express technical details. Given I'm logged in as an administrator could apply to a CLI, client-side GUI, or Web-based application. It's within the step *definitions* that the rubber meets the road and code is created to interact with the application.

The first step of the Outside-In cycle is to produce a failing scenario, and to do that we'll need a step definition, but how should it be implemented? Rails applications contain many layers, from the model and the database all the way up to the web browser, and this leaves us with options and choices in how step definitions interact with an application.

We want scenarios to exercise a vertical slice through all of our code, but we also want them to run fast. The fastest scenarios are going to bypass HTTP, routing, and controllers and just talk directly to the models. The slowest ones are going to exercise everything through the web browser, giving us the fullest coverage, the most confidence, and, unfortunately, the least desire to run them on a regular basis!

So what's a pragmatic story teller to do? Naturally, *it depends*. When building step definitions for a Rails application, we typically deal with three step definition styles for interacting with a Web-based system in order to specify its behaviour:

- *Direct Model Access*: Access ActiveRecord models directly, bypassing routing, controllers, and views. This is the fastest but least integrated style.
- *Simulated Browser*: Access the entire MVC stack using Webrat, a DSL for interacting with web applications. This style provides a reliable level of integration while remaining fast enough for general use, but doesn't exercise JavaScript.
- *Automated Browser*: Access the entire Rails MVC stack in a real web browser by driving interactions with the Webrat API and its support for piggy-backing on Selenium. This style is fully integrated but is the slowest to run and can be challenging to maintain.

General Recommendations

Fast is better than slow, of course, but integrated is better than isolated when we're looking for confidence that an app will work in the hands of users once it is shipped. When writing Cucumber scenarios, integration and speed are opposing forces. This conundrum is illustrated in Figure 20.1, on the following page. The balance of these forces that feels best will vary a bit from developer to developer, but we can provide some guidelines based on experience exploring a variety of approaches.

We recommend using Direct Model Access in Givens to prepare the state of the system, except for logging-in or other actions that set up browser session state. Use Simulated Browser with Webrat for Whens and Thens. This helps to drive out the pieces that a user will interact with, providing confidence that the component parts are working well together, but still produces a suite that can be executed relatively quickly and without depending on a real web browser.

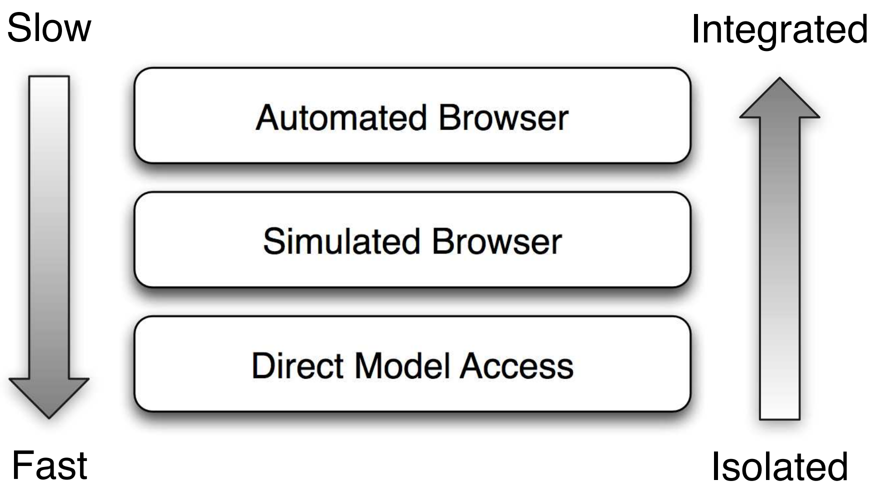

Figure 20.1: Comparing step definition styles

If there is any JavaScript or AJAX, add scenarios that use the Automated Browser approach in their Whens and Thens for the *happy path* and critical less common paths. The added value we get from doing this is exercising client side code, so when no client code is necessary, there is no reason to use the browser.

Edge Cases

For features that produce many edge cases, it can be useful to drive a few through the Rails stack and the rest using just Direct Model Access for everything. This may seem more like a unit test, but keep in mind that scenarios are about communication. We want to make sure that we're writing the right code. If the customer asks for specific error messages depending on a variety of error conditions, then it's OK to go right to the model if that's the source of the message, as long as the relevant slice of the full stack is getting sufficient coverage from other scenarios.

In this chapter, we'll start with the simplest style, Direct Model Access, and walk through implementing a feature. Then we'll explore using Webrat for the Simulated Browser style in Chapter 21, *Simulating the*

Cucumber::Rails::World

Cucumber::Rails::World is the bridge between Cucumber and Rails. It provides the Rails integration testing methods within each scenario.

When Cucumber's Rails support is loaded by requiring cucumber/rails/world in features/support/env.rb, instances of Cucumber::Rails::World are configured to be the World for each scenario:

```
World do
  Cucumber::Rails::World.new
end
```

Cucumber::Rails::World inherits Rails' ActionController::IntegrationTest, and makes surprisingly few modifications to the superclass behaviour. Each scenario is run in a newly instantiated Cucumber::Rails::World. This gives us access to all of the functionality of Rails' Integration tests and RSpec's Rails-specific matchers, including simulating requests to the application and specifying behaviour with RSpec expectations.

In the default configuration, it runs each scenario in an isolated DB transaction. You can disable this by removing the following line from the features/support/env.rb generated by Cucumber:

```
Cucumber::Rails.use_transactional_fixtures
```

If you disable per-scenario transactions, you'll have to worry about records left over from one scenario affecting the results of the next. This often leads to inadvertent and subtle ordering dependencies in your scenario build. For these reasons, we *strongly* recommend using the transactional fixtures setting.*

*. Don't use use_transactional_fixtures with Selenium. We'll discuss this in detail in Chapter 22, *Automating the Browser with Webrat and Selenium*, on page 350

Browser with Webrat, on page 326 and Automated Browser in Chapter 22, *Automating the Browser with Webrat and Selenium*, on page 350.

20.2 Direct Model Access

Direct Model Access step definitions execute quickly and are immune to changes in the controller and view layers, but that speed and isolation comes at a price. DMA step definitions don't provide much assurance that the application works, and they are unlikely to catch bugs beyond those that should be caught by granular RSpec code examples.

They do, however, facilitate conversation between the customer and developers, and will catch regressions if the logic inside the models is broken in the future. In this way, DMA step definitions are useful for exercising fine grained behaviours of a system, when driving all of them through the full stack would be too cumbersome.

To see this in action, let's look at some scenarios for a movie box office system we'll call Showtime. Start by bootstrapping a rails app. We'll assume you've already got RSpec, rspec-rails, Cucumber and Webrat installed, and we'll rely on system-wide gems:[1]

```
$ rails showtime
$ cd showtime
$ script/generate cucumber
```

The customer wants the structured movie schedule data to be distilled into a human-readable one line showtime description for display on a website. Create a feature file named showtime_descriptions.feature in the features directory and add the following text to it:

Download cucumber_rails/01/features/showtime_descriptions.feature

```
Feature: Showtime Descriptions

  So that I can find movies that fit my schedule
  As a movie goer
  I want to see accurate and concise showtimes

@focus
  Scenario: Show minutes for times not ending with 00
    Given a movie
    When I set the showtime to "2007-10-10" at "2:15pm"
    Then the showtime description should be "October 10, 2007 (2:15pm)"

  Scenario: Hide minutes for times ending with 00
    Given a movie
    When I set the showtime to "2007-10-10" at "2:00pm"
    Then the showtime description should be "October 10, 2007 (2pm)"
```

We'll use the --tag command line option in combination with the @focus tag before the first scenario to run only that scenario. Go ahead and run script/cucumber --tag @focus from the project root, and you'll see that Cucumber only runs the scenario tagged @focus. You'll also see

1. See Section 19.3, *System-wide gems*, on page 310.

that all of the steps are undefined, and that Cucumber has provided code snippets for the missing step definitions:

```
1 scenario (1 undefined)
3 steps (3 undefined)
0m0.050s

You can implement step definitions for undefined steps with these snippets:

Given /^a movie$/ do
  pending
end

When /^I set the showtime to "([^\"]*)" at "([^\"]*)"$/ do |arg1, arg2|
  pending
end

Then /^the showtime description should be "([^\"]*)"$/ do |arg1|
  pending
end
```

Getting the First Scenario to Pass

We'll implement the step definitions for the first scenario using the Direct Model Access style. Create a file named showtime_steps.rb in the features/step_definitions directory, copy in the snippets cucumber supplied, and modify them as follows:

Download cucumber_rails/01/features/step_definitions/showtime_steps.rb

```
Given /^a movie$/ do
  @movie = Movie.create!
end

When /^I set the showtime to "([^\"]*)" at "([^\"]*)"$/ do |date, time|
  @movie.update_attribute(:showtime_date, Date.parse(date))
  @movie.update_attribute(:showtime_time, time)
end

Then /^the showtime description should be "([^\"]*)"$/ do |showtime|
  @movie.showtime.should == showtime
end
```

The step definitions are executed in the context of a Rails environment, so we can use any techniques that work in Rails unit tests or RSpec model specs. This includes creating models in the database and using RSpec's Expectations API.

Because all of the steps are run in the same Cucumber World, the @movie instance variable created in the Given() step is available to all subsequent steps.

Now run cucumber -t focus so we can see how we're doing. You should see the following in the output:

```
Scenario: Show minutes for times not ending with 00
  Given a movie
    uninitialized constant Movie (NameError)
    features/showtime_descriptions.feature:9:in `Given a movie'
```

The first step is failing because it references a Movie object that we have yet to create. Go ahead and create that using the rspec_model generator, and then run the migration for the development and test environments:

```
$ script/generate rspec_model movie showtime_date:date showtime_time:time
    exists  app/models/
    exists  spec/models/
    exists  spec/fixtures/
    create  app/models/movie.rb
    create  spec/models/movie_spec.rb
    create  spec/fixtures/movies.yml
    exists  db/migrate
    create  db/migrate/XXXXXXXXXXXXXX_create_movies.rb
$ rake db:migrate
$ rake db:test:prepare
```

RSpec's model generator works just like Rails' model generator, except it puts fixture files in spec/fixtures instead of test/fixtures, and it creates movie_spec.rb instead of movie_test.rb.

Now run cucumber -t focus and you should see that the second step is passing because we already added the attributes, but we get an undefined method 'showtime' for the third step. To get that to pass, go ahead and modify movie.rb as follows:

Download cucumber_rails/02/app/models/movie.rb

```ruby
class Movie < ActiveRecord::Base

  def showtime
    "#{formatted_date} (#{formatted_time})"
  end

  def formatted_date
    showtime_date.strftime("%B %d, %Y")
  end

  def formatted_time
    showtime_time.strftime("%l:%M%p").strip.downcase
```

Joe Asks...

Where does RSpec fit into this picture?

In this example, we go straight from a Cucumber scenario to the Rails model code without any more granular code examples written in RSpec. This is really just to keep things simple and focused on Cucumber for this chapter.

We have yet to introduce you to the other styles of step definitions, or the Rails-specific RSpec contexts provided by the rspec-rails library. As you learn about them in the coming chapters, you'll begin to get a feel for how all these puzzle pieces fit together, and how to balance the different tools and approaches.

```
  end
end
```

Now run script/cucumber -t focus again:

```
./script/cucumber -t focus

Feature: Showtime Descriptions

  So that I can find movies that fit my schedule
  As a movie goer
  I want to see accurate and concise showtimes

  Scenario: Show minutes for times not ending with 00
    Given a movie
    When I set the showtime to "2007-10-10" at "2:15pm"
    Then the showtime description should be "October 10, 2007 (2:15pm)"

1 scenario (1 passed)
3 steps (3 passed)
0m0.170s
```

That's looking much better, isn't it? This would probably be a good time to commit to a version control system. Working scenario by scenario like this, we get the benefit of ensuring we don't break previously passing scenarios as we continue to add behaviour and refactor.

Completing the Feature

Now that we've got the first scenario passing, let's see how we're doing on the second one. Run both scenarios with cucumber (without the -t option), and you should see this in the output:

Download cucumber_rails/02/out/02.one_failing

```
Scenario: Hide minutes for times ending with 00
  Given a movie
  When I set the showtime to "2007-10-10" at "2:15pm"
  Then the showtime description should be "October 10, 2007 (2pm)"
    expected: "October 10, 2007 (2pm)",
         got: "October 10, 2007 (2:00pm)" (using ==)
    Diff:
    @@ -1,2 +1,2 @@
    -October 10, 2007 (2pm)
    +October 10, 2007 (2:00pm)
```

Now we can go back to our Movie model and enhance the logic of the formatted_time() method.

Download cucumber_rails/03/app/models/movie.rb

```
def formatted_time
  format_string = showtime_time.min.zero? ? "%l%p" : "%l:%M%p"
  showtime_time.strftime(format_string).strip.downcase
end
```

That should be enough to get us to green:

```
2 scenarios (2 passed)
6 steps (6 passed)
0m0.071s
```

Success! We've completed our work on the "Showtime Descriptions" feature. Our passing scenarios tell us that we've written the right code, and that we're done. Before we leap into the next chapter, let's take a second to consider what we learned.

20.3 What We Just Learned

Like most important development decisions, when choosing a step definition style there are opposing forces on each side that need to be considered and balanced. Direct Model Access step definitions offer the speed and flexibility of model specs at the cost of reduced confidence that the application is working for its users.

For most situations, it makes more sense to create a more integrated set of step definitions that ensure the Models, Views and Controllers are working together correctly, even though they will execute a bit slower. Next we'll take a look at how we can use Webrat to implement either the Simulated Browser or Automated Browser styles to do just that.

Chapter 21

Simulating the Browser with Webrat

Even though we call Rails an MVC framework, there are really more than three layers in a Rails app. In addition to model, view, and controller, we've also got a routing layer, a persistence layer (the class methods in Rails models) and a database, and we want to ensure that all of these layers work well together.

In the last chapter, we introduced Direct Model Access step definitions and used them to implement Givens, Whens and Thens. This approach can be useful to specify fine-grained Model behaviours, but running those scenarios doesn't give us any confidence that the different layers of our application are working well together.

We rarely use DMA-only scenarios in practice, and when we do it's to augment a strong backbone of coverage established by Simulated Browser scenarios exercising the full Rails stack. We covered DMA first because it's the simplest style, but the primary role of DMA step definitions is to help keep our Simulated and Automated Browser scenarios focused by quickly setting up repeated database state in Givens, as we'll see later in this chapter.

We consider the Simulated Browser style to be the default approach for implementing Whens and Thens for a Rails app because it strikes a good balance between speed and integration. We can count on the software to work correctly in the hands of our end users when we ship, and we can execute the scenarios quickly as the requirements and code evolve.

If you're building an application without much JavaScript, the Simulated Browser (combined with DMA for Givens) is likely all you'll need. It's a fast, dependable alternative to in-browser testing tools like Selenium and Watir. Even when JavaScript is important to the user experience, we like to start with a set of Simulated Browser scenarios, and then add Automated Browser scenarios (which we'll cover in Chapter 22, *Automating the Browser with Webrat and Selenium*, on page 350) to drive client side interactions.

If you've ever written a Rails integration test, you've probably used the Simulated Browser style of testing. In that context, methods like get_via_redirect() and post_via_redirect() build confidence because they simulate requests that exercise the full stack, but they don't make it easy to express user behaviours clearly. Throughout this chapter we'll explore how Webrat builds on this approach to help us bridge the last mile between page loads and form submissions, and the behaviour our applications provide to the real people whose lives they touch.

21.1 Writing Simulated Browser Step Definitions

Let's walk through implementing a few step definitions for a simple scenario using the Simulated Browser style. We'll be building on the web-based movie box office system from last chapter. The next requirement is that visitors should be able to browse movies by genre. Start by creating a file named browse_movies.feature in the features directory with the following content:

Download simulated_browser/01/features/browse_movies.feature

```
Feature: Browse Movies

  So that I quickly can find movies of interest
  As a movie goer
  I want to browse movies by genres

  Scenario: Add movie to genre

    Given a genre named Comedy
    When I create a movie Caddyshack in the Comedy genre
    Then Caddyshack should be in the Comedy genre
```

As usual, we'll begin by running the file with Cucumber to point us at which step definitions we need to implement:

```
Feature: Browse Movies
```

```
  So that I quickly can find movies of interest
  As a movie goer
  I want to browse movies by genres

  Scenario: Add movie to genre
    Given a genre named Comedy
    When I create a movie Caddyshack in the Comedy genre
    Then Caddyshack should be in the Comedy genre

1 scenario (1 undefined)
3 steps (3 undefined)
0m0.086s

You can implement step definitions for undefined steps with these snippets:

Given /^a genre named Comedy$/ do
  pending
end

When /^I create a movie Caddyshack in the Comedy genre$/ do
  pending
end

Then /^Caddyshack should be in the Comedy genre$/ do
  pending
end
```

The "Given a genre named Comedy" step could be implemented using either DMA or the Simulated Browser style. Using a Simulated Browser would ensure that the Views and Controllers used to create Genres are working with the models properly. DMA won't go through those layers of the stack, but provides a bit more convenience, simplicity and speed.

So which style should we use? Let's imagine we already have scenarios that thoroughly exercise the interface to manage Genres using the Simulated Browser style in a manage_genres.feature file. With that coverage already in place, we can benefit from the DMA style without reducing our confidence in the application. As we add features throughout the evolution of an application, we see a pattern emerge in which we implement DMA Givens for a Model that has its own Simulated Browser scenarios elsewhere in the Cucumber suite.

Since we're just imagining that those Genre scenarios are in place, we won't create them, but we will need to create a Genre model and migration. We can use the RSpec model generator to do that:

```
script/generate rspec_model genre name:string
rake db:migrate && rake db:test:prepare
```

Now create a genre_steps.rb file in features/step_definitions/ and add the following code:

Download simulated_browser/01/features/step_definitions/genre_steps.rb

```
Given /^a genre named Comedy$/ do
  @comedy = Genre.create!(:name => "Comedy")
end
```

The step will pass because all it needs is the Genre model and table that we just created. Running the scenario again shows us that our When is the next pending step to turn our attention to:

```
Feature: Browse Movies

  So that I quickly can find movies of interest
  As a movie goer
  I want to browse movies by genres

  Scenario: Add movie to genre
    Given a genre named Comedy
    When I create a movie Caddyshack in the Comedy genre
    Then Caddyshack should be in the Comedy genre

1 scenario (1 undefined)
3 steps (2 undefined, 1 passed)
0m0.115s

You can implement step definitions for undefined steps with these snippets:

When /^I create a movie Caddyshack in the Comedy genre$/ do
  pending
end

Then /^Caddyshack should be in the Comedy genre$/ do
  pending
end
```

The wireframe for the Add Movie screen shown in Figure 21.1, on the following page, shows that a user will need to provide a movie's title, release year, and genres to add it to the system. Since our When step specifies the main *action* of the scenario, we'll use the Simulated Browser to drive this interaction through the full Rails stack.

Before we look at how Webrat can help us with this, let's see what Rails provides out-of-the-box. If you were to implement the "When I create a movie Caddyshack in the Comedy genre" step with the Rails integration testing API, you might end up with something like the following:

Figure 21.1: Creating a Movie with a form

Download simulated_browser/misc/features/step_definitions/movie_steps.rb

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  get_via_redirect movies_path
  assert_select "a[href=?]", new_movie_path, "Add Movie"

  get_via_redirect new_movie_path

  assert_select "form[action=?][method=post]", movies_path do
    assert_select "input[name=?][type=text]", "movie[title]"
    assert_select "select[name=?]", "movie[release_year]"
    assert_select "input[name=?][type=checkbox][value=?]", "genres[]", @comedy.id
  end

  post_via_redirect movies_path, :genres => [@comedy.id], :movie =>
    { :title => "Caddyshack", :release_year => "1980" }

  assert_response :success
end
```

This gets the job done, but a lot of implementation details like HTTP methods, form input names, and URLs have crept up into our step definition. These sorts of details will change through the lifespan of an application and can make scenarios quite brittle. We could mitigate some of that risk by extracting helper methods for specifying forms and posts that might appear in multiple scenarios, but that still leaves a significant issue.

With the generated HTML being specified separately from the post, it is entirely possible to assert_select "input[name=?]", "movie[name]" and then post to movies_path, :movie => { :title => "Caddyshack"}. This specifies that the form displays an input for movie[name], but then the step posts movie[title]. If the form is incorrectly displaying a movie[name] field, this step will pass, but the application will not work correctly.

Luckily, there's a better way that makes the Simulated Browser approach not only viable but enjoyable to work with.

Like the Rails integration testing API, Webrat works like a fast, invisible browser. It builds on that functionality by providing a simple, expressive DSL for manipulating a web application. We can use Webrat to describe the same interaction at a high level, using language that is similar to how you might explain using the application to a non-technical friend:

Download simulated_browser/01/features/step_definitions/movie_steps.rb

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  visit movies_path
  click_link "Add Movie"
  fill_in "Title", :with => "Caddyshack"
  select "1980", :from => "Release Year"
  check "Comedy"
  click_button "Save"
end
```

That certainly *feels* a lot better than the first version. Notice how Webrat let us focus on exactly the details an end user would experience and didn't force us to worry about how it will be built. The sole implementation detail remaining is using the movies_path() route as an entry point.

In addition to being more expressive, Webrat also delivers on the promise of catching regressions without the false positives described earlier. Don't worry about the details of how this works just yet. That will become clear throughout the rest of this chapter.

By re-running the scenario with Cucumber, it will show us where to start implementing:

```
Feature: Browse Movies

  So that I quickly can find movies of interest
  As a movie goer
  I want to browse movies by genres

  Scenario: Add movie to genre
    Given a genre named Comedy
    When I create a movie Caddyshack in the Comedy genre
      undefined method `movies_path' for
            #<ActionController::Integration::Session:0x21eeeb4> (NoMethodError)
      ./features/step_definitions/movie_steps.rb:2:in
            `/^I create a movie Caddyshack in the Comedy genre$/'
      features/browse_movies.feature:10:in
            `When I create a movie Caddyshack in the Comedy genre'
    Then Caddyshack should be in the Comedy genre

1 scenario (1 failed)
3 steps (1 failed, 1 undefined, 1 passed)
0m0.102s

You can implement step definitions for undefined steps with these snippets:

Then /^Caddyshack should be in the Comedy genre$/ do
  pending
end
```

At this point, the outside-in development process described in Section 19.2, *Outside-In Rails Development*, on page 307 leads us through the steps necessary to get that feature completed. To get the first step passing, we need a MoviesController with view templates for the index and new actions, along with changes to config/routes.rb and a migration to update the movies table.

The upcoming chapters dive into the specifics of spec'ing views, controllers and models, so to keep this example focused on the Simulated Browser style, we'll leave the development of this code as an exercise for you. Once those additions and changes are in place, re-running our scenario shows us that we've got one step left:[1]

```
Feature: Browse Movies
```

1. If you want to run the feature yourself, and you're not quite ready to develop the necessary code on your own, you'll find the necessary code in simulated_browser/02 in the code download. Just cd into that directory and run cucumber features.

```
  So that I quickly can find movies of interest
  As a movie goer
  I want to browse movies by genres

  Scenario: Add movie to genre
    Given a genre named Comedy
    When I create a movie Caddyshack in the Comedy genre
    Then Caddyshack should be in the Comedy genre

1 scenario (1 undefined)
3 steps (1 undefined, 2 passed)
0m0.196s

You can implement step definitions for undefined steps with these snippets:

Then /^Caddyshack should be in the Comedy genre$/ do
  pending
end
```

To browse movies by genre, a site visitor would click over to the Comedy page, which displays one movie entitled Caddyshack. The Webrat step definition for our Then reflects this:

Download simulated_browser/03/features/step_definitions/movie_steps.rb

```ruby
Then /^Caddyshack should be in the Comedy genre$/ do
  visit genres_path
  click_link "Comedy"
  response.should contain("1 movie")
  response.should contain("Caddyshack")
end
```

To get this to pass, we need to add a GenresController with an index and a "show" view displaying a list of movies in the genre. We also need to go back to the MoviesController and get it to collaborate with the models to persist the movie and its genres correctly.

Again, in practice we'd drop down to isolated code examples with RSpec to drive the design and implementation of our objects. A few cycles of Red, Green, Refactor later and we should be all set:[2]

```
Feature: Browse Movies

  So that I quickly can find movies of interest
  As a movie goer
  I want to browse movies by genres
```

2. cd into simulated_browser/03 in the code download and run cucumber features to run the feature yourself.

```
  Scenario: Add movie to genre
    Given a genre named Comedy
    When I create a movie Caddyshack in the Comedy genre
    Then Caddyshack should be in the Comedy genre

1 scenario (1 passed)
3 steps (3 passed)
0m0.270s
```

Great. The passing scenario is telling us we're done. By leveraging the DMA style for Givens and combining it with the Simulated Browser style with Webrat for Whens and Thens, we've reached a good balance of expressive specification, speed and coverage. We can read the scenario to understand what we should expect from the application, and we can be quite confident that it will work for our users when we ship it.

Throughout the rest of the chapter, we'll dive into the details of Webrat's features and how they work. Let's start by looking at how Webrat lets you navigate from page to page in your application.

21.2 Navigating to Pages

Just as a user can't click any links or submit any forms until he has typed a URL into his browser's address bar and requested a web page, Webrat can't manipulate a page until you've given it a place to start. The visit() method lets you open a page of your application.

Inside each scenario, visit() must be called before any other Webrat methods. Usually you'll call it with a routing helper, like we did in our When step definition from the previous section:

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  visit movies_path
  # ...
end
```

Behind the scenes, Webrat leverages Rails' integration testing functionality to simulate GET requests, and layers browser-like behaviour on top. Like other Webrat methods that issue requests, it looks at the response code returned to figure out what to do next:

Successful (200-299) or Bad Request (400-499) Webrat stores the response so that subsequent methods can fill out forms, click links, or inspect its content.

Redirection (300-399) If the redirect is to a URL within the domain of the application, Webrat issues a new request for the destination specified by the redirect, preserving HTTP headers and including a proper Location header. If the redirect is external, Webrat saves it as the response for later inspection but won't follow it.

Server Error (500-599) Webrat raises a Webrat::PageLoadError. If you want to specify that making a request produces an error, you can use RSpec's raise_error() to catch it.

Clicking links

Once you've opened a page of your application using visit(), you'll often want to navigate to other pages. Rather than using visit() to load each URL in succession, it's convenient to simulate clicking links to jump from page to page.

click_link() lets you identify a link by its text and follows it by making a request for the URL it points to. To navigate to the URL in the *href*, wherever that may be, of a link with the text "Comedy" we wrote:

```
Then /^Caddyshack should be in the Comedy genre$/ do
  # ...
  click_link "Comedy"
  # ...
end
```

click_link() can lead to a more natural flow in your step definitions and has the advantage that your step definitions are less bound to your routing scheme. On the other hand, each page load takes a little bit of time, so to keep your scenarios running quickly you'll want to avoid navigating through many pages of the site that aren't directly related to what you're testing. Instead, you could pick an entry point for visit() closer to the area of the application you're concerned with.

In addition to clicking links based on the text between the <*a*> tags, Webrat can locate links by their *id* and *title* values. For example, if we have the following HTML:

```
<a href="/" title="Example.com Home" id="home_link">
  Back to homepage
</a>
```

Then the following step definitions would all be equivalent:

```
When /^I click to go back to the homepage$/ do
  # Clicking the link by its title
  click_link "Example.com Home"
end

When /^I click to go back to the homepage$/ do
```


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```
  # Clicking the link by its id
  click_link "home_link"
end

When /^I click to go back to the homepage$/ do
  # Clicking the link by its text
  click_link "Back to homepage"
end
```

click_link() has rudimentary support for handling JavaScript links generated by Rails' link_to() for non-GET HTTP requests. Since it can't actually run any JavaScript, it relies on matching the *onclick* value with regular expressions. This functionality, though limited, can be useful when dealing with RESTful Rails applications that aren't implemented with obtrusive JavaScript techniques.

Let's say the box office application requires that a moderator approves movie listings before they are visible on the site. Here's how you might express that with Webrat:

```
When /^I approve the listing$/ do
  click_link "Approve"
end
```

And here's the likely implementation:

```
<%= link_to "Approve", approve_movie_path(movie), :method => :put %>
```

When clicked, the link would generate a PUT request to the approve_movie_path. You can disable this functionality by passing the :javascript => false option to click_link():

```
When /^I approve the listing$/ do
  click_link "Approve", :javascript => false
end
```

Instead of sending a PUT request, this tells Webrat to issue a GET request as if the JavaScript were not present. This can be useful when you want to specify the app works correctly for users without JavaScript enabled.

Now that we're comfortable navigating to pages within our application, we can take a look at how to use Webrat to submit forms.

21.3 Manipulating Forms

Once we've reached a page of interest, we'll want to trigger actions before we can specify outcomes. In the context of a web-based application, that usually translates to filling out and submitting forms. Let's

webrat_steps.rb

You might be looking at the step definitions used throughout this chapter and wondering if you'll be forced to write step definitions for every When and Then step in each of your app's scenarios. After all, maintaining separate step definitions for both "When I click the Save button" and "When I click the Delete button" (and more) would get tedious pretty quickly.

Fortunately, Cucumber has just the feature to help us out of this: parameterized step definitions. Instead of maintaining a step definition for each button, we can write one that's reusable by wrapping the Webrat API:

```
When /^I click the "(.+)" button$/ do |button_text|
  click_button button_text
end
```

In fact, Cucumber ships with a bunch of these sort of step definitions in a webrat_steps.rb file. It was added to your project's step_definitions directory when you ran the Cucumber generator.

Be sure to take a look at what's in there. It can save you quite a bit of time as you're implementing new scenarios.

take a look at Webrat's methods to do that. They'll serve as the bread and butter of most of our When step definitions.

fill_in()

You'll use fill_in() to type text into *text* fields, *password* fields, and <*textarea*>s. We saw an example of this in the When step definition of our box office example:

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  # ...
  fill_in "Title", :with => "Caddyshack"
  # ...
end
```

fill_in() supports referencing form fields by *id*, *name* and <*label*> text. Therefore, if we've got a conventional Rails form with proper label tags like this:

```
<dl>
  <dt>
```

```
    <label for="movie_title">Title</label>
  </dt>
  <dd>
    <input type="text" name="movie[title]" id="movie_title" />
  </dd>
</dl>
```

Then all of the following would be functionally equivalent:

```
Line 1 When /^I fill in the movie title Caddyshack$/ do
-        # using the field's label's text
-        fill_in "Title", :with => "Caddyshack"
-      end
5
-      When /^I fill in the movie title Caddyshack$/ do
-        # using the field's id
-        fill_in "movie_title", :with => "Caddyshack"
-      end
10
-      When /^I fill in the movie title Caddyshack$/ do
-        # using the field's name
-        fill_in "movie[title]", :with => "Caddyshack"
-      end
```

In practice, referencing fields by label text is preferred. That way we can avoid coupling our step definitions to class and field names, which are more likely to change as we evolve the application. In the above example, if we renamed the Movie class to Film, we'd have to change line 8 which uses the field *id* and line 13 which uses the field *name*, but line 3 would continue to work just fine. Unless otherwise noted, Webrat's other form manipulation methods support targeting fields using these three strategies.

Beyond making your step definitions easier to write and maintain, providing active form field labels is a good habit to get into for accessibility and usability.

check() and uncheck()

check() lets you click a checkbox which was not checked by default or had been previously unchecked. Here's an example:

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  # ...
  check "Comedy"
  # ...
end
```

To uncheck a checkbox that was checked by default or has been previously checked, you'd write:

```
When /^I uncheck Save as draft$/ do
  uncheck "Save as draft"
end
```

choose()

You'll use choose() to manipulate *radio* form fields. Just like a browser with a GUI, Webrat ensures only one radio button of a given group is checked at a time.

Let's say we wanted to select "Premium" from a list of plan levels on a signup page. You might write:

```
When /^I choose to create a Premium plan$/ do
  choose "Premium"
end
```

select()

You'll use select() to pick options from select drop-down boxes.

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  # ...
  select "1980"
  # ...
end
```

By default, Webrat will find the first option on the page that matches the text. This is usually fine. If you'd like to be more specific, or you have multiple selects with overlapping options, you can provide the :from option. Then, Webrat will only look for the option inside selects matching the label, name or id. For example:

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  # ...
  select "1980", :from => "Release Year"
  # ...
end
```

select_date(), select_time() and select_datetime()

When rendering a form, Rails typically exposes date and time values as a series of <*select*> fields. Each individual select doesn't get its own <*label*> so filling in a date using Webrat's select() method is a bit cumbersome:

```
When /^I select October 1, 1984 as my birthday$/ do
  select "October", :from => "birthday_2i"
  select "1", :from => "birthday_3i"
  select "1984", :from => "birthday_1i"
end
```

To ease this pain, Webrat now supports filling out conventional Rails date and time fields with the select_date(), select_time() and select_datetime() methods. They act like a thin layer on top of select() to hide away the Rails-specific implementation details. Here's how you might use them:

```
When /^I select April 26, 1982$/ do
  # Select the month, day and year for the given date
  select_date Date.parse("April 26, 1982")
end

When /^I select 3:30pm$/ do
  # Select the hour and minute for the given time
  select_time Time.parse("3:30PM")
end

When /^I select January 23, 2004 10:30am$/ do
  # Select the month, day, year, hour and minute for the given time
  select_datetime Time.parse("January 23, 2004 10:30AM")
end
```

All three of the methods also support Strings instead of Date or Time objects, in which case they'll do the required parsing internally.

Unlike select(), they don't support the :from option because no single <*label*>, input *name* or *id* could identify the different <*select*> fields that need to be manipulated. Instead, to help when there are multiple date or time fields on the same page, they support an :id_prefix option used to specify the attribute name:

```
When /^I set the start time to 1pm$/ do
  select_time Time.parse("1:00PM"), :id_prefix => "start_time"
end

When /^I set the end time to 3:30pm$/ do
  select_time Time.parse("3:30PM"), :id_prefix => "end_time"
end
```

attach_file()

To simulate file uploads, Webrat provides the attach_file() method. Instead of passing a file field's value as a string, it stores an ActionController::TestUploadedFile in the params hash that acts like a Tempfile object a controller would normally receive during a multipart request.

When you use it, you'll want to save the fixture file to be uploaded somewhere in your app's source code. We usually put these in spec/fixtures. Here's how you could implement a step definition for uploading a photo:

```
When /^I attach my Vacation photo$/ do
  attach_file "Photo", "#{Rails.root}/spec/fixtures/vacation.jpg"
```

```
end
```

By default, Rails' TestUploadedFile uses the text/plainMIME type. When that's not right, you can pass in a specific MIME type as a third parameter to attach_file():

```
When /^I attach my Vacation photo$/ do
  attach_file "Photo",
              "#{Rails.root}/spec/fixtures/vacation.jpg",
              "image/jpeg"
end
```

set_hidden_field()

Occasionally, it can be useful to manipulate the value of a hidden form field when using the Simulated Browser approach. The fill_in() method, like an app's real users, will never manipulate a hidden field, so Webrat provides a set_hidden_field() specifically for this purpose:

```
When /^I select Bob from the contact list dialog$/ do
  set_hidden_field "user_id", :to => @bob.id
end
```

Use this method with caution. It's interacting with the application in a different way than any end user actually would, so not all of the integration confidence normally associated with the Simulate Browser style applies, but it can help in a pinch.

click_button()

After you've filled out your fields using the above methods, you'll submit the form. If there's only one *submit* button on the page, you can simply use:

```
When /^I click the button$/ do
  click_button
end
```

If you'd like to be a bit more specific or there is more than one button on the page, click_button() supports specifying the button's *value*, *id* or *name*. Let's say you have the following HTML on your page:

```
<input type="submit" id="save_button" name="save" value="Apply Changes" />
```

There are three ways you could click it using the Webrat API:

```
When /^I click the button$/ do
  # Clicking a button by id
  click_button "save_button"
end
```

```
When /^I click the button$/ do
  # Clicking a button by the name attribute
  click_button "save"
end

When /^I click the button$/ do
  # Clicking a button by its text (value attribute)
  click_button "Apply Changes"
end
```

Just like when navigating from page to page, when Webrat submits a form it will automatically follow any redirects, and ensure the final page did not return a server error. There's no need to check the response code of the request by hand. The returned page is stored, ready to be manipulated or inspected by subsequent Webrat methods.

submit_form()

Occasionally, you might need to submit a form that doesn't have a submit button. The most common example is a select field that is enhanced with JavaScript to auto-submit its containing form. Webrat provides the submit_form() method to help in these situations. To use it, you'll need to specify the <*form*>'s *id* value:

```
When /^I submit the quick navigation form$/ do
  submit_form "quick_nav"
end
```

reload()

Real browsers provide a reload button to send another request for the current page to the server. Webrat provides the reload() method to simulate this action:

```
When /^I reload the page$/ do
  reload
end
```

You might find yourself using this if you want to ensure that refreshing a page after an important form submission behaves properly. Webrat will repeat the last request, resubmitting forms and their data.

21.4 Specifying Outcomes with View Matchers

Simply by navigating from page to page and manipulating forms in Whens, you've been implicitly verifying some behaviour of your application. If a link breaks, a server error occurs, or a form field disappears, your scenario will fail. That's a lot of coverage against regressions for free. In Then steps, we're usually interested in explicitly specifying the contents of pages and Webrat provides three custom RSpec matchers to help with this.

contain()

The simplest possible specification of a page is to ensure it displays the right words. Webrat's contain() takes a bit of text and ensures it's in the response's content:

```
Then /^I should see Thank you!$/ do
  response.should contain("Thank you!")
end
```

contain() also works with regular expressions instead of strings:

```
Then /^I should see Hello$/ do
  response.should contain(/Hello/i)
end
```

You'll find you can accommodate almost all of your day to day uses of the contain() matcher with a couple of reusable step definitions from Cucumber's generated webrat_steps.rb file described in the sidebar on page 337:

```
Then /^I should see "(.+)"$/ do |text|
  response.should contain(text)
end

Then /^I should not see "(.+)"$/ do |text|
  response.should_not contain(text)
end
```

contain() will match against the HTML decoded text of the document, so if you want to ensure "Peanut butter & jelly" is on the page, you'd type just that in the string, not "Peanut butter & jelly".

have_selector()

Imagine you're building an online photo gallery. Specifying the text on the page probably isn't good enough if you're looking to make sure the photo a user uploaded is being rendered in the album view. In this case, it can be quite useful to ensure the existence of a CSS selector using Webrat's have_selector():

```
Then /^I should see the photo$/ do
  response.should have_selector("img.photo")
end
```

As you'd expect, that specifies there is at least one <*img*> element on the page with a class of *photo*. Webrat supports the full set of CSS3 selectors like the :nth-child pseudo-class, giving it lots of flexibility. The image's *src* is particularly important in this case, so we might want to check that too:

```
Then /^I should see the photo$/ do
  response.should have_selector("img.photo", :src => photo_path(@photo))
end
```

Webrat will take any keys and values specified in the options hash and translate them to requirements on the element's attributes. It's just a more readable way to do what you can do with CSS's img[src=...] syntax but saves you from having to worry about escaping strings.

Occasionally the number of elements matching a given selector is important. It's easy to imagine a scenario that describes uploading a couple photos and specifying the number of photos in the album view should increase. This is supported via the special :count option:

```
Then /^I should see the photo$/ do
  response.should have_selector("img.photo", :count => 5)
end
```

When we don't care where on the page a piece of text might be, contain() gets the job done, but in some cases the specific element the text is in may be important. A common example would be ensuring that the correct navigation tab is active. To help in these cases, Webrat provides the :content option. Here's how you use it:

```
Then /^the Messages tab should be active$/ do
  response.should have_selector("#nav li.selected", :content => "Messages")
end
```

This tells Webrat to make sure that at least one element matching the selector contains the specified string. Like contain(), the provided string is matched against the HTML decoded content so there's no need to use HTML escaped entities.

Finally, for cases when you need to get fancy, have_selector() supports nesting. If you call it with a block, the block will be passed an object representing the elements matched by the selector and within the block you can use any of Webrat's matchers. Here's how you might check that the third photo in an album is being rendered with the right image tag and caption:

```
Then /^the Vacation photo should be third in the album$/ do
  response.should have_selector("#album li:nth-child(3)") do |li|
```

```
    li.should have_selector("img", :src => photo_path(@vacation_photo))
    li.should contain("Vacation Photo")
  end
end
```

By combining the power of CSS3 selectors with a few extra features, Webrat's have_selector() should provide all you need to write expectations for the vast majority of your step definitions. For the rare cases where CSS won't cut it, let's take a look at the have_xpath() matcher, which lets you go further.

have_xpath()

When CSS just isn't powerful enough, Webrat exposes have_xpath() as a matcher of last resort. It's infinitely powerful, but due to the nature of XPath it's usually not the most expressive. Here's an example from a recent project:

```
Then /^the page should not be indexable by search engines$/ do
  response.should have_xpath(".//meta[@name = 'robots' and @content = 'noindex, nofo...*TRUNC*
  response.should_not have_xpath(".//meta[@name = 'robots' and @content = 'all']")
end
```

Under the hood, have_selector() actually works by translating CSS selectors to XPath and using the have_xpath() implementation. That means all of the have_selector() features we explored work with have_xpath() too.

This implementation strategy hints at an interesting rule about CSS and XPath: *All CSS selectors can be expressed as XPath, but not all XPath selectors can be expressed as CSS.* There are a lot of occasionally useful features XPath supports that CSS does not, like traversing up the document tree (e.g. give me all <*div*>s containing a <*p*>). While an overview of XPath is outside the scope of this book, it's a good thing to get familiar with if you find yourself wanting more power than CSS selectors can provide.

21.5 Building on the Basics

Now that we've seen how to manipulate forms and specify page content with Webrat, we'll take a look at some of Webrat's more advanced, less commonly used features. You probably won't need them day to day, but it's helpful to have a rough idea of what's available so you can recognize cases when they might come in handy.

Working Within a Scope

Sometimes targeting fields by a label isn't accurate enough. Going back to our box office example application, we might want a form where a user can add multiple genres at once. Each row of the form would have its own <*label*> for the genre name, but using Webrat's fill_in() method would always manipulate the input field in the first row.

For these cases, Webrat provides the within() method. By providing a CSS selector, you can scope all of the contained form manipulations to a subset of the page. Here's how you could fill out the second genre name field:

```
When /^I fill in Horror for the second genre name$/ do
  within "#genres li:nth-child(2)" do
    fill_in "Name", :with => "Horror"
  end
end
```

If no elements matching the CSS selector are found on the page, Webrat will immediately raise a Webrat::NotFoundError. Like most other Webrat methods, if multiple elements match, it will use the first one in the HTML source.

Locating Form Fields

When a form is rendered with pre-filled values, you may want to check that the proper values are present when the page loads. To help with this, Webrat exposes methods that return objects representing fields on the page, which include accessors for their values. Here's a simple example based on field_labeled(), which looks up input fields based on their associated <*label*>s:

```
Then /^the email address should be pre-filled$/ do
  field_labeled("Email").value.should == "robert@example.com"
end
```

Checkboxes also provide a checked?() method for convenience:

```
Then /^the Terms of Service checkbox should not be checked$/ do
  field_labeled("I agree to the Terms of Service").should_not be_checked
end
```

When <*label*>-based lookups won't work, you can use field_named() which matches against the field's *name* value, or field_with_id() which matches against the field's *id*:

```
Then /^the email address should be pre-filled$/ do
  field_named("user[email]").value.should == "robert@example.com"
end
```

```
Then /^the email address should be pre-filled$/ do
  field_with_id("user_email").value.should == "robert@example.com"
end
```

Dropping Down to HTTP

To keep our scenarios as expressive and maintainable as possible, we generally try to avoid tying them to implementation details. For example, our users aren't concerned with the URL of the page they end up on, just that it's showing them the right information. Building our specifications of the app's behaviour on page content rather than URLs aligns our executable specifications with our users' interactions.

For the rare cases where the lower level operation of the application is important to the customers or it's the only available option for specifying a behaviour, Webrat provides a few methods that expose these details. To check the current URL of the session after the last request (and following redirects), you can use the current_url() method:

```
Then /^the page URL should contain the album SEO keywords$/ do
  current_url.should =~ /vacation-photos/
end
```

If your application does some form of browser sniffing or you're building a REST API, you might be interested in specifying the behaviour of an app in the presence of a specific HTTP header. You can set any request header for the duration of the test with Webrat's header() method:

```
Given /^I'm browsing the site using Safari$/ do
  header "User-Agent", "Mozilla/5.0 (Macintosh; U; Intel Mac OS X 10_5_6; en-us)"
end

When /^I request the users list using API version 2.0$/ do
  header "X-API-Version", "2.0"
  visit users_path
end
```

When the MIME type should affect the behaviour of the application, you can use the http_accept() method as a shortcut to set the Accept header. It can be called with a small set of symbols that map to MIME types or a MIME type string:

```
Given /^my web browser accepts iCal content$/ do
  http_accept :ics
end

Given /^my user agent accepts MP3 content$/ do
  http_accept "audio/mpeg"
```

```
end
```

Finally, if you're going to use the HTTP protocol's built in Basic authentication mechanism, Webrat includes a basic_auth() method for setting the HTTP_AUTHORIZATION header to the encoded combination of a username and password:

```
Given /^I am logged in as "robert" with the password "secret"$/ do
  basic_auth "robert", "secret"
end
```

When Things Go Wrong

Every once in awhile, you'll hit a point where you think a step should be passing but it's failing. It might raise a Webrat::NotFoundError about a field that's not present or complain that an expected element is missing. Before diving into your test.log or the Ruby debugger, it's good to take a look at the page as Webrat is seeing it, to check if it matches your understanding of what should be rendered.

You can use the save_and_open_page() method to capture the most recent response at any point in your scenario, and open it up in a web browser as a static HTML file on your development machine. Just drop it in before any line that seems to be misbehaving:

```
When /^I uncheck Save as draft$/ do
  save_and_open_page
  uncheck "Save as draft"
end
```

Now when you re-run the scenario, you'll be able to see the page response as Webrat captured it. If you're on Mac OS X, the file is opened automatically in your default browser. Otherwise, you can find it in the tmp directory below the project root.

21.6 Wrapping Up

Before we move on to looking at how the Automated Browser style of step definitions can be used to exercise interactions that are dependent on JavaScript, let's take a moment to consider what we've learned.

- Webrat simulates a browser by building on the functionality of the Rails integration testing API, providing an expressive language to describe manipulating a web application.
- By specifying behaviour at a high level and avoiding coupling our tests to implementation details, we can build expressive and robust

step definitions that give us confidence that the full Rails stack stays working while avoiding brittle scenarios.

- Leveraging the DMA style for Givens can provide convenience, simplicity and speed without reducing confidence. We use this approach when the actions required to get to a specific database state have already been exercised through the full Rails stack in their own Simulated Browser scenarios.
- Through the course of describing the actions in our scenarios in our When steps, Webrat implicitly ensures that requests are successful and the right links and form elements are on the page. In our Then steps we specify the outcomes from our scenarios in terms of expected text and elements using Webrat's view matchers.

Chapter 22

Automating the Browser with Webrat and Selenium

In the last chapter we explored how Webrat can simulate the core functionality of a Web browser that you need when building a web application—navigating to pages, filling out forms, and submitting them to the server. This will allow you to specify 80% of the behaviour for most applications without ever loading up Firefox.

This simulated approach doesn't help when you depend on rich client-side interactions built with JavaScript, however, and for that we look to Selenium.[1] Selenium is a software testing tool originally developed at ThoughtWorks that can automate most modern Web browsers. Webrat supports a Selenium mode that translates the Webrat API calls to Selenium calls, allowing you to run the exact same Cucumber feature with and without running a real Web browser.

By writing your step definitions with the Webrat API, you don't have to rewrite them as your application evolves to include more client-side enhancements. You can always use whichever execution mode is appropriate for a given scenario (or run the same scenario in both modes) without having to use different tools.

Before we get started, you'll need to install one new gem that we haven't installed yet.

```
[sudo] gem install selenium-client
```

Now let's take a look at how this works.

1. http://seleniumhq.org/

22.1 Getting Started

To demonstrate just how easy it is to get started with Webrat's Selenium support, we'll walk through updating one of our Cucumber features from the last chapter to use it. Here's what it says:

Download simulated_browser/01/features/browse_movies.feature

```
Feature: Browse Movies

  So that I quickly can find movies of interest
  As a movie goer
  I want to browse movies by genres

  Scenario: Add movie to genre

    Given a genre named Comedy
    When I create a movie Caddyshack in the Comedy genre
    Then Caddyshack should be in the Comedy genre
```

And the three step definitions that make it executable:

Download simulated_browser/03/features/step_definitions/genre_steps.rb

```
Given /^a genre named Comedy$/ do
  @comedy = Genre.create!(:name => "Comedy")
end
```

Download simulated_browser/03/features/step_definitions/movie_steps.rb

```
When /^I create a movie Caddyshack in the Comedy genre$/ do
  visit movies_path
  click_link "Add Movie"
  fill_in "Title", :with => "Caddyshack"
  select "1980", :from => "Release Year"
  check "Comedy"
  click_button "Save"
end

Then /^Caddyshack should be in the Comedy genre$/ do
  visit genres_path
  click_link "Comedy"
  response.should contain("1 movie")
  response.should contain("Caddyshack")
end
```

And here's the env.rb file used by Cucumber to setup the environment:

Download simulated_browser/03/features/support/env.rb

```
# Sets up the Rails environment for Cucumber
ENV["RAILS_ENV"] ||= "cucumber"
require File.expand_path(File.dirname(__FILE__) + '/../../config/environment')
require 'cucumber/rails/world'
```

```
# Comment out the next line if you don't want Cucumber Unicode support
require 'cucumber/formatter/unicode'

# Comment out the next line if you don't want transactions to
# open/roll back around each scenario
# Cucumber::Rails.use_transactional_fixtures

# Comment out the next line if you want Rails' own error handling
# (e.g. rescue_action_in_public / rescue_responses / rescue_from)
Cucumber::Rails.bypass_rescue

require 'webrat'

Webrat.configure do |config|
  config.mode = :selenium
  config.selenium_wait_timeout = 10
end

class ActiveSupport::TestCase
  setup do |session|
    session.host! "localhost:3001"
  end
end

require 'cucumber/rails/rspec'
require 'webrat/core/matchers'
```

To modify this feature file to run through Selenium, we had to make three changes to env.rb. First, comment out the line that causes Rails to use a transaction around each scenario:

```
# Cucumber::Rails.use_transactional_fixtures
```

When using Selenium, Cucumber runs in a separate process than the Rails application, as shown in Figure 22.1, on the next page. Since they'll be using different database connections, we can't wrap each of our scenarios with a transaction in our Cucumber process. If we did, the Rails process would never see the data we set up for it.

The downside of turning off transactions is we'll now be responsible for ensuring a "clean" database state is provided for each test on our own. We'll look at strategies for doing that a bit later in this chapter.

Next, we'll configure the Rails ActionController::Integration::Session#host() so that it generates URLs pointing to localhost:3001:

```
class ActiveSupport::TestCase
  setup do |session|
    session.host! "localhost:3001"
  end
```

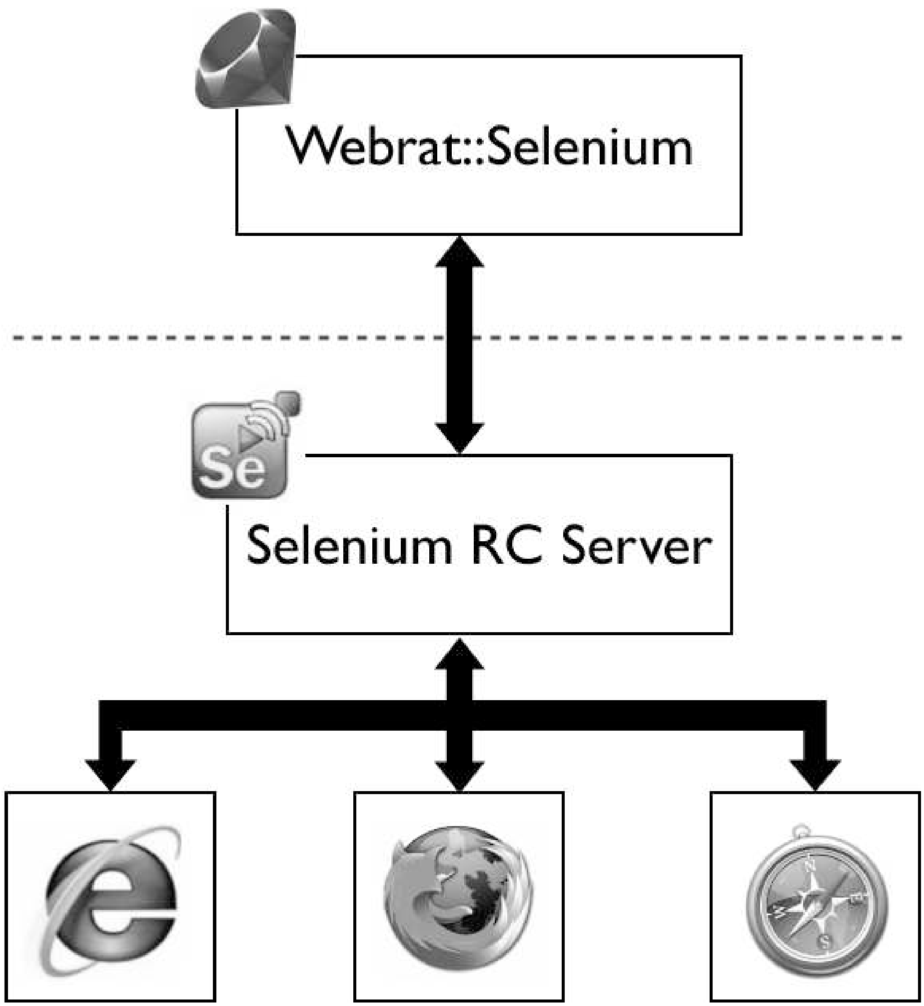

Figure 22.1: Selenium Process Architecture

```
end
```

By default, if you use a routing helper like users_url() in a step definition, you'll get a URL in the form of http://test.host/.... With these lines, generated URLs will point to http://localhost:3001 instead, which is where Webrat will automatically boot an instance of your application.

Finally, we change Webrat's mode from :rails to :selenium:

```
Webrat.configure do |config|
  config.mode = :selenium # was :rails
end
```

Let's give that a run, and see what happens:

```
$ rake features
..
==> Waiting for Selenium RC server on port 4444... Ready!
==> Waiting for rails application server on port 3001... Ready!
..
Finished in 11.679288 seconds.

2 tests, 2 assertions, 0 failures, 0 errors
```

While the above output was appearing on your terminal, Firefox opened, loaded up your app, and ran through our Cucumber scenario like an invisible user following a script. As you accumulate more scenarios to run through Selenium, it can be pretty fun to watch.

Now that we've seen how we to configure Webrat, Cucumber, and Rails to work with Selenium, we'll explore the nitty gritty details of writing Selenium-driven scenarios to describe your application's behaviour.

22.2 Writing step definitions for Selenium

Fortunately, most of the techniques for writing and maintaining step definitions for simulating the browser apply equally well when automating the browser with Selenium. There are a few things to watch out for and also some new tricks we can use.

Setting up database state in Givens

Like simulating the browser as we saw in Section 21.1, *Writing Simulated Browser Step Definitions*, on page 327, it's useful to use Direct Model Access to setup models in the Given steps of a Selenium scenario. By specifying the behaviour associated with creating those models in separate Cucumber features, we can do this to speed up our suite without sacrificing confidence in our coverage.

Unlike when simulating the browser, we have to turn off Rails' transactional fixture setting so the records we write to the database from our test process are visible to the application process. As a side effect, we have to worry about ensuring that each scenario starts off with a clean database state.

There are a couple ways to achieve that goal. The simplest is to manually destroy all of the records in an After() hook declared in features/support/env.rb:

```
After do
  Movie.destroy_all
  Genre.destroy_all
  # ...
end
```

As you might guess, this technique can get a bit cumbersome and error prone as the application grows. Eventually, you might want something that can quickly remove all the records in the database without needing to list out all your model classes. Ben Mabey's database_cleaner[2] plugin is a handy little library to give you just that. To install it, run the following command:

```
script/plugin install git://github.com/bmabey/database_cleaner.git
```

Now add the following lines to features/support/env.rb:

```
require 'database_cleaner'
require 'database_cleaner/cucumber'
DatabaseCleaner.strategy = :truncation
```

Setting DatabaseCleaner.strategy to :truncation tells the plugin to run a TRUNCATE TABLE statement for each table in the database. TRUNCATE TABLE has the same effect as a DELETE statement that removes all rows, but it can be much faster.[3]

Manipulating the application in Whens

Like Givens, Whens work mostly the same with Selenium as they do when simulating a browser, but there are a few key new concepts to explore.

Dropping down to the selenium-client API

Occasionally, you might want to perform an action in your Selenium scenario that has no analog in a simulated, non-JavaScript environ-

2. http://github.com/bmabey/database_cleaner
3. You can read more about the minor differences between TRUNCATE TABLE and DELETE at http://dev.mysql.com/doc/refman/5.1/en/truncate.html.

ment. For example, you might want to drag and drop a photo in a gallery or double click on a <*div*> element. One of Webrat's goals is to ensure the programmer maintains the full power of it's underlying tools, so it tries to make this as easy as possible.

Under the hood, Webrat's Selenium support is built on the selenium-client Ruby library maintained by Philippe Hanrigou. When you call a Webrat method like fill_in(), it's translated to the appropriate call on an instance of Selenium::Client::Driver. Webrat exposes this instance through the selenium() method so you can easily leverage the full selenium-client API:

```
selenium.dragdrop("id=#{dom_id(@photo1)}", "+350, 0")
```

An explanation of the full selenium-client API is outside the scope of this chapter, but there is good documentation available at http://selenium-client.rubyforge.org/.

Waiting

Each of the Webrat API methods covered in [CROSS REF] like click_link() and fill_in() work similarly in Selenium mode, but there's one additional concern intrinsic to the Selenium environment you need to watch out for: *waiting*.

When simulating a browser, everything happens in one Ruby process. A call to click_button() causes your scenario to pause while your application code processes the request before returning control to your step definition to verify the response. When using Selenium, however, Cucumber and the Rails application server run in separate processes so we have to worry about concurrency issues like race conditions.

The typical solution to this involves instructing Selenium to wait for various conditions at points where the server or browser must do some work before the scenario can proceed. Webrat tries to make this seamless by *implicitly waiting* inside each action or expectation. Here's an example of how it works from Webrat::SeleniumSession:

```
def check(label_text)
  locator = "webrat=#{label_text}"
  selenium.wait_for_element locator, :timeout_in_seconds => 5
  selenium.click locator
end
```

Selenium uses various locators to find elements on the page. Webrat waits for the element to be available in the DOM before clicking on it.

In this way, Webrat's API means you don't have to think about concurrency very much. It doesn't do any waiting until your code interacts with the page and then it waits for exactly what you're trying to manipulate.

So, with Webrat handling the waiting for you, why do you need to worry about it at all? There are three primary use cases:

- The Webrat's default timeout of five seconds is not long enough for the application code to finish. In this case, one option is to add your own explicit wait at that spot before the Webrat call:

```
When /^I agree to the Terms of Service$/ do
  selenium.wait_for_element "id=tos_checkbox", :timeout_in_seconds => 10
  check "I agree to the Terms of Service"
end
```

- You need to wait for something other than the element's presence. In this case, you can simply add an additional wait for whatever you need before the Webrat call:

```
When /^I agree to the Terms of Service$/ d
  selenium.wait_for_condition "window.Effect.Queue.size() == 0", 10
  check "I agree to the Terms of Service"
end
```

- You're not using the Webrat API. If you're using the technique described in [CROSS REF], you have to add your own waits. Webrat provides the wait_for() method to help in these situations. It takes a block:

```
wait_for(:timeout => 3) do
  selenium.dragdrop("id=#{dom_id(@photo1)}", "+350, 0")
end
```

  The wait_for() name will execute the block repeatedly until it runs without raising a Selenium, Webrat, or RSpec ExpectationNotMetError error or times out. In this way, it's a wait in the Cucumber process rather than the browser.

  You can also take a look at selenium-client's API documentation to get an idea of the features it provides for waiting inside the Web browser, which can be better for some situations.

Executing arbitrary JavaScript

Sometimes, for maximum flexibility, you might find yourself wanting to execute a snippet of JavaScript in the browser during the scenario execution. For example, I've used this technique to replace a third-party

Flash component with a fake in order to specify that our integration with it works properly.

The selenium-client library offers a get_eval() method for this:

```
When /^the Google API call returns no results$/ do
  selenium.get_eval(<<-JS)
    var currentWindow = selenium.browserbot.getCurrentWindow();
    currentWindow.onGoogleRequestComplete({});
  JS
end
```

JavaScript executed with get_eval() runs in the context of the Selenium window. To get access to the window where your application is open, we have to use the special selenium.browserbot.getCurrentWindow() call.

Specifying outcomes in Thens

Webrat's three RSpec matchers are all available in Selenium mode: contain(), have_selector() and have_xpath(). Like the methods for manipulating the application, they all implicitly wait for the expected content to appear (or disappear).

It's worth noting that in simulated mode Webrat uses the excellent libxml2 C library for XPath lookups, but in Selenium mode it leverages the browser's XPath implementation. This can vary a bit across browser versions (and, not surprisingly, is most error prone in Internet Explorer).

For situations where Webrat's API doesn't have what you're looking for, you can leverage the selenium-client API for more flexibility. It's got about a dozen methods (prefixed with "is_") that check the state of the browser and return booleans:

```
Then /^the first photo should be first in the album$/ do
  wait_for do
    selenium.is_ordered("id=#{dom_id(@photo1)}", "id=#{dom_id(@photo2)}").should be_...*TRUNC*
  end
end
```

Finally, you can use the power to execute arbitrary code in the browser to craft Thens based on anything you can access from JavaScript. For example, if our site kept track of the number of AJAX requests fired by a page in ajax.requestCounter, we could write a step definition like this:

```
Then /^three AJAX requests should have executed$/ do
  ajax_requests = selenium.get_eval(<<-JS)
    var currentWindow = selenium.browserbot.getCurrentWindow();
    currentWindow.ajax.requestCounter;
```

```
  JS
  ajax_requests.to_i.should == 3
end
```

get_eval() returns strings, so in this example we have to call to_i() on ajax_requests if you want to compare it as an integer.

22.3 Debugging Selenium issues

The highly integrated nature of Selenium-backed scenarios is a double edged sword. On one hand, it gives us the power to work with our application in an environment very similar to how it will be deployed. On the other hand, with so many layers involved, from Selenium and Firefox all the way down to the database, there's a much bigger chance that problems in your test environment itself will lead to programmers tearing their hair out while debugging failures.

Before we wrap up, we'll take a look at a few general problems you might run into and some ways to approach solutions. With any luck, we'll be able to save some of *your* hair along the way.

Server Errors

When using a simulated browser, server errors are easy to spot. The exception bubbles up, and the scenario fails immediately with a message and a backtrace. When using Selenium, however, that's a luxury we don't get out of the box.

When investigating a Selenium failure, one of the first things you should always do is verify in the Rails log that no unexpected server errors (500s or 404s) occurred. If an AJAX request triggered an exception in your application, the information you get from the Rails log will be a lot more helpful to tracking down the root cause than the timeout exception printed to your console.

Isolation Issues

Isolation issues can cause problems with any sort of automated testing process, but are particularly common in Selenium environments. They'll usually manifest themselves as scenarios that produce a different result when running on their own compared to when run as a part of a suite.

Unfortunately, there's no catch all solution here. Be aware of any state that might carry from one scenario to the next, and isolate as much

this copy is (B12.0 printing, December 3, 2009)

as you can. Use (or build) tools and abstractions that make keeping that isolation simple, like database_cleaner. If you're using data stores beyond the database (like the filesystem or Memcache), consider how they should be "cleaned" as well.

You'll also want to be careful to isolate your Selenium suite from external dependencies. If your scenarios fail when an third-party web service hiccups, it will erode your team's confidence in your build results.

One way I like to root out these sorts of issues is by running the Selenium suite with my laptop's network connection turned off. If anything behaves differently, it's a pointer to an inadvertent external dependency that has crept it.

Timing Issues

The last class of Selenium trouble spots to keep an eye out for is timing issues. Because the Rails application server is running in a separate process, it's impossible for your Cucumber step definitions to know how long it will take for anything to complete. This leads to concurrency bugs like race conditions that cause erratic results. When you run into a scenario that fails one out of ten times, this is probably the culprit.

Webrat does its best to combat this by using generous timeouts and waiting for the specific conditions it needs before continuing. If you tell Webrat to click a button, for example, it will first wait for the button to exist on the page. It's a simple technique, but Selenium does not handle it automatically, so you should consider using it whenever you access the selenium-client API directly.

Despite its best efforts, Webrat's waiting behaviour is not perfect. Webrat can only check for *existence* of an element before proceeding. While your page is loading, it might have a button in the DOM before all JavaScript events have been registered. In these cases, Webrat might see the button and proceed to click it too early. The fix will depend on the specifics of your situation, but usually involves adding additional wait statements before you call the Webrat API.

22.4 Wrapping Up

Automating a browser with Selenium is a deep topic, with a lot of tiny details. Let's take a second to review what we've just learned.

- Webrat allows you to migrate from simulated scenarios to Selenium when it becomes appropriate for your application. There's no need to worry that you'll have to rewrite all of your existing step definitions if and when that day comes.
- Running in a Selenium environment involves multiple Ruby processes, so we need to turn off the per-scenario transactions that helped ensure the database state stayed isolated. Without this convenience, we have to take steps to ensure our scenarios clean up after themselves.
- The Webrat API works with Selenium, but we're not limited to it. It's easy to drop down to the selenium-client API as needed. For maximum flexibility, selenium-client allows executing arbitrary JavaScript inside the browser window.
- The fully-integrated nature of Selenium-backed scenarios is a double edged sword. With many moving parts, the chance of obscure bugs creeping in increases. While there's no silver bullets to many of these issues, being aware of what you might run into will save you some trouble down the line.

Chapter 23

Rails Views

The user interface is subject to more change than just about any other part of an application. These changes are driven by usability concerns, design aesthetics, and evolving requirements. Clearly, this makes producing simple, flexible views desirable and beneficial, but there is more.

We use views to display data provided by models which are, in turn provided by controllers. As such, these views are clients of controllers and models. By focusing on views first, writing the code we wish we had, we are able to keep the views simple and lean on them to tell us what they need from the rest of the stack. This leads to controllers and models with targeted APIs that are well aligned with the application behaviour.

23.1 Writing View Specs

A view spec is a collection of code examples for a particular view template. Unlike examples for POROs (plain old ruby objects), view examples are inherently state-based. We provide data to the view and then set expectations about the rendered content.

In most cases, we're interested in the semantic content as it pertains to requirements of the application, as opposed to the syntactical correctness of the markup. The main exception to this is forms, in which case we do want to specify that form elements are rendered correctly within a form tag.

Now you may be thinking that we've already covered these same details with Cucumber and Webrat in the last couple of chapters, so why should we also have isolated view specs? This question is being asked quite a lot as we prepare to print this book, so you're not alone if you're asking it. We'll address this question at the end of the chapter, in Section 23.6, *When should I write view specs?*, on page 383, but that will make more sense after you get a feel for how view specs work and the benefits they provide.

Getting Started

To get started, let's generate a fresh Rails app with RSpec, rspec-rails, and Webrat installed:

```
$ rails views_example
$ cd views_example
$ sudo gem install rspec rspec-rails webrat
$ script/generate rspec
```

We're going to use the Webrat matchers that you learned about in Chapter 21, *Simulating the Browser with Webrat*, on page 326. To configure this, uncomment the following line in spec_helper.rb:

```
require 'webrat/integrations/rspec-rails'
```

That's it. That file configures everything for us, so Webrat and RSpec are ready to go.

We're going to build a view that displays a message, and we'll drive it out with a spec. Create a ./spec/views/messages/ directory and add a show.html.erb_spec.rb file with the following content:

Download rails_views/messages/01/spec/views/messages/show.html.erb_spec.rb

```
require 'spec_helper'

describe "messages/show.html.erb" do
  it "displays the text of the supplied message" do
    render
    response.should contain("Hello world!")
  end
end
```

render(), response(), and contain()

Given no arguments, the render() method on the first line in the example renders the file passed to the outermost describe() block, "messages/show.html.erb" in this case. The rendered content is stored in the response, which is passed to the Webrat contain() matcher on the second line. If the response body contains "Hello world!" the example will pass.

The script/generate rspec command we ran earlier installed a script/spec command. Use that now to run the spec:

```
script/spec spec/views/messages/show.html.erb_spec.rb
```

You should see the following failure:

```
Missing template messages/show.html.erb
```

The template doesn't exist yet, so add show.html.erb to the app/views/messages/ directory (which you'll need to create) and run the spec again.

```
expected the following element's content to include "Hello world!"
```

This time it failed because there's nothing in the show.html.erb template. Observing the practice of temporary sins to get to the green bar, add "Hello world!" to show.html.erb, run the spec again and watch it pass. Now we know that the example is correctly wired up to the view implementation.

The sin we committed was creating duplication between the spec and the implementation. Let's see what we can do about washing that away. The example says that messages/show.html.erb displays the text of the supplied message, but the implementation is simply hard coded. Based on the example, here's the code we wish we had in show.html.erb:

Download rails_views/messages/03/app/views/messages/show.html.erb

```
<%=h @message.text %>
```

Add that to the file and run the example again, and now you should see You have a nil object when you didn't expect it!, referencing the line we just added. The view expects a @message variable to be set up for it. This will be the controller's responsibility once we get there, but in this case there *is no controller yet*. This puts the responsibility on the view spec itself.

assigns()

To support this, rspec-rails provides an assigns method, which we use to provide data to the view. Modify the spec as follows:

Download rails_views/messages/03/spec/views/messages/show.html.erb_spec.rb

```
it "displays the text of the supplied message" do
  assigns[:message] = stub("Message", :text => "Hello world!")
  render
  response.should contain("Hello world!")
end
```

The new first line of the example creates a test stub which stubs the text() method with a return value of “Hello world!” and assigns it to assigns[:message]. This generates a @message instance variable for the view.[1]

Run the spec again and it should pass. And that's it for the first example. Pretty simple, right? While this example didn't do justice to the intricacies views are often composed of, it did give us just enough to start us with a foundation in which to build.

In addition to understanding the basics of a view spec, here are a few more things we can glean from what we just did:

Directory organization The directory structure for view specs mimics the directory structure found in app/views/. For example, specs found in spec/views/messages/ will be for view templates found in app/views/messages/.

File naming View specs are named after the template they provide examples for, with an _spec.rb appended to the filename. For example, index.html.erb would have a corresponding spec named index.html.erb_spec.rb.

Always require spec_helper.rb Every view spec will need to require the spec_helper.rb file. Otherwise you'll get errors about core rspec or rspec-rails methods not existing.

Describing view specs The outer describe() block in a view spec uses the path to the view minus the app/views/ portion. This is used by the render() method when it is called with no arguments, keeping things clean and DRY.

Now that you've got the basics down, let's explore a little deeper.

23.2 Mocking Models

When working outside-in we often discover the need for a model that doesn't exist yet. Rather than switch focus to the model, we can create a mock_model() and remain focused on the view we're working on.

Mock Example

Building on the messages example, we'll introduce the need for a model and continue driving the view. Following convention we learned about

1. Be sure to use assigns() *before* rendering the view!

earlier this chapter, add a spec named new.html.erb_spec.rb in the spec/views/messages/ directory with the following content:

Download rails_views/messages/03/spec/views/messages/new.html.erb_spec.rb

```
require 'spec_helper'

describe "messages/new.html.erb" do
  it "renders a form to create a message" do
    assigns[:message] = stub("Message")
    render
    response.should have_selector("form",
      :method => "post",
      :action => messages_path
    ) do |form|
      form.should have_selector("input", :type => "submit")
    end
  end
end
```

Run the spec and you should see the now familiar Missing template error. Go ahead and create a new.html.erb template in app/views/messages with the following code:

Download rails_views/messages/04/app/views/messages/new.html.erb

```
<% form_for @message do |f| %>
  <%= f.submit "Save" %>
<% end %>
```

Run the spec and now the MissingTemplate error is gone, but the spec still fails with a new error:

```
undefined method `spec_mocks_mock_path' for #<ActionView::Base:0x2216d38>
```

The form_for() method used in the view interacts with the object it's given as though it were an ActiveRecord model. We're using a stub, and it doesn't know how to respond to the different messages it gets from form_for().

We can use the mock_model() method to provide a mock object that is configured to respond in this context as though it were an ActiveRecord model. Update the before block to use mock_model() instead of stub():

Download rails_views/messages/05/spec/views/messages/new.html.erb_spec.rb

```
describe "messages/new.html.erb" do
  it "renders a form to create a message" do
    assigns[:message] = mock_model(Message)
    render
    response.should have_selector("form",
      :method => "post",
```

```
      :action => messages_path
    ) do |form|
      form.should have_selector("input", :type => "submit")
    end
  end
end
```

Running the spec results in a failure:

```
uninitialized constant Message
```

The Message class we passed to mock_model() doesn't exist yet, so we need to create it. We'll use a plain ruby class for now, and we'll add it right to the spec. We can add a real ActiveRecord model later.

Download rails_views/messages/06/spec/views/messages/new.html.erb_spec.rb

```
require 'spec_helper'

class Message; end
```

Run the spec again and you'll see this:

```
ActionView::TemplateError in 'messages/new.html.erb should \
                              render a form to create a message'
undefined method `message_path' for #<ActionView::Base:0x259278c>
```

At this point the example is failing because there is no message_path route. Go ahead and update the routes.rb file to produce the appropriate paths:

Download rails_views/messages/07/config/routes.rb

```
ActionController::Routing::Routes.draw do |map|
  map.resources :messages
end
```

The example should still be failing, but for a different reason:

```
expected following output to contain a <form method='post' action='/messages'/> tag
```

By default, mock_model produces a mock which acts like an existing record (e.g. new_record?() returns false). When form_for gets an existing record it produces a form action to *update* the record, which is not what we want. We want a form which posts to *create* a new record. We can do this by telling the mocked model to act like a new record:

Download rails_views/messages/07/spec/views/messages/new.html.erb_spec.rb

```
it "renders a form to create a message" do
  assigns[:message] = mock_model(Message).as_new_record
  render
  response.should have_selector("form",
    :method => "post",
```

```
    :action => messages_path
  ) do |form|
    form.should have_selector("input", :type => "submit")
  end
end
```

After adding as_new_record(), run the spec and you should see one example, zero failures.

Now that we've got the form working, let's add some input fields. We'll start with a text field for the message title:

Download rails_views/messages/08/spec/views/messages/new.html.erb_spec.rb

```
it "renders a text field for the message title" do
  message = mock_model(Message, :title => "the title").as_new_record
  assigns[:message] = message
  render
  response.should have_selector("form") do |form|
    form.should have_selector("input",
      :type => "text",
      :name => "message[title]",
      :value => "the title"
    )
  end
end
```

Run that, watch it fail, and then implement the view to resolve that failure:

Download rails_views/messages/09/app/views/messages/new.html.erb

```
<% form_for @message do |f| %>
  <%= f.text_field :title %>
  <%= f.submit "Save" %>
<% end %>
```

Run the spec again and this example passes, but now the first example is failing with:

```
Mock 'Message_1001' received unexpected message :title
```

RSpec's mock objects let us know when they receive messages they don't expect. In this case, the text_field() helper in the view is asking @message, the mock message, for its title attribute, but it hasn't been told to expect that request, so it raises an error.

The first example doesn't care about the message title, so we don't want to have to tell the mock to expect title(). What we *can* do is tell the mocked message to ignore any messages it's not expecting by acting as a null object. This will let us write focused examples without introducing unnecessary verbosity in other examples. Go ahead and add as_null_object():

Download rails_views/messages/10/spec/views/messages/new.html.erb_spec.rb

```
it "renders a form to create a message" do
  assigns[:message] = mock_model(Message).as_new_record.as_null_object
  render
  response.should have_selector("form",
    :method => "post",
    :action => messages_path
  ) do |form|
    form.should have_selector("input", :type => "submit")
  end
end
```

Run the spec and you should see 2 examples, 0 failures. We had red, and now we have green. Time to refactor. At this point the view implementation is pretty clean, but we do have some duplication we can remove from the two examples. Modify new.html.erb_spec.rb as follows

Download rails_views/messages/10-1/spec/views/messages/new.html.erb_spec.rb

```
require 'spec_helper'

class Message; end

describe "messages/new.html.erb" do
  before(:each) do
    assigns[:message] = mock_model(Message).as_new_record.as_null_object
  end

  it "renders a form to create a message" do
    render
    response.should have_selector("form",
      :method => "post",
      :action => messages_path
    ) do |form|
      form.should have_selector("input", :type => "submit")
    end
  end

  it "renders a text field for the message title" do
    assigns[:message].stub(:title).and_return("the title")
    render
    response.should have_selector("form") do |form|
      form.should have_selector("input",
        :type => "text",
        :name => "message[title]",
        :value => "the title"
      )
    end
```

```
  end
end
```

Because the assigns hash can be used to set and access values, we can assign a mock message to assigns[:message] in the before() block and then add a method stub to it in the second example.

Now let's specify that the form has a text area for the text of the message. We can stub text() on assigns[:message] just as we stubbed title in the previous example:

Download rails_views/messages/10-2/spec/views/messages/new.html.erb_spec.rb

```
it "renders a text area for the message text" do
  assigns[:message].stub(:text).and_return("the message")
  render
  response.should have_selector("form") do |form|
    form.should have_selector("textarea",
      :name => "message[text]",
      :content => "the message"
    )
  end
end
```

This should fail with

```
expected following output to contain a
  <textarea name='message[text]'>the message</textarea> tag;
```

Add <%= f.text_area :text %> to the view and the example should pass. Note that adding a new field to the form doesn't cause other examples to fail this time. This is because we used as_null_object() in the before() block. This will hold true for any additional fields we describe in specs later, so this one-time refactoring will have benefits throughout the development of this view.

Mock models that act as_null_object keep view specs lean and simple, allowing each example to be explicit about only the things it cares about. They also save us from unwanted side-effects being introduced in other examples.

Now let's take a closer look at mock_model.

mock_model()

The mock_model() method sets up an RSpec mock with common ActiveRecord methods stubbed out. In its most basic form mock_model can be called with a single argument: the class you want to represent as an ActiveRecord model. The class must exist, but it doesn't have to be a subclass of ActiveRecord::Base. Here are the default stubs on a mocked model:

new_record? Returns false since mocked models represent existing records by default.

id Returns an auto-generated number to represent an existing record.

to_param Returns a string version of the id.

Just like standard mocks/stubs in RSpec, additional methods can be stubbed by passing in an additional Hash argument of method name/value pairs. For example:

```
user = mock_model(User,
  :login => "zdennis",
  :email => "zdennis@example.com"
)
```

When we don't want the mock to represent an existing record, we can tell it to be a new record by sending it the as_new_record() message:

```
new_user = mock_model(User).as_new_record
```

This will change the default values stubbed by mock_model to the following:

new_record? Will return true just like a new ActiveRecord object.

id Will return nil just like a new ActiveRecord object.

to_param Will return nil just like a new ActiveRecord object.

Mock models are particularly useful when the model we need doesn't exist yet. The tradeoff is that we have to use as_null_object() to keep them quiet. Once the model exists, however, rspec-rails offers us alternative: stub_model().

stub_model

The stub_model() method is similar to mock_model() except that it creates an actual instance of the model. This requires that the model has a corresponding table in the database.

You create a stub_model just like a mock_model: the first argument is the model to instantiate, and the second argument is a Hash of method/value pairs to stub.

```
user = stub_model(User)

user = stub_model(User,
```

```
  :login => "zdennis",
  :email => "zdennis@example.com"
)
```

Similar to mock_model, a stubbed model represents an existing record by default, and we can tell it to act like a new record with as_new_record(). In fact, stub_model is a lot like mock_model, with just a couple of exceptions.

Because stub_model creates an ActiveRecord model instance, we don't need to tell it to act as_null_object() to keep it quiet when asked for its attributes. ActiveRecord will just return nil in those cases, as long as the attribute *is* defined in the schema.

The other difference is that stub_model() prohibits the model instance from accessing the database. If it receives any database related messages, like save(), or update_attributes(), it will raise an error:

```
Spec::Rails::IllegalDataAccessException: stubbed models are not allowed to \
access the database
```

This can be a good indicator that the view is doing something it shouldn't be doing, or that the method in question should really be stubbed out in the example.

Neither mock_model() and stub_model() are restricted to view specs. As you'll see later this chapter and in the following chapter on controller specs, the can be very helpful throughout the spec suite.

23.3 Working with Partials

We left off our messages example having produced a form to create a simple message. Let's add a sidebar component to display recent messages. Open up the new.html.erb_spec.rb again and add the following example:

Download rails_views/messages/11/spec/views/messages/new.html.erb_spec.rb

```ruby
it "renders recent messages" do
  assigns[:recent_messages] = [
    mock_model(Message, :text => "Message 1").as_null_object,
    mock_model(Message, :text => "Message 2").as_null_object
  ]
  render
  response.should have_selector(".recent_messages") do |sidebar|
    sidebar.should have_selector(".message", :content => "Message 1")
    sidebar.should have_selector(".message", :content => "Message 2")
  end
```

```
end
```

This new example fails with expected following output to contain a <.recent_messages/> tag. Let's modify the view to get it to pass:

Download rails_views/messages/11/app/views/messages/new.html.erb

```
<div class="sidebar">
  <ul class="recent_messages">
    <% @recent_messages.each do |message| %>
      <li class="message"><%=h message.text %></li>
    <% end %>
  </ul>
</div>

<% form_for @message do |f| %>
  <%= f.text_field :title %>
  <%= f.text_area :text %>
  <%= f.submit "Save" %>
<% end %>
```

Now run the spec and the new example passes, but the first three are all failing because the view now depends on a :recent_messages key in the assigns hash that is only being set up by the new example. Even though the other examples aren't interested in :recent_messages, they still have to supply it for the view to render properly.

Because the other examples don't care what's in assigns[:recent_messages], however, we can just supply an empty array in the before(:each) block:

Download rails_views/messages/11/spec/views/messages/new.html.erb_spec.rb

```
before(:each) do
  assigns[:message] = mock_model(Message).as_new_record.as_null_object
  assigns[:recent_messages] = []
end
```

Now all four examples should be passing.

Semantics vs Syntax

Notice that we added a *sidebar* container on the page, but it's not referenced in the spec. The spec does reference elements with the classes recent_messages and message, but it does not specify that those elements should be ul and li, or that the ul is inside a div.

While we care about the semantic details, we do *not* care about syntactic detail. This distinction is not always black and white. For example, we care that the messages are inside a recent_messages container, and that has both semantic and syntactic implications.

Semantic HTML and view specs complement each other. They both provide meaning about what's being displayed beyond the basics of the markup. Even if the presentation of the recent messages changes, as long as they each use the message class, and continue to live inside an element with the recent_messages class, we can rest assured that they are still being displayed. This adds to the flexibility of the view and its spec.

Extracting Partials for Organization

Now that we've got a sidebar, let's move it out into its own partial. Not for re-use at this point, but just for organization.

Create an app/views/messages/_sidebar.html.erb template and move the sidebar container to reside in that partial. Be sure to modify the code in the partial _sidebar.html.erb partial to rely on a recent_messages method rather than on an instance variable.

Download rails_views/messages/12/app/views/messages/_sidebar.html.erb

```
<div class="sidebar">
  <ul class="recent_messages">
    <% recent_messages.each do |message| %>
      <li class="message"><%=h message.text %></li>
    <% end %>
  </ul>
</div>
```

Now update the new.html.erb template to render the sidebar partial, passing in the appropriate locals:

Download rails_views/messages/12/app/views/messages/new.html.erb

```
<%= render :partial => "sidebar",
           :locals => { :recent_messages => @recent_messages } %>

<% form_for @message do |f| %>
  <%= f.text_field :title %>
  <%= f.text_area :text %>
  <%= f.submit "Save" %>
<% end %>
```

Run the spec again—four examples, zero failures.

At this point we *could* reorganize the specs to reflect the new structure but, because the new partial has one client, we wouldn't get much benefit from doing so in this case. As you'll soon see, however, there are cases in which we can benefit from specs that describe partials in isolation.

Extracting Partials for Re-use

At this point the new page has a form to create a message and it has a sidebar to display recent messages. But how often is there a new page without a corresponding edit page? Not that often. We need a way to allow users to edit their messages. Who else is going to fix those typos?

We're going to extract the form for re-use, which is exactly like extracting the sidebar for organization, except that we'll also extract the form's spec from new.html.erb_spec.rb.

Start by creating app/views/messages/_form.html.erb, copying over the form from app/views/messages/new.html.erb, and rendering the _form partial from the new template:

Download rails_views/messages/14/app/views/messages/new.html.erb

```
<%= render :partial => "sidebar",
           :locals => { :recent_messages => @recent_messages } %>

<%= render :partial => "form",
           :locals => { :message => @message } %>
```

Download rails_views/messages/14/app/views/messages/_form.html.erb

```
<% form_for message do |f| %>
  <%= f.text_field :title %>
  <%= f.text_area :text %>
  <%= f.submit "Save" %>
<% end %>
```

Be sure to update the call to form_for() to utilize the message variable passed in from the locals rather than relying on the @message instance variable. Now run spec/views/messages/new.html.erb_spec.rb and it should still be passing.

Next, create spec/views/messages/_form.html.erb_spec.rb and copy over all the three form-related examples from spec/views/messages/new.html.erb_spec.rb. You'll need to modify them to render the partial instead of the new template, and pass in the appropriate locals:

Download rails_views/messages/14/spec/views/messages/_form.html.erb_spec.rb

```
require 'spec_helper'

describe "messages/_form.html.erb" do
  before(:each) do
    @message = mock_model(Message).as_new_record.as_null_object
  end

  it "renders a form to create a message" do
    render :locals => { :message => @message }
```

```
    response.should have_selector("form",
      :method => "post",
      :action => messages_path
    ) do |form|
      form.should have_selector("input", :type => "submit")
    end
  end

  it "renders a text field for the message title" do
    @message.stub(:title).and_return("the title")
    render :locals => { :message => @message }
    response.should have_selector("form") do |form|
      form.should have_selector("input",
        :type => "text",
        :name => "message[title]",
        :value => "the title"
      )
    end
  end

  it "renders a text area for the message text" do
    @message.stub(:text).and_return("the message")
    render :locals => { :message => @message }
    response.should have_selector("form") do |form|
      form.should have_selector("textarea",
        :name => "message[text]",
        :content => "the message"
      )
    end
  end
end
```

We're using @message here instead of assigns[:message] because we're specifying that the form renders the message from the locals hash, not assigns.

Once you see that passing, add an example to new.html.erb_spec.rb to specify that it renders the _form partial:

Download rails_views/messages/14/spec/views/messages/new.html.erb_spec.rb

```
before(:each) do
  assigns[:message] = mock_model(Message).as_null_object
  assigns[:recent_messages] = []
end

it "renders the messages/form" do
  template.should_receive(:render).with(
    :partial => "form",
    :locals => { :message => assigns[:message] }
  )
  render
```

```
end
```

If you run new.html.erb_spec.rb now, you'll see four passing examples, including the three we just copied to the _form spec. Because those same examples are passing in the _form spec, we can safely remove them from the new spec.

Getting back to the _form partial, for it to be usable for both the new and edit templates it's going to have to get a bit smarter. It's going to need to render the form's action attribute to point to the messages_path() for a new record and the message_path(@message) for an existing record.

The first example in the _form spec already specifies how the form should be rendered for a new record, so we just need to add a new example to specify how it handles an existing record. Start by moving the call to as_new_record() from the before block to the example, and then wrapping the example in a context block as follows:

Download rails_views/messages/15/spec/views/messages/_form.html.erb_spec.rb

```
before(:each) do
  @message = mock_model(Message).as_null_object
end

context "when the message is a new record" do
  it "renders a form to create a message" do
    render :locals => { :message => @message.as_new_record }
    response.should have_selector("form",
      :method => "post",
      :action => messages_path
    ) do |form|
      form.should have_selector("input", :type => "submit")
    end
  end
end
```

Run that and you should see 3 examples, 0 failures. Now add a new example specifying an existing record:

Download rails_views/messages/15/spec/views/messages/_form.html.erb_spec.rb

```
context "when the message is an existing record" do
  it "renders a form to update a message" do
    render :locals => { :message => @message }
    response.should have_selector("form",
      :method => "post",
      :action => message_path(@message)
    ) do |form|
      form.should have_selector("input", :type => "submit")
    end
  end
```

```
end
```

Run that and you should see 4 examples, 0 failures. The new example passed right away because the edit template uses the Rails form_for() method, which implicitly renders the correct form tags for new records and existing records based on the record!

Now that we're done refactoring, we can go back into spec-driving mode and add an example that expects the edit template to render the form partial. Go ahead and create a spec for edit with the following example:

Download rails_views/messages/15/spec/views/messages/edit.html.erb_spec.rb

```
describe "messages/edit.html.erb" do
  before(:each) do
    assigns[:message] = mock_model(Message).as_null_object
  end

  it "renders the messages/form partial" do
    template.should_receive(:render).with(
      :partial => "form",
      :locals => { :message => assigns[:message] }
    )
    render
  end
end
```

Run that spec, watch it fail, and add a edit.html.erb template that renders the partial:

Download rails_views/messages/15/app/views/messages/edit.html.erb

```
<%= render :partial => "form", :locals => { :message => @message } %>
```

Run the spec again and, voila! We're back to green.

This time we extracted a partial with the goal of re-use, not just to organize the application code. By extracting a partial with its own spec, any changes to requirements for this form will only impact this one spec and the form itself. This helps keep views and their specs very easy to maintain.

Speaking of maintaining specs, let's look at a few techniques for managing specs as they grow and repetitive patterns emerge.

23.4 Refactoring Code Examples

Over time, patterns emerge and take shape in view specs. They range from single statement patterns, like expecting similar content in different specs, to completely duplicated examples. RSpec supports two techniques for removing this sort of duplication: shared examples and custom matchers.[2]

Shared Examples

View specs may be the sweet spot for shared examples in Rails apps since the examples are easily isolated from one another and there's no need to share state across examples. You can simply override the expected assigns, or pass in the appropriate options to render().

In the last section, we extracted a form partial from the new page so we could re-use it in the edit page. At the end of the process we had duplicated examples in new.html.erb_spec.rb and edit.html.erb_spec.rb specifying that each template renders the form partial. We can remove this duplication by using a shared example group to consolidate the example to one location with a good description.

Create a spec/support/shared_examples.rb file with the following shared example:

Download rails_views/messages/16/spec/support/shared_examples.rb

```
shared_examples_for "a template that renders the messages/form partial" do
  it "renders the messages/form partial" do
    template.should_receive(:render).with(
      :partial => "form",
      :locals => { :message => assigns[:message] }
    )
    render
  end
end
```

Now update new.html.erb_spec.rb to utilize the shared example. Add the following line to the spec:

Download rails_views/messages/16/spec/views/messages/new.html.erb_spec.rb

```
it_should_behave_like "a template that renders the messages/form partial"
```

Run the spec again—three examples, zero failures. Let's do a quick sanity check to make sure it's doing what we expect. Open the new template and remove the form. Now run the spec again—it should fail. Go ahead and put the form back in place, run the spec again, and watch

2. See Section 17.3, *Custom Matchers*, on page 290 and Section 12.5, *Sharing Examples in a Module*, on page 196.

it pass. Now we can be confident our shared example is doing what we expect.

With the shared example working let's remove the original example which specified that the form partial gets rendered. The new.html.erb_spec.rb should look like:

Download rails_views/messages/17/spec/views/messages/new.html.erb_spec.rb

```
require 'spec_helper'

describe "messages/new.html.erb" do
  before(:each) do
    assigns[:message] = mock_model(Message).as_null_object.as_new_record
    assigns[:recent_messages] = []
  end

  it_should_behave_like "a template that renders the messages/form partial"

  it "renders recent messages" do
    assigns[:recent_messages] = [
      mock_model(Message, :text => "Message 1").as_null_object,
      mock_model(Message, :text => "Message 2").as_null_object
    ]
    render
    response.should have_selector(".recent_messages") do |sidebar|
      sidebar.should have_selector(".message", :content => "Message 1")
      sidebar.should have_selector(".message", :content => "Message 2")
    end
  end
end
```

For practice, make the same change to edit.html.erb_spec.rb. Then let's explore writing custom matchers.

Custom Matchers

As an application grows, we find ourselves expecting similar content in many view specs. We see the same links, form fields, custom HTML components, and even convention-based markup. For these cases, we can write custom matchers to reduce duplication and produce more expressive examples.

Consider a project which utilizes a convention for using anchor tags and CSS to produce visually stunning buttons used throughout the app. We might end up with a number of examples that look like this:

Download rails_views/messages/17/spec/views/buttons.html.erb_spec.rb

```
it "has a button to create a message" do
  render
```

```
  response.should have_selector("a.button", :href => messages_path)
end
```

We can improve on that by pulling out the pattern into a custom matcher method. Then we don't duplicate the effort of having to remember the appropriate CSS selector each time we use a button. Here's our new matcher, which simply decorates a call to Webrat's have_selector matcher:

Download rails_views/messages/17/spec/support/matchers.rb

```
Spec::Matchers.define :have_button do |href|
  match do |response|
    extend Webrat::Matchers
    response.should have_selector("a.button", :href => href)
  end
end
```

Now our examples can be slightly improved:

Download rails_views/messages/17/spec/views/buttons.html.erb_spec.rb

```
it "has a button to create a message" do
  render
  response.should have_button(messages_path)
end
```

This example is a little win. It increases the clarity of each example that expects a button. If the convention changes, we've isolated that change to one place—the have_button() method.

23.5 Specifying Helpers

Rails helpers keep model transformations, markup generation, and other sorts of view logic cleanly separated from erb templates. This makes templates clean and maintainable, and makes it easier to reuse little display nuggets that have a habit of reappearing throughout our applications.

Consider the common problem of displaying parts of a view only to administrators. One nice solution is to use a block helper, like this:

```
<%- display_for(:admin) do -%>
  Only admins should see this
<%- end -%>
```

The rspec-rails plugin provides a specialized ExampleGroup for specifying helpers in isolation. To see this in action, create a spec/helpers/roles.rb file. Assuming that views have access to a current_user() method, here's an example for the case in which the current_user is in the given role:

Download rails_views/messages/18/spec/helpers/application_helper_spec.rb

```
require 'spec_helper'

describe ApplicationHelper do
  describe "#display_for(:role)" do
    context "when the current user has the role" do
      it "displays the content" do
        user = stub('User', :in_role? => true)
        helper.stub(:current_user).and_return(user)
        content = helper.display_for(:existing_role) {"content"}
        content.should == "content"
      end
    end
  end
end
```

The helper() method returns an object that includes the helper module passed to describe(). In this case, that's the ApplicationHelper. If you run that spec now you should it fail with:

```
undefined method `display_for'
```

Here's the implementation that gets this to pass:

Download rails_views/messages/18/app/helpers/application_helper.rb

```
module ApplicationHelper
  def display_for(role)
    yield
  end
end
```

Now add another example for the negative case:

Download rails_views/messages/19/spec/helpers/application_helper_spec.rb

```
context "when the current user does not have the role" do
  it "does not display the content" do
    user = stub('User', :in_role? => false)
    helper.stub(:current_user).and_return(user)
    content = helper.display_for(:existing_role) {"content"}
    content.should == nil
  end
end
```

And here's the modified display_for() method that passes both examples:

Download rails_views/messages/19/app/helpers/application_helper.rb

```
def display_for(role)
  yield if current_user.in_role?(role)
end
```

As you can see, helper specs make it easy to drive out presentation logic in granular, reusable chunks.

So now that we know how to write view and helper specs, let's explore the question we posed at the beginning of the chapter.

23.6 When should I write view specs?

While we've been working on this book, the BDD toolset has been evolving at lightning speed. With the increasing capability of Cucumber + Webrat, the overlap between Cucumber step definitions and view specs increases as well, as the boundaries of what belongs where become more and more gray.

So how can you know whether view specs make sense for you and your project? Here are a few questions you can ask yourself to help make that decision.

Are you using Cucumber and Webrat? If you're not using Cucumber and Webrat, then view specs are going to provide a lot of value you're probably not getting otherwise.

Will a Cucumber failure give me the right message? Sometimes the failure message we get from Cucumber points us directly to a clean point of failure. A missing template error, for example, is very specific. When the messsage doesn't tell us exactly what we need to do next, however, that's a good case for a view spec.

Is there any functionality beyond basic CRUD actions/views? View specs provide us an opportunity to discover APIs that we need from the controllers and models. This is not that valuable when the APIs are following the most standard conventions. The value increases, however, as we stray from them.

In general, our recommendation is to err on the side of too many view specs rather than too few. The only way to really get a feel for the benefits of them is to learn to write them well. And only once you really understand how they fit in the flow are you going to be able to make well grounded decisions about if and when to use them.

23.7 What We Just Learned

User Interface changes more often than just about anything else in an application. View specs help us to specify the details that should remain stable through markup changes, and help to discover the requirements of of other components further down the stack. In this chapter, we discussed these facts as well as:

- Specifying syntactic detail makes code examples brittle. We want to specify view semantics without getting bogged down in syntactic detail.
- View specs use a custom example group provided by the rspec-rails library.
- View specs live in a directory tree parallel to the views themselves, and follow a naming convention of spec/path/to/view.html.erb_spec.rb for app/path/to/view.html.erb.
- Use Webrat's have_xpath() and have_selector() matchers for view specs.
- Use mock_model() and stub_model() to isolate view specs from the database and underlying business logic of your models.
- Partials can have their own view specs.
- Helpers have their own specs that live in the spec/helpers directory.
- Extract shared examples and custom matchers to help keep view specs DRY.

As we mentioned earlier, view specs help us to identify the instance variables that our controllers will need to supply. In the next chapter, we'll take a look at specifying controllers in isolation from views, and models.

Rails' controllers are like waiters in a restaurant. A customer orders a steak dinner from a waiter. The waiter takes the request and tells the kitchen that he needs a steak dinner. When the steak dinner is ready the waiter delivers it the customer for her enjoyment.

► Craig Demyanovich

Chapter 24

Rails Controllers

The restaurant metaphor does a great job describing the role of controllers in a Rails application. Just as a waiter need not know how to prepare a steak dinner, a controller doesn't need to know the details of building a model. Keeping these details out of the controller provides a natural separation of concerns between the controller and the model, which makes the models easier to change, extend, and re-use.

This chapter will show you how to develop controllers outside-in using controller specs as the driving force.

24.1 Controller Specs

A controller spec is a collection of examples of the expected behaviour of actions on a single controller. Whereas views are inherently state-based, controllers are naturally interaction-based. They wait at the edges of a Rails app to mediate interaction between models and views, given an incoming request. We therefore set expectations about interactions, process the action, and look at assigned instance variables and flash messages made available for the view.

By default, controller specs don't render views.[1] Combine that fact with judicious use of mocks and stubs for interaction with the model, and now we can specify controller interactions in complete isolation from the other components. This pushes us to build skinny controllers and helps us to discover objects with well named methods to encapsulate the real work.

1. You can tell controller specs to render views with the integrate_views() method.

A simple guideline for a controller is that it should know *what* to do, but not *how* to do it. Controllers that know too much about the *how* become responsible for too many things and as a result become bloated, messy, and hard to understand. This will become clear as we work through an example.

We'll use the same Rails app that we used in the last chapter.

A Worked Example

In the last chapter we built up the view which contained the form to create a message. Now we're going to develop a controller action responsible for processing that form submission and creating the message. Start by creating a spec/controllers/ directory with a messages_controller_spec.rb file with the following content:

Download rails_controllers/messages/01/spec/controllers/messages_controller_spec.rb

```
Line 1 require 'spec_helper'
     2
     3 describe MessagesController, "POST create" do
     4
     5   it "creates a new message"
     6
     7   it "saves the message"
     8
     9 end
```

You read about three approaches to generating pending examples in Section 12.2, *Pending Examples*, on page 187. The examples on lines 5 and 7 are *pending* because they have no blocks.

Run the spec and you should see *uninitialized constant MessagesController* due to the reference on line 3 to a non-existent MessagesController. Controller specs require that the class being spec'd is actually a subclass of ActionController::Base, so create that class in app/controllers/messages_controller.rb:

Download rails_controllers/messages/02/app/controllers/messages_controller.rb

```
class MessagesController < ApplicationController
end
```

Now run the spec again, and now the output should tell you that there are 2 examples, 0 failures, 2 pending.

The first pending example specifies that the create() action builds a new message, so let's add a block that sets that expectation.

Download rails_controllers/messages/03/spec/controllers/messages_controller_spec.rb

```
it "creates a new message" do
```

Joe Asks...

Isn't Message.should_receive(:new) implementation?

At some level, yes it is, but it's not the same as specifying internal implementation details that only occur within the object being spec'd. We're specifying the interaction with other objects in order to isolate this example from anything that might go wrong, or does not yet exist in the other objects. That way when a controller spec fails, you know that it's because the controller is not behaving correctly and can quickly diagnose the problem.

One of the motivations for this approach in Rails controller specs is that we don't have to worry about changes to model validation rules causing failures in controller specs. Rails fixtures can also help solve that problem if you use them judiciously. Test data builders like Fixjour, Factory Girl, Object Daddy and Machinist can also help. But fixtures and Test Data Builders all use a database, which slows down the specs, even if they maintain rapid fault isolation.

```
  Message.should_receive(:new).with("text" => "a quick brown fox")
  post :create, :message => { "text" => "a quick brown fox" }
end
```

This fails with No action responded to create, so add the create action now, implementing just enough code to pass this example:

Download rails_controllers/messages/03/app/controllers/messages_controller.rb

```
def create
  Message.new(params[:message])
end
```

The spec output should say 2 examples, 0 failures, 1 pending. Moving right along, the second example specifies that the controller saves the message. Again, add a block to express the expectation:

Download rails_controllers/messages/03/spec/controllers/messages_controller_spec.rb

```
it "saves the message" do
  message = mock_model(Message)
  Message.stub(:new).and_return message
  message.should_receive(:save)
  post :create
```


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```
end
```

The example should fail with the following message:

```
Mock 'Message_1001' expected :save with (any args) once, but received it 0 times
```

To get this to pass all we need to do is call save() on the message:

Download rails_controllers/messages/04/app/controllers/messages_controller.rb

```
def create
  message = Message.new(params[:message])
  message.save
end
```

Run the spec again and you'll see the second example is now passing, but we broke the first example in the process: 2 examples, 1 failure. There is no message object in the first example, and there needs to be one for the code in the action to run.

We can get the first example to pass without impacting the second example by introducing a mock message:

Download rails_controllers/messages/04/spec/contr . . . rs/messages_controller_refactor1_spec.rb

```
Line 1  it "creates a new message" do
     2    message = mock_model(Message, :save => nil)
     3    Message.should_receive(:new).
     4      with("text" => "a quick brown fox").
     5      and_return(message)
     6    post :create, :message => { "text" => "a quick brown fox" }
     7  end
```

Here we create a mock message on line 2 and tell the Message class to return it in response to new() on line 5.

Run the examples and you'll see 2 examples, 0 failures.

We've made progress, but we've also introduced some duplication between the two examples. We can clean that up by extracting out the common bits to a before(:each) block:

Download rails_controllers/messages/04/spec/contr . . . rs/messages_controller_refactor2_spec.rb

```
describe MessagesController, "POST create" do

  before(:each) do
    @message = mock_model(Message, :save => nil)
    Message.stub(:new).and_return(@message)
  end

  it "creates a new message" do
    Message.should_receive(:new).
```

```
      with("text" => "a quick brown fox").
      and_return(@message)
    post :create, :message => { "text" => "a quick brown fox" }
  end

  it "saves the message" do
    @message.should_receive(:save)
    post :create
  end

end
```

The spec should still have 2 examples, 0 failures.

Adding context specific examples

Our spec isn't done though. Controllers typically do different things depending on whether or not the work they delegate succeeds or fails. Let's start with the *happy path* case and specify what should happen when the save() succeeds. Add these pending examples after the second example:

Download rails_controllers/messages/05/spec/controllers/messages_controller_spec.rb

```
context "when the message saves successfully" do
  before(:each) do
    @message.stub(:save).and_return(true)
  end

  it "sets a flash[:notice] message"

  it "redirects to the messages index"
end
```

The context() method is an alias for describe(). We use it in specs to make a distinction between the thing we're describing and the context in which some event is taking place. In this case, we're describing the create() action on the MessagesController in the context of a successful save.

By convention, though not enforced programatically, we express the same *given* in a before() block within the context block. In this case, we'll stub the save() method, telling it to return true. This is Rails' way of indicating that the save() succeeded.

Let's fill in the code for the first example:

Download rails_controllers/messages/05/spec/controllers/messages_controller_flash_spec.rb

```
it "sets a flash[:notice] message" do
  post :create
```

```
  flash[:notice].should == "The message was saved successfully."
end
```

That example fails because the flash[:notice] is nil. Let's update the create action:

Download rails_controllers/messages/06/app/controllers/messages_controller.rb

```
def create
  message = Message.new(params[:message])
  if message.save
    flash[:notice] = "The message was saved successfully."
  end
end
```

That example should be passing now, so let's move on to the next example:

Download rails_controllers/messages/06/spec/contr . . . ers/messages_controller_redirect_spec.rb

```
it "redirects to the messages index" do
  post :create
  response.should redirect_to(messages_path)
end
```

This example fails with expected redirect to "/messages", got no redirect. Add the redirect to get it to pass:

Download rails_controllers/messages/07/app/controllers/messages_controller.rb

```
def create
  message = Message.new(params[:message])
  if message.save
    flash[:notice] = "The message was saved successfully."
    redirect_to messages_path
  end
end
```

Now that both happy path examples are passing, we can move on to the case of an unsuccessful save. Add a new context to the spec:

Download rails_controllers/messages/07/spec/contr . . . lers/messages_controller_failure_spec.rb

```
context "when the message fails to save" do
  before(:each) do
    @message.stub(:save).and_return(false)
  end

  it "assigns @message"

  it "renders the new template"
end
```

Just like we did before, we express the context in a before() block, but this time we tell the save() to return false, indicating that the save() failed.

Run the spec and you should see 6 examples, 0 failures, 2 pending. Let's fill in the first pending example:

Download rails_controllers/messages/07/spec/contr . . . llers/messages_controller_assign_spec.rb

```
it "assigns @message" do
  post :create
  assigns[:message].should == @message
end
```

The assigns() method returns a hash representing instance variables that were assigned to the view by the controller. The example fails saying it expected a Message object, but got nil. Let's update the action to make it pass:

Download rails_controllers/messages/08/app/controllers/messages_controller.rb

```
def create
  @message = Message.new(params[:message])
  if @message.save
    flash[:notice] = "The message was saved successfully."
    redirect_to messages_path
  end
end
```

6 examples, 0 failures, 1 pending. Now let's fill out the last example:

Download rails_controllers/messages/08/spec/contr . . . sages_controller_render_template_spec.rb

```
it "renders the new template" do
  post :create
  response.should render_template("new")
end
```

This example fails with expected "new", got "messages/create". We can get this to pass by rendering the new action. Let's update the create action:

Download rails_controllers/messages/09/app/controllers/messages_controller.rb

```
def create
  @message = Message.new(params[:message])
  if @message.save
    flash[:notice] = "The message was saved successfully."
    redirect_to messages_path
  else
    render :action => "new"
  end
end
```

6 examples, 0 failures (none pending)! Now we've got a fully implemented controller action. While it's fresh in our heads let's reflect on the spec and the action.

What we just did

The create() action we just implemented is typical in Rails apps. The controller passes the params it receives to the model, delegating the real work. By specifying the interactions with the model instead of the result of the model's work, we are able to keep the spec and the implementation simple and readable.

This is what it means to have a controller know *what* to do without knowing the details of *how* to do it. Any complexity related to building a message will be specified and implemented in the Message model.

The spec we used to drive this action into existence can be used to illustrate some basic conventions we like to follow for controller specs:

Directory organization The directory structure for controller specs parallels the directory structure found in app/controllers/.

File naming Each controller spec is named after the controller it provides examples for, with _spec.rb appended to the filename. For example, sessions_controller_spec.rb contains the specs for sessions_controller.rb.

Always require spec_helper.rb Each controller spec should require the spec_helper.rb file, which sets up the environment with all the right example group classes and utility methods.

Example group names The docstring passed to the outer-most describe() block in a controller spec typically includes the type of request and the action the examples are for.

While driving out the create() action we focused on one example at a time. Once each example passed, we looked for and extracted any duplication to a before block, allowing each example to stay focused, clear, and DRY. And when we found examples that pertained to a given context, we used context blocks with clear descriptions to organize them.

This spec also introduced a number of methods which provide a good foundation for writing controller specs. Many of these methods come directly from ActionController::TestCase, which Rails uses for functional tests. Let's look a closer at each of the methods we used.

assigns()

We use the assigns() method to specify the instance variables we expect to be assigned in the view. It takes a single argument—a symbol that indicates the name of the instance variable.

Note that the assigns() method available in controller specs is different from the one available in view specs. In view specs assigns() is used to set instance variables for a view *before rendering the view*. In controller specs we use assigns() to set expectations about instance variables assigned for the view *after calling the controller action*.

flash()

We use the flash() method to specify messages we expect to be stored in the flash hash. It uses the same API to access flash in the spec as you would use in the controller, which makes it convenient and easy to remember when working with flash.

post()

We use the post() method to simulate a POST request. It can take three arguments. The first argument is the name of the action to call. The second argument (optional) is a hash of key/value pairs to make up the params. The third argument (also optional) is a hash of key/value pairs that make up the session hash for the controller.

```
# no params or session data
post :create

# with params
post :create, :id => 2

# with params and session data
post :create, { :id => 2 }, { :user_id => 99 }
```

The post() method comes directly from ActionController::TestCase, which offers similar methods for get, put, delete, head and even xml_http_request requests. All but the xml_http_request and its alias, xhr, have the same signature as the post() method.

The xml_http_request() and xhr() methods introduce one additional argument to the front: the type of request to make. Then the other arguments are just shifted over. For example:

```
# no params or session data
xhr :get, :index

# with params
```

Isolation and Integration Modes

Controller specs use a specialized example group, which can run in either of two modes: isolation and integration. These both really refer to isolation from or integration with view rendering.

In isolation mode, the default, views are never actually rendered. If we stub out the model layer as well, we can drive out controllers in complete isolation from views, models, and the database. This keeps the controller specs lean and reduces the noise involved with managing a web of dependencies in the view or the model. It also provides quick fault isolation. You'll always know that a failing controller spec means that the controller is not behaving correctly.

The view templates do not need to exist in isolation mode. They can also be empty, or broken, and the controller specs will pass as long as the controller is doing its job.

If you're more comfortable with the views being rendered, you can use the Integration mode, which allows the controller to render views. Just tell the example group to integrate views with the integrate_views() method:

```
describe MessagesController do
  integrate_views
  ...
```

In this mode, controller specs are like Rails functional tests—one set of examples for both controllers and views. The benefit of this approach is that you get wider coverage from each spec. Experienced Rails developers may find this an easier approach to begin with, however we encourage you to explore using the isolation mode and revel in its benefits.

```
xhr :get, :show, :id => 2

# with params and session data
xhr :get, :show, { :id => 2 }, { :user_id => 99 }
```

render_template()

We use the render_template() method to specify the template we expect a controller action to render. It takes a single argument—the path to the template that we are rendering.

The path argument can be in any of three forms. The first is the path to the template minus the app/views/ portion:

```
response.should render_template("messages/new")
```

The second is a short hand form of the first. If the template being rendered is a part of the controller being spec'd you can pass in just the template name:

```
# this will expand to "messages/new" in a MessagesController spec
response.should render_template("new")
```

The third approach is to specify the full filename of the template to be rendered including the filename extension. This lets us specify that the controller should pick a template in the same way it does when the app runs. For example, we can set an expectation that the controller will find and render the messages/new.js.erb template when making a request for JavaScript:

```
# controller action
def new
  respond_to :js, :html
end

# in the spec
get :new, :format => "js"
response.should render_template("new.js.erb")
```

redirect_to()

We use the redirect_to() method to specify that the action should redirect to a pre-defined location. It has the same API as its Rails' counterpart, assert_redirected_to().

```
# relying on route helpers
response.should redirect_to(messages_path)

# relying on ActiveRecord conventions
response.should redirect_to(@message)

# being specific
response.should redirect_to(:controller => "messages", :action => "new")
```

24.2 Application Controller

We typically specify controller behaviour directly through controller actions, but sometimes we want behaviour applied to every controller and invoked indirectly. Perhaps we want to log every incoming request, or add application wide error handling. We don't want to specify this over and over again on every action, so let's explore a technique that allows us to specify these sorts of behaviours just once.

Let's add uniform error handling for AccessDenied exceptions. We'll start by creating spec/controllers/application_controller_spec.rb with the following content:

Download rails_controllers/messages/15/spec/controllers/application_controller2_spec.rb

```
require 'spec_helper'

describe ApplicationController, "handling AccessDenied exceptions" do

  it "redirects to the /401.html (access denied) page" do
    get :index
    response.should redirect_to('/401.html')
  end

end
```

This should fail with

```
No route matches {:action=>"index", :controller=>"application"}
```

In most controller specs we write examples for controllers used directly in the app. Here we are going to specify behaviour of every controller's superclass, ApplicationController, which isn't exposed to the app.

One common approach is to create a controller right in the spec. In this case we need an index action, so we'll add that to the controller, programming it to raise the AccessDenied error that we're expecting in the example.

Download rails_controllers/messages/15/spec/controllers/application_controller3_spec.rb

```
describe ApplicationController, "handling AccessDenied exceptions" do
▶   class FooController < ApplicationController
▶     def index
▶       raise AccessDenied
▶     end
▶   end

  it "redirects to the /401.html (access denied) page" do
    get :index
    response.should redirect_to('/401.html')
  end
end
```

We're still getting No route matches {:action=>"index", :controller=>"application"}. It's trying to call index() on ApplicationController, but we want to call it on FooController instead. We can use the controller_name() method to tell the examples to do just that:

Download rails_controllers/messages/15/spec/controllers/application_controller4_spec.rb

```
describe ApplicationController, "handling AccessDenied exceptions" do
  class FooController < ApplicationController
    def index
      raise AccessDenied
    end
  end
  controller_name 'foo'

  it "redirects to the /401.html (access denied) page" do
    get :index
    response.should redirect_to('/401.html')
  end
end
```

Now we get No route matches {:action=>"index", :controller=>"foo"}. Progress. This is similar to the failure we got before, but now it is trying to hit the index action on the FooController and there is no route to the FooController. Now we don't want a FooController in the application, so we don't want to add this to routes.rb either, so we'll add the mapping right in the spec, like this:

Download rails_controllers/messages/15/spec/controllers/application_controller5_spec.rb

```
describe ApplicationController, "handling AccessDenied exceptions" do
  class FooController < ApplicationController
    def index
      raise AccessDenied
    end
  end
  controller_name 'foo'

  before(:each) do
    ActionController::Routing::Routes.draw do |map|
      map.resources :foo
    end
  end

  it "redirects to the /401.html (access denied) page" do
    get :index
    response.should redirect_to('/401.html')
  end
end
```

Now it fails with uninitialized constant ApplicationController::AccessDenied. We can get past this by adding an AccessDenied exception. Add it in lib/access_denied.rb:

Download rails_controllers/messages/16/lib/access_denied.rb

```
class AccessDenied < StandardError
end
```

Now the spec fails with AccessDenied, which is the logical failure we want. All that's left to do is to rescue from the AccessDenied error and redirect to "/401.html" in ApplicationController:

Download rails_controllers/messages/17/app/controllers/application.rb

```
class ApplicationController < ActionController::Base

  rescue_from AccessDenied, :with => :access_denied

protected

  def access_denied
    redirect_to "/401.html"
  end

end
```

Success! We now have 1 example, 0 failures. There is, however, one more thing we need to do before we leave this example. The routes we added for the FooController are global state, and any time we set any sort of global state in an example, it's our responsibility to clean up after ourselves! All we need to do is add a after(:each) block which reloads the routes:

Download rails_controllers/messages/17/spec/controllers/application_controller2_spec.rb

```
after(:each) do
  ActionController::Routing::Routes.reload!
end
```

The spec should still be at 1 example, 0 failures, and now we're not polluting the routes with references to FooController.

24.3 FAQ

Controllers are the lynchpins of every interaction between a user and a Rails application. As such, they present a wide array of technical problems to solve. And before we can solve a problem, we first have to ask how we can spec it!

While a complete survey of scenarios we come across with controllers is beyond the scope of this book, we're going to take a look at a few of the more common ones.

this copy is (B12.0 printing, December 3, 2009)

How do I spec file uploads?

From the controller's perspective, an uploaded file is just another parameter that gets passed through to a model. And since uploading files involve integrating controllers, models, the database, and even the file system, we encourage you to rely on Cucumber and Webrat to provide that level of integration.

It is possible, however, to utilize a controller spec to provide the necessary integration to spec file uploads. Rails' provides an ActionController::TestUploadedFile class which can be used to represent an uploaded file in the params hash of a controller spec, like this:

```
describe UsersController, "POST create" do
  after do
    # if files are stored on the file system
    # be sure to clean them up
  end

  it "should be able to upload a user's avatar image" do
    image = fixture_path + "/test_avatar.png"
    file = ActionController::TestUploadedFile.new image, "image/png"
    post :create, :user => { :avatar => file }
    User.last.avatar.original_filename.should == "test_avatar.png"
  end
end
```

This spec would require that you have a test_avatar.png image in the spec/fixtures directory. It would take that file, upload it to the controller, and the controller would create and save a real User model.

How do I spec actions that send email

A mailer is just another collaborator that a controller interacts with, so spec'ing a controller action that sends an email is a lot like spec'ing an action that creates a model.[2] We can use the same techniques we applied when implementing the create action on the MessagesController, leading to interaction-based examples like this:

```
describe UsersController, "POST create" do
  before(:each) do
    @user = mock_model(User)
    User.stub!(:new).and_return @user
    UserMailer.stub!(:deliver_confirmation)
  end
```

2. For help specifying mailers themselves, see http://github.com/bmabey/email-spec.

```
  it "sends a confirmation email to the user" do
    UserMailer.should_receive(:deliver_confirmation).with(@user)
    post :create
  end

  # ...
end
```

How do I spec filters?

As their names suggest, before, after, and around filters are methods that are executed before, after, or around (i.e. part before and part after) controller actions. Filters support pre and post-processing like authentication and output formatting. Although we don't recommend this, filters are also commonly used as an alternative to extracting private methods in order to share behaviour.[3]

Regardless of how they are used, we generally don't specify that a specific filter is used, or even exists. We do, however, find a distinction between how we specify behaviour when we use filters for behaviour sharing vs pre and post-processing. Consider the following spec:

```
describe EventsController do
  context "accessed by an anonymous visitor" do
    it "denies access to the create action" do
      controller.should_not_receive(:create)
      post :create
    end
  end
end
```

Here we are invoking the create() action, but specifying that the controller should not receive the create() message. An implementation that satisfies this spec probably uses a before_filter:

```
before_filter :login_required, :only => :create
```

We don't, however, specify that we're using a filter for this.

24.4 What We Just Learned

- Controllers coordinate the interaction between the user and the application and should know *what* to do, but not *how* to do it.

3. Using filters as a behaviour sharing mechanism often results in a loss of cohesion that makes the code less intention-revealing.

- Specifying the desired interaction helps us to discover objects with well named methods to encapsulate the real work.
- Controller specs use a custom example group provided by the rspec-rails library.
- Controller specs live in a directory tree parallel to the controllers themselves, and follow a naming convention of spec/controllers/my_controller_spec.rb for app/controllers/my_controller.rb.
- Use the redirect_to() matcher to confirm redirects.
- Use the render_template() matcher to confirm the template being rendered.
- Use the assigns() method to confirm the instance variables assigned for the view.
- Use the flash() method to confirm the flash messages stored for the view.
- Use mock_model() and stub_model() to isolate controller specs from the database and underlying business logic of your models.
- Extract spec helpers and custom macros to help keep your controller specs DRY.

If Rails controllers are like waiters in a restaurant, Rails models are the kitchen staff. They know how to cook a steak to order.

► Zach Dennis

Chapter 25

Rails Models

Rails models reflect the problem domain for which we're providing a software solution, and they vary significantly from app to app and model to model. Some models will be rich objects with complex behaviour, while others may be simple data containers.

When we work outside-in, we *discover* model interfaces in Cucumber step definitions, view specs and views, controller specs and controllers. These are the places we write *the code we wish we had*, and letting them guide us results in model interfaces that best suit the needs of the application.

Once we've learned what models we need, we can drive them out just as we would any type of object. In this chapter we're going to do just that, building on the messaging application we've been working on in Chapter 24, *Rails Controllers*, on page 385 and Chapter 23, *Rails Views*, on page 362, using RSpec Model Specs to drive out the behaviour of our models.

25.1 Writing Model Specs

Rails models are a lot closer to POROs than Rails controllers and views. We can create them using new(), and we can call methods on them directly. This makes specs for Rails models a lot more straightforward. As you'll see, we approach them just like we did in the Codebreaker example in Part I of this book.

There are some differences between Rails models and POROs, however, so RSpec offers a specialized ExampleGroup for specifying models. Similar to the ExampleGroups for controllers and views, the ModelExampleGroup wraps the behaviour defined in ActiveRecord::TestCase. This gives us access to facilities like fixtures, and, by default, wraps each example in a transaction so that our database is always in a known state at the beginning of each example.

We won't be able to answer every question about specifying Rails models in a single chapter, as there is certainly enough material here for an entire book. Our goal is to demonstrate some basic principles and guidelines that you can use as you work on your own applications. And with that, let's write some code.

Making it real

In Chapter 23, *Rails Views*, on page 362 we used mock_model() to provide views with the code we wish we had. Now it's time to take what we learned about the requirements of the model and make it real. We know from the view specs that we need text and title attributes for instances of Message. Let's imagine they also lead us to want a recipient_id to represent the user who receives the messsage, and that all of these fields are required for a Message to be considered valid.

We left off with a Message class that is not derived from ActiveRecord::Base, so let's regenerate that file and the supporting migration using the rspec_model generator. Be sure to let the generator overwrite app/models/message.rb when it asks.

```
$ script/generate rspec_model message title:string text:text recipient_id:integer
        exists  app/models/
        create  spec/models/
        create  spec/fixtures/
    overwrite app/models/message.rb? (enter "h" for help) [Ynaqdh] y
         force  app/models/message.rb
        create  spec/models/message_spec.rb
        create  spec/fixtures/messages.yml
        create  db/migrate
        create  db/migrate/XXXXXXXXXXXXXX_create_messages.rb
$ rake db:migrate
$ rake db:test:prepare
```

Specifying Validations

Since we know what fields are required we'll create pending examples for each of them to start. Go ahead and replace the generated code in message_spec.rb with the following:

Download rails_models/messages2/01/spec/models/message_spec.rb

```
require 'spec_helper'
```

```
describe Message do
  it "is valid with valid attributes"

  it "is not valid without a title"

  it "is not valid without text"

  it "is not valid without a recipient"
end
```

The first example will make clear what it takes to produce a valid message, and provide context for the other examples. Run that spec and you should see 4 examples, 0 failures, 4 pending. All four examples are pending, so let's implement the first example as follows:

Download rails_models/messages2/01/spec/models/message_example1_spec.rb

```
it "is valid with valid attributes" do
  Message.new.should be_valid
end
```

Run the spec again and you should see 4 examples, 0 failures, 3 pending this time. The first example is passing without making any changes because the model, by default, does not validate the presence of any attributes. Now implement the second example as follows:

Download rails_models/messages2/01/spec/models/message_example2_spec.rb

```
it "is not valid without a title" do
  message = Message.new :title => nil
  message.should_not be_valid
end
```

Now we have 4 examples, 1 failure, 2 pending, with the example we just implemented failing. Modify the model as follows to get it to pass:

Download rails_models/messages2/02/app/models/message.rb

```
class Message < ActiveRecord::Base
  validates_presence_of :title
end
```

The new example passes with that change, but we still have 4 examples, 1 failure, 2 pending. The is valid with valid attributes example is failing because we changed what it means for a Message to be valid. We'll need to update the example so that it constructs the Message with a title:

Download rails_models/messages2/02/spec/models/message_example1_spec.rb

```
it "is valid with valid attributes" do
  Message.new(:title => "foo").should be_valid
end
```

Now we have 4 examples, 0 failures, 2 pending. The first two examples are both passing, so we've made some progress. Of course we still have two pending examples so go ahead and implement the next example as follows:

Download rails_models/messages2/02/spec/models/message_example2_spec.rb

```
it "is not valid without text" do
  message = Message.new :text => nil
  message.should_not be_valid
end
```

Run the spec and we get 4 examples, 0 failures, 1 pending. Only one example pending means that we now have three examples passing. But wait a minute. Weren't we expecting this new example to fail? We were, but we're getting a false positive. The example passes because the model is invalid, but the model is invalid because it's missing the title attribute, not the text attribute that is the subject of the example. To expose this, update the example to supply a title:

Download rails_models/messages2/02/spec/models/message_example3_spec.rb

```
it "is not valid without text" do
  message = Message.new :text => nil, :title => "foo"
  message.should_not be_valid
end
```

With that change, the third example now fails as expected, so go ahead and make it pass by validating the presence of text in the model. Of course, once you do that, the is valid with valid attributes example will fail again because we only set it up with a title and it's validating the presence of text now as well. Go ahead update that example to provide both title and text as follows:

Download rails_models/messages2/02/spec/models/message_example4_spec.rb

```
it "is valid with valid attributes" do
  Message.new(:title => "foo", :text => "bar").should be_valid
end
```

Now we've got 4 examples, 0 failures, 1 pending.

Looking back at the is not valid without text example, it seems odd that we have to specify a title attribute in an example for the text attribute. If we don't add a text attribute to the example for the title we can never be certain that it's passing for the right reason. The examples are leaking! Let's refactor a bit before we move on the last pending example.

Refactoring leaky examples

Each example is setting up the model in the appropriate state by supplying the proper attributes. This worked fine when we had only one attribute to worry about, but as soon as we added the second attribute we ran into issues. If we keep heading down this path we'll end up with verbose examples that are brittle and time consuming to maintain.

Let's take the approach of setting up a valid message once, in a before(:each) block. This allows each example to configure the message with the appropriate state without having to worry about additional criteria used to set up a valid message.

The first example, is valid with valid attributes, is already building a valid message, so we can borrow its implementation. Create a before(:each) block which assigns a valid Message to a @message instance variable:

Download rails_models/messages2/03/spec/models/message_example1_spec.rb

```
describe Message do
  before(:each) do
    @message = Message.new(:title => "foo", :text => "bar")
  end

  it "is valid with valid attributes" do
    Message.new(:title => "foo", :text => "bar").should be_valid
  end
```

Run the spec and you should see 4 examples, 0 failures, 1 pending. Now update the first example to rely on the @message instance variable instead of constructing its own message:

Download rails_models/messages2/03/spec/models/message_example2_spec.rb

```
describe Message do
  before(:each) do
    @message = Message.new(:title => "foo", :text => "bar")
  end

  it "is valid with valid attributes" do
    @message.should be_valid
  end
```

The spec should still be passing, with one pending example. Now update the second example to rely on the @message instance variable as well:

Download rails_models/messages2/03/spec/models/message_example3_spec.rb

```
it "is not valid without a title" do
  @message.title = nil
  @message.should_not be_valid
end
```

The spec should still have 4 examples, 0 failures, 1 pending. As we've refactored, we've made several changes that have not changed the result. Let's do a little sanity check to make sure that everything is still wired up correctly. Comment out @message.title = nil in the second example, and re-run the spec, and watch it fail with expected valid? to return false, got true.

With the second example failing for the right reason, uncomment that line and then update the third example to rely on the @message instance variable and run the spec. With a green bar and three clean examples we can implement the pending example, is not valid without a recipient:

Download rails_models/messages2/03/spec/models/message_example4_spec.rb

```
it "is not valid without a recipient" do
  @message.recipient = nil
  @message.should_not be_valid
end
```

The example fails with undefined method 'recipient' for Message. Although we have a recipient_id attribute on the Message model we want recipient to be an association pointing to the user who's receiving the message. Let's define the association in the Message model:

Download rails_models/messages2/04/app/models/message.rb

```
class Message < ActiveRecord::Base
  belongs_to :recipient, :class_name => User.name

  validates_presence_of :title, :text
end
```

Run the spec again and now it's failing with the expected message: expected valid? to return false, got true. Update the Message model to require a recipient:

Download rails_models/messages2/05/app/models/message.rb

```
class Message < ActiveRecord::Base
  belongs_to :recipient, :class_name => User.name

  validates_presence_of :title, :text, :recipient
end
```

The example we just wrote is passing now, but the first example is valid with valid attributes is failing again because it doesn't account for the recipient. We can fix this by giving the @message instance variable a recipient:

Download rails_models/messages2/05/spec/models/message_example1_spec.rb

```
before(:each) do
  @message = Message.new(
    :title => "foo",
    :text => "bar",
    :recipient => mock_model(User)
  )
end
```

We use mock_model() so we don't have to worry about generating the User yet. Now all examples are passing: 4 examples, 0 failures. Here's the full message_spec.rb:

Download rails_models/messages2/05/spec/models/message_example2_spec.rb

```
require 'spec_helper'

describe Message do
  before(:each) do
    @message = Message.new(
      :title => "foo",
      :text => "bar",
      :recipient => mock_model(User)
    )
  end

  it "is valid with valid attributes" do
    @message.should be_valid
  end

  it "is not valid without a title" do
    @message.title = nil
    @message.should_not be_valid
  end

  it "is not valid without text" do
    @message.text = nil
    @message.should_not be_valid
  end

  it "is not valid without a recipient" do
    @message.recipient = nil
    @message.should_not be_valid
  end

end
```

What We Just Did

We started with a migration for the messages table that included attributes we learned about while specifying other parts of the application. Then

Joe Asks...

Should I spec associations?

Generally speaking, no. Well, not directly, anyhow. Associations should not be added unless they are serving the needs of some behaviour. Consider an Order which calculates its total value from the sum of the cost of its Items. We might introduce a has_many :items association to satisfy the relevant examples. Since the association is being added to support the calculation which is being specified, there is no need to spec it directly.

The same applies to association options. The :foreign_key or the :class_name options are structural, not behavioural. They're just part of wiring up the association, and an that requires them won't work correctly without them, so there is no need to spec them directly either.

we drove the validation requirements of the Message model one example at a time. When the examples started to leak we stopped adding functionality and refactored them so we could easily add the next example. This not only kept the examples DRY, it more importantly kept them clear and focused.

In addition to the examples we wrote we can use the spec to illustrate some basic conventions about model specs:

Directory organization The directory structure for model specs mimics the directory structure found in app/models/. For example, specs found in spec/models/ will be for models found in app/models/.

File naming Model specs are named after the model they provide examples for, with an _spec.rb appended to the filename. For example, message.rb would have a corresponding spec named message_spec.rb.

require 'spec_helper' Every model spec will need to require the spec_helper.rb file. Otherwise you will get errors about core rspec or rspec-rails methods not existing.

Now that we've got the basic behaviour of the Message model specified let's introduce some business rules into the application.

25.2 Specifying Business Rules

Our message app works well for sending unlimited messages, but our customer wants users to sign up for subscriptions that limit the number of messages they can send in a month. We'll imagine that we've already expressed these new requirements in Cucumber scenarios, and we're ready to start driving out code that will satisfy them.

Express business rules in models

In his article entitled *Skinny Controller, Fat Model,*[1] Jamis Buck recommends keeping views and controller actions as lean as possible, pushing business logic down to the model. This guideline has a profound effect on the maintainablity of application code, and its specs as well.

As mentioned earlier in this chapter, model specs are more straightforward than view and controller specs because we can create and call methods directly on model instances. There is also a natural tendency for application logic to change more frequently than business logic. Therefore, the more business logic we can express in models, which are easier to spec and change less often, the easier it will be to modify our controllers and views, which house the application logic that tends to change more often.

In our current design, the MessagesController is responsible for building and then saving a message. As we are about to add some complexity to this functionality, now would be a good time to push that responsibility down to the model. We'll do that by making a change to the create() action, so that it tells the current_user to send a message, rather than creating it directly in the action:

Download rails_models/beta2/01/app/controllers/messages_controller.rb

```ruby
def create
  @message = current_user.send_message params[:message]
  if @message.new_record?
    render :action => "new"
  else
    flash[:notice] = "The message was saved successfully."
    redirect_to messages_path
  end
end
```

The line that sends the message not only helps to push the logic to the model, it is also a much better expression of what's really going on in

1. http://weblog.jamisbuck.org/2006/10/18/skinny-controller-fat-model

the action. We're not just creating a message, we're sending one from the current user. This clarity is a small win, but as the code base grows these little wins make an application much easier to understand and evolve.

Before we press forward, generate a migration to create the users table with a login attribute. User models usually need more attributes, like passwords, but we're not concerned with those aspects of a user right now. Once you've got the migration in place, run rake db:migrate and db:test:prepare, and now we're ready to drive out these new business rules.

Focus on Behaviour

When thinking about models it's tempting to jump ahead and think of all of the relationships and functionality we *just know* they're going to need. Developing models this way can lead to inconsistent APIs with far too many public methods and relationships, which then become hard to maintain.

Focusing on the behaviour first leads to clean, cohesive models, so that's what we're going to do. Create a spec for the User model which describes the behaviour of send_message:

Download rails_models/beta2/01/spec/models/user_example1_spec.rb

```
require 'spec_helper'

describe User do

► describe "#send_message" do
►   it "sends a message to another user"
► end

end
```

The happy path for send_message is that the user has not gone over the monthly limit and will be able to send a message to another user. Let's move this pending example into a new context() to better express this:

Download rails_models/beta2/01/spec/models/user_example2_spec.rb

```
require 'spec_helper'

describe User do

  describe "#send_message" do

►   context "when the user is under their subscription limit" do
```

```
      it "sends a message to another user"
    end

  end

end
```

Now fill in the example with what we expect to happen when one user sends a message to another:

Download rails_models/beta2/01/spec/models/user_example3_spec.rb

```
describe "#send_message" do

  context "when the user is under their subscription limit" do

    it "sends a message to another user" do
      msg = zach.send_message(
        :recipient => david
      )
      david.received_messages.should == [msg]
    end

  end

end
```

Now that we've defined a clean interface for sending messages, run the spec, and it fails with undefined local method 'zach'. With the expectation clear, let's supply the necessary setup for the example to run, starting with zach and david as local variables:

Download rails_models/beta2/01/spec/models/user_example4_spec.rb

```
describe "#send_message" do

  context "when the user is under their subscription limit" do

    it "sends a message to another user" do
      zach = User.create!
      david = User.create!
      msg = zach.send_message(
        :recipient => david
      )
      david.received_messages.should == [msg]
    end

  end

end
```

Run the spec again, the example fails with undefined method 'send_message'. Add an empty send_message() method to the User model:

Download rails_models/beta2/02/app/models/user.rb

```
class User < ActiveRecord::Base

  def send_message(message_attrs)
  end

end
```

The example still fails, but now it's due to undefined method 'received_messages' on User. We need a received_messages association, so add that and run the spec:

Download rails_models/beta2/03/app/models/user.rb

```
class User < ActiveRecord::Base
  has_many :received_messages, :class_name => Message.name,
    :foreign_key => "recipient_id"

  def send_message(message_attrs)
  end

end
```

Now the example fails because it expects david.received_messages() to return [msg], but it got [] instead. To get this to pass, modify send_message() such that it creates a message using the message_attrs parameter. This is :recipient => david in our example.

Download rails_models/beta2/04/app/models/user.rb

```
class User < ActiveRecord::Base
  has_many :received_messages, :class_name => Message.name,
    :foreign_key => "recipient_id"

  def send_message(message_attrs)
    Message.create! message_attrs
  end

end
```

Run the spec and it fails with Validation failed: Text can't be blank, Title can't be blank. This is happening because the Message validates the presence of the title and text attributes. Because send_message() is just passing the attributes hash to the Message constructor, we can include those attributes directly in the example:

Download rails_models/beta2/04/spec/models/user_example1_spec.rb

```
it "sends a message to another user" do
```

```
  zach = User.create!
  david = User.create!
  msg = zach.send_message(
    :title => "Book Update",
    :text => "Beta 11 includes great stuff!",
    :recipient => david
  )
  david.received_messages.should == [msg]
end
```

Voila! The spec is now passing with 1 example, 0 failures. We've added the title and text attributes to get the sends a message to another user example to pass, but what should happen to those attributes? Let's add an example that specifies that those values make their way to the Message:

Download rails_models/beta2/04/spec/models/user_example2_spec.rb

```
it "creates a new message with the submitted attributes" do
  zach = User.create!
  david = User.create!
  msg = zach.send_message(
    :title => "Book Update",
    :text => "Beta 11 includes great stuff!",
    :recipient => david
  )
  msg.title.should == "Book Update"
  msg.text.should == "Beta 11 includes great stuff!"
end
```

This passes right away, but that's OK in this case, as the example communicates a requirement of this method.

Additional outcomes

At this point a user can send a message to a recipient, but the sender has no way to review the messages she sent. We need to add an expectation that the sender is associated with the message as well as the recipient. Add an example to express that expectation:

Download rails_models/beta2/04/spec/models/user_example3_spec.rb

```
context "when the user is under their subscription limit" do
  it "adds the message to the sender's sent messages"
end
```

This example is similar to the example we just got passing, so let's copy its example body into the new example and change the expectation to look at the sender's sent_messages:

Download rails_models/beta2/04/spec/models/user_example4_spec.rb

```
    it "adds the message to the sender's sent messages" do
```

```
      zach = User.create!
      david = User.create!
      msg = zach.send_message(
        :title => "Book Update",
        :text => "Beta 11 includes great stuff!",
        :recipient => david
      )
      zach.sent_messages.should == [msg]
    end
```

Running the spec results in the example failing with an undefined method 'sent_messages'. We'll need to add an association to make this pass. Also, the messages table doesn't have a sender_id field so be sure to make a migration which adds it. Here's what the model should end up looking like:

Download rails_models/beta2/05/app/models/user.rb

```
class User < ActiveRecord::Base
  has_many :received_messages, :class_name => Message.name,
    :foreign_key => "recipient_id"
  has_many :sent_messages, :class_name => Message.name,
    :foreign_key => "sender_id"

  def send_message(message_attrs)
    Message.create! message_attrs
  end

end
```

Execute the spec and the example is still failing because it expects an array with one message, but found an empty array. Now let's update the send_message() method implementation to use the sent_messages association to create the message:

Download rails_models/beta2/06/app/models/user.rb

```
class User < ActiveRecord::Base
  has_many :received_messages, :class_name => Message.name,
    :foreign_key => "recipient_id"
  has_many :sent_messages, :class_name => Message.name,
    :foreign_key => "sender_id"

  def send_message(message_attrs)
    sent_messages.create! message_attrs
  end

end
```

And we're back to green with 3 examples, 0 failures. Now we can safely clean up the duplication between the examples. To start let's consolidate the creation of zach and david in one spot. Pull up the assignments of zach and david into a before(:each) block as instance variables:

Download rails_models/beta2/06/spec/models/user_example1_spec.rb

```
describe "#send_message" do
  before(:each) do
    @zach = User.create!
    @david = User.create!
  end

  it "creates a new message with the submitted attributes" do
```

The spec should still be green although we're not using the new instance variables. Update the first example, creates a new message with the submitted attributes, to rely on the instance variables:

Download rails_models/beta2/06/spec/models/user_example2_spec.rb

```
it "creates a new message with the submitted attributes" do
  msg = @zach.send_message(
    :title => "Book Update",
    :text => "Beta 11 includes great stuff!",
    :recipient => @david
  )
  msg.title.should == "Book Update"
  msg.text.should == "Beta 11 includes great stuff!"
end
```

Run the spec, make sure it's still green, then update the other two examples to use the instance variables. When you're done the spec should still be at a green bar, 3 examples, 0 failures.

With specs for the happy path passing with the supporting code implemented, now it's time to start exploring the edge cases. We'll begin with what happens when the user is over their subscription's monthly limit.

Edge Cases

When we tell a User to send a message, a record is created in the messages table. We can use that knowledge to specify what happens when a message is not sent: it should not create a record in the messages table. Let's express that in a new example in user_spec.rb:

Download rails_models/beta2/06/spec/models/user_example3_spec.rb

```
context "when the user is over their subscription limit" do
  it "does not create a message" do
    lambda {
      @zach.send_message(
        :title => "Book Update",
        :text => "Beta 11 includes great stuff!",
```

```
        :recipient => @david
      )
    }.should_not change(Message, :count)
  end
end
```

Run the spec and watch that new example fail with count should not have changed, but did. We need to set up the example so the user has already reached their subscription limit. Writing the code we wish we had, we might end up with something like this in send_message():

```
def send_message(message_attrs)
  if subscription.can_send_message?
    sent_messages.create message_attrs
  end
end
```

This lets the subscription dictate if a message can be sent on a user-by-user basis. Run that and you'll see three failures with undefined local variable or method `subscription'. We've got a few different things to do to get this to pass, so let's back that change out and run the examples again to make sure they're all passing.

Introduce a before(:each) block inside the context which utilizes a *stub* to ensure a user can't send a message:

Download rails_models/beta2/06/spec/models/user_example4_spec.rb

```
context "when the user is over their subscription limit" do
  before(:each) do
    @zach.subscription = Subscription.new
    @zach.subscription.stub!(:can_send_message?).and_return false
  end

  it "does not create a message" do
    lambda {
      @zach.send_message(
        :title => "Book Update",
        :text => "Beta 11 includes great stuff!",
        :recipient => @david
      )
    }.should_not change(Message, :count)
  end
end
```

Now the latest example fails with uninitialized constant Subscription. We need a Subscription model and a migration that generates the subscriptions table and a subscription_id on the users table. Go ahead and add all that, and then the example should fail with an undefined method 'subscription='. Now let's add a Subscription association to the User model:

Download rails_models/beta2/08/app/models/user.rb

```
▶ belongs_to :subscription
```

The spec should be back to the original failure, count should not have changed, but did. Update send_message to rely on the stubbed can_send_message?() method:

Download rails_models/beta2/09/app/models/user.rb

```
▶ def send_message(message_attrs)
▶   if subscription.can_send_message?
▶     sent_messages.create! message_attrs
▶   end
▶ end
```

The does not create a message example should now be passing, but the other three are failing. We're relying on the subscription to determine when messages can be sent so we'll need to update @zach to be able to send messages for the failing examples. Add the following before block to the context for the failing examples:

Download rails_models/beta2/10/spec/models/user_spec.rb

```
  context "when the user is under their subscription limit" do
▶   before(:each) do
▶     @zach.subscription = Subscription.new
▶     @zach.subscription.stub!(:can_send_message?).and_return true
▶   end
```

Run the spec, you should have 4 examples, 0 failures. Right now the two inner before blocks give @zach a Subscription. Let's remove the duplication by pulling up the subscription assignment to the outer before block:

Download rails_models/beta2/10/spec/models/user_example1_spec.rb

```
  describe "#send_message" do
    before(:each) do
▶     @zach = User.create! :subscription => Subscription.new
      @david = User.create!
    end

    context "when the user is under their subscription limit" do
      before(:each) do
        @zach.subscription.stub!(:can_send_message?).and_return true
      end
```

Run the spec again, it should still be green with 4 examples, 0 failures. You may have noticed that both contexts stub the can_send_message?() method. This is fine, but it exposes a missing example. What's the expected interaction between the user and the can_send_message?() method?

The send_message() method should be passing in the user as the argument to can_send_message?(). Without that the subscription won't know who to apply the rules against. Add an example outside of context that makes that expectation explicit:

Download rails_models/beta2/10/spec/models/user_example2_spec.rb

```
describe "#send_message" do
  before(:each) do
    @zach = User.create! :subscription => Subscription.new
    @david = User.create!
  end

  it "asks the subscription if the user can send a message" do
    @zach.subscription.should_receive(:can_send_message?).with(@zach)
    @zach.send_message(:title => "Book Update")
  end
```

This example uses a message expectation to drive out the appropriate interaction. Isolating this expectation in an example allows us to be confident that the user trying to send the message is the same user the subscription checks the rules for.

Run the spec, the latest example should fail. Update the send_message() method to pass self to can_send_message?() in order to make it pass:

Download rails_models/beta2/10/app/models/user.rb

```
def send_message(message_attrs)
  if subscription.can_send_message?(self)
    sent_messages.create! message_attrs
  end
end
```

And voila! The spec is all green: 5 examples, 0 failures. This wraps up the User model, given our current needs. Next, we'll implement the can_send_message?() method.

25.3 Exercise

As you can see from the work we've done so far, model specs are not all that different from the kind of specs we would write for any PORO. We've got a little bit of work left to satisfy the requirement of limiting the number of messages sent in a month, and we're going to leave this work as an exercise for you.

All that remains to satisfy the requirement is to implement the can_send_message?() method on Subscription. In order to control how many messages can be sent in a month, the subscription will need to be know how many messages have already been sent. We can build two different sets of examples from this information:

- when a user has not gone over the limit for the month
- when a user has gone over the limit for the month

Create a Subscription spec with these contexts for the can_send_message?() method.

Download rails_models/beta2/11/spec/models/subscription_example2_spec.rb

```
describe "#can_send_message?" do
  context "when a user has not reached the subscription limit for the month" do
    it "returns true"
  end

  context "when a user has reached the subscription limit for the month" do
    it "returns false"
  end
end
```

Now go forth and write failing examples, get them to pass, and refactor your code! Be sure to keep the cycles small and keep the example and implementation code clean and readable. When you're finished you can compare your work with the code listings at the end of this chapter, but whether or not you end up with exactly what we did is not important. The important thing is that you use the opportunity to get more comfortable with the red/green/refactor cycle of TDD.

25.4 Useful Tidbits

In addition to what we've just gone through here are a few more pieces of useful information you can employ when writing model specs.

Db or Not Db

The model specs we've written have all relied on interaction with a database. This is one way to write model specs, but it's not the only way. We can also disconnect model specs from a database. You may be wondering why would you want to do that? Well, speed!

Hitting a database for each example takes time. Connections need to be made, queries sent/parsed/optimized/executed, and results need to be returned. Over time, a project accumulates more models and more behaviour, and models specs can easily go from taking a few seconds to several minutes. And the longer they take the *less we tend to run them*. This works against our effort to produce quality code quickly.

There are many cases in which we write examples for business logic that happens to belong in a model, but doesn't require a database. Removing the database bottleneck when we don't need it can speed things up considerably.

The rspec-rails library doesn't provide a way to do this natively, but we can look to libraries like Dan Manges' UnitRecord[2] and Avdi Grimm's NullDb[3] for help. They both disconnect specs from the database by using the schema.rb to supply information about the tables and attributes that models rely on.

There are times however when we want to interact with the database to expose behaviour or to boost confidence that an example is actually exercising something. UnitRecord and NullDb both provide ways for examples to interact with a database for these cases. This gives us the best of both worlds. Speed takes priority by default, but we can access a database when we need it.

Test Data Builders

Test Data Builders give us a centralized mechanism we can use to construct objects in code examples. They allow for variability in the test data being created, which in Rails typically means accepting overriding values via a hash.

The Test Data Builder pattern separates the construction of an object from its representation so the construction process can be re-used. This can turn an overly verbose and obfuscated example into a clear, easy to read example.

Here's an overly verbose example which obfuscates the important part of the example. It's hard to tell that the :text attribute is important:

```
it "is not valid ..." do
  message = Message.create!(
    :title => "some title",
    :text => "some text",
    :recipient => User.create!(
      :login => "bob",
      :password => "password",
```

2. UnitRecord - http://github.com/dan-manges/unit-record/tree/master
3. NullDb project - http://nulldb.rubyforge.org

```
      :password_confirmation => "password"
    )
  )
  ...
end
```

Here's what the construction of the message in this example would look like using Test Data Builder libraries designed specifically to work with ActiveRecord. They all remove unnecessary verbosity, increase readability, and make it immediately apparent that the :text attribute is important to the example:

```
# Fixjour and FixtureReplacement
message = create_message(:text => "some text")

# FactoryGirl
message = Factory(:message, :text => "some text")

# ObjectDaddy
message = Message.generate(:text => "some text")

# Machinist
message = Message.make(:text => "some text")
```

Fixjour, FixtureReplacement, FactoryGirl, Machinist and ObjectDaddy are all battle-tested and offer mature APIs, relying on convention and offering namespaces, declarative methods, sequences, association support, and DSL-like definitions.

Custom Macros

We can write custom macros for model specs using the same techniques we employed in the controllers chapter.

- Identify an example or group of examples to pull into a macro
- Extract the example(s) into a method on a module
- Update spec/spec_helper.rb to include the module
- Update the spec to use the macro

Matchers

RSpec-rails provides some additional matchers that can be useful in model specs.

be_valid()

The be_valid() matcher is used to set the expectation that your model is or is not valid:

```
model.should be_valid
model.should_not be_valid
```

error_on() and errors_on()

The error_on() and errors_on() methods extend RSpec's have() matcher for use with ActiveRecord models in order to set an expectation that a particular attribute has an error or not. It will call valid?() on the model in order to prepare the errors.

```
model.should have(:no).errors_on(:title)
model.should have(1).error_on(:body)
model.should have(2).errors_on(:caption)
```

record() and records()

The record() and records() methods also extend the have() matcher for use with ActiveRecord models. These let us set an expectation of the number of records. It calls find(:all) on the model in order to determine the count.

```
ModelClass.should have(:no).records
ModelClass.should have(1).record
```

Writing your own

You can always write your own matchers when you find yourself duplicating the same expectation in multiple examples or in a more verbose way than you'd like. The techniques to write custom matchers for ActiveRecord models are the same that you learned in Section 17.3, *Custom Matchers*, on page 290.

25.5 What We Just Learned

Throughout this chapter we focused on the behaviour of models by setting clear expectations through examples. By combining the outside-in approach with our knowledge of Rails we were able to write good clean specs while still taking advantage of ActiveRecord benefits in our implementation.

- Models reflect the problem domain for which you're providing a software solution, and they vary significantly from model to model, app to app.

- Models house the domain logic for an application.
- Models in Rails usually refer to ActiveRecord models although you may find you create models which are straight-up POROs.
- Model specs use a custom example group provided by the rspec-rails library.
- Model specs live in a directory tree parallel to the models themselves, and follow a naming convention of spec/model/my_model_spec.rb for app/model/my_model.rb.
- Focusing on model behaviour while taking advantage of ActiveRecord provided features can save time and effort.
- Use mock_model() and stub_model() to isolate controller specs from the database and underlying business logic of your models.
- Test data builder libraries can be used to reduce unneeded verbosity and improve clarity, maintainability of specs and even step definitions for Cucumber scenarios.
- You can extract duplication and common patterns in your model specs into custom macros and matchers using the same techniques you'd use for view specs and controller specs.
- RSpec-rails provides a few helpful ActiveRecord matchers to make writing model examples more expressive: be_valid(), errors_on(), and records().

25.6 Code Listing for Exercise

Download rails_models/beta2/16/spec/models/subscription_spec.rb

```ruby
require 'spec_helper'

describe Subscription do

  describe "#can_send_message?" do
    before(:each) do
      @subscription = Subscription.create!(:limit => 1)
      @user = User.create!(:subscription => @subscription)
    end

    context "when a user has not reached the subscription limit for the month" do
      it "returns true" do
        @subscription.can_send_message?(@user, Date.today).should be_true
      end
    end
```

```
    context "when a user has reached the subscription limit for the month" do
      it "returns false" do
        @user.sent_messages << Message.create!(
          :title => "foo",
          :text => "bar",
          :recipient => mock_model(User)
        )
        @subscription.can_send_message?(@user, Date.today).should be_false
      end
    end

  end
end
```

Download rails_models/beta2/16/app/models/subscription.rb

```
class Subscription < ActiveRecord::Base

  def can_send_message?(user, date)
    range = date.beginning_of_month .. date.end_of_month
    number_sent = user.sent_messages.in_date_range(range).count
    number_sent < limit
  end

end
```

Appendix A
RubySpec

Coming soon ...

Appendix B

RSpec's Built-In Expectations

Here is a summary of all of the expectations that are supported directly by RSpec.

Equality

Expression	Passes if ...
actual.should equal(expected)	actual.equal?(expected)
actual.should eql(expected)	actual.eql?(expected)
actual.should == expected	actual == expected

Expression	Passes unless ...
actual.should_not equal(expected)	actual.equal?(expected)
actual.should_not eql(expected)	actual.eql?(expected)
actual.should_not == expected	actual == expected

Arbitrary Predicates

Expression	Passes if ...
actual.should be_[predicate]	actual.predicate?
actual.should be_a_[predicate]	actual.predicate?
actual.should be_an_[predicate]	actual.predicate?

Expression	Passes if ...
actual.should be_[predicate](*args)	actual.predicate?(*args)
actual.should be_a_[predicate](*args)	actual.predicate?(*args)
actual.should be_an_[predicate](*args)	actual.predicate?(*args)

Expression	Passes unless ...
actual.should_not be_[predicate]	actual.predicate?
actual.should_not be_a_[predicate]	actual.predicate?
actual.should_not be_an_[predicate]	actual.predicate?

Expression	Passes unless ...
actual.should_not be_[predicate](*args)	actual.predicate?(*args)
actual.should_not be_a_[predicate](*args)	actual.predicate?(*args)
actual.should_not be_an_[predicate](*args)	actual.predicate?(*args)

Regular Expressions

Expression	Passes if ...
actual.should match(expected)	actual.match?(expected)
actual.should =~ expected	actual =~ expected

Expression	Passes unless ...
actual.should_not match(expected)	actual.match?(expected)
actual.should_not =~ expected	actual =~ expected

Comparisons

Expression	Passes if ...
actual.should be < expected	actual < expected
actual.should be <= expected	actual <= expected
actual.should be >= expected	actual >= expected
actual.should be > expected	actual > expected

Collections

Expression	Passes if ...
actual.should include(expected)	actual.include?(expected)
actual.should have(n).items	actual.items.length == n or actual.items.size == n
actual.should have_exactly(n).items	actual.items.length == n or actual.items.size == n
actual.should have_at_least(n).items	actual.items.length >= n or actual.items.size >= n
actual.should have_at_most(n).items	actual.items.length <= n or actual.items.size <= n

Expression	Passes unless ...
actual.should_not include(expected)	actual.include?(expected)
actual.should_not have(n).items	actual.items.length == n or actual.items.size == n
actual.should_not have_exactly(n).items	actual.items.length == n or actual.items.size == n

Errors

Expression	Passes if ...
proc.should raise_error	proc raises any error
proc.should raise_error(type)	raises specified type of error
proc.should raise_error(message)	raises error with specified message
proc.should raise_error(type, message)	raises specified type of error with specified message

Expression	Passes unless ...
proc.should_not raise_error	proc raises any error
proc.should_not raise_error(type)	raises specified type of error
proc.should_not raise_error(message)	raises error with specified message
proc.should_not raise_error(type, message)	raises specified type of error with specified message

Symbols

Expression	Passes if ...
proc.should throw_symbol	proc throws any symbol
proc.should throw_symbol(type)	proc throws specified symbol

Expression	Passes unless ...
proc.should_not throw_symbol	proc throws any symbol
proc.should_not throw_symbol(type)	proc throws specified symbol

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Floating Point Comparisons

Expression	Passes if ...
actual.should be_close(expected, delta)	actual > (expected - delta) and < (expected + delta)

Expression	Passes unless ...
actual.should_not be_close(expected, delta)	actual < (expected + delta) or > (expected - delta)

Contracts

Expression	Passes if ...
actual.should respond_to(*messages)	messages.each { |m| m.respond_to?(m) }

Expression	Passes unless ...
actual.should_not respond_to(*messages)	messages.each { |m| m.respond_to?(m) }

When All Else Fails...

Expression	Passes if ...
actual.should satisfy { |actual| block }	the block returns true

Expression	Passes unless ...
actual.should_not satisfy { |actual| block }	the block returns true

Appendix C

Codebreaker Refactored

Download cb/69/features/support/stats.rb

```
module Codebreaker
  class Stats
    attr_reader :codes

    def initialize
      @counts = (1..4).collect { Hash.new {|h,k| h[k] = 0} }
      @codes = []
    end

    def puts(code)
      if code =~ /^\w \w \w \w$/
        codes << code.split
        codes.last.each_with_index do |color, index|
          @counts[index][color] += 1
        end
      end
    end

    def count_for(color, position)
      @counts[position-1][color]
    end
  end
end
```

Appendix D

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