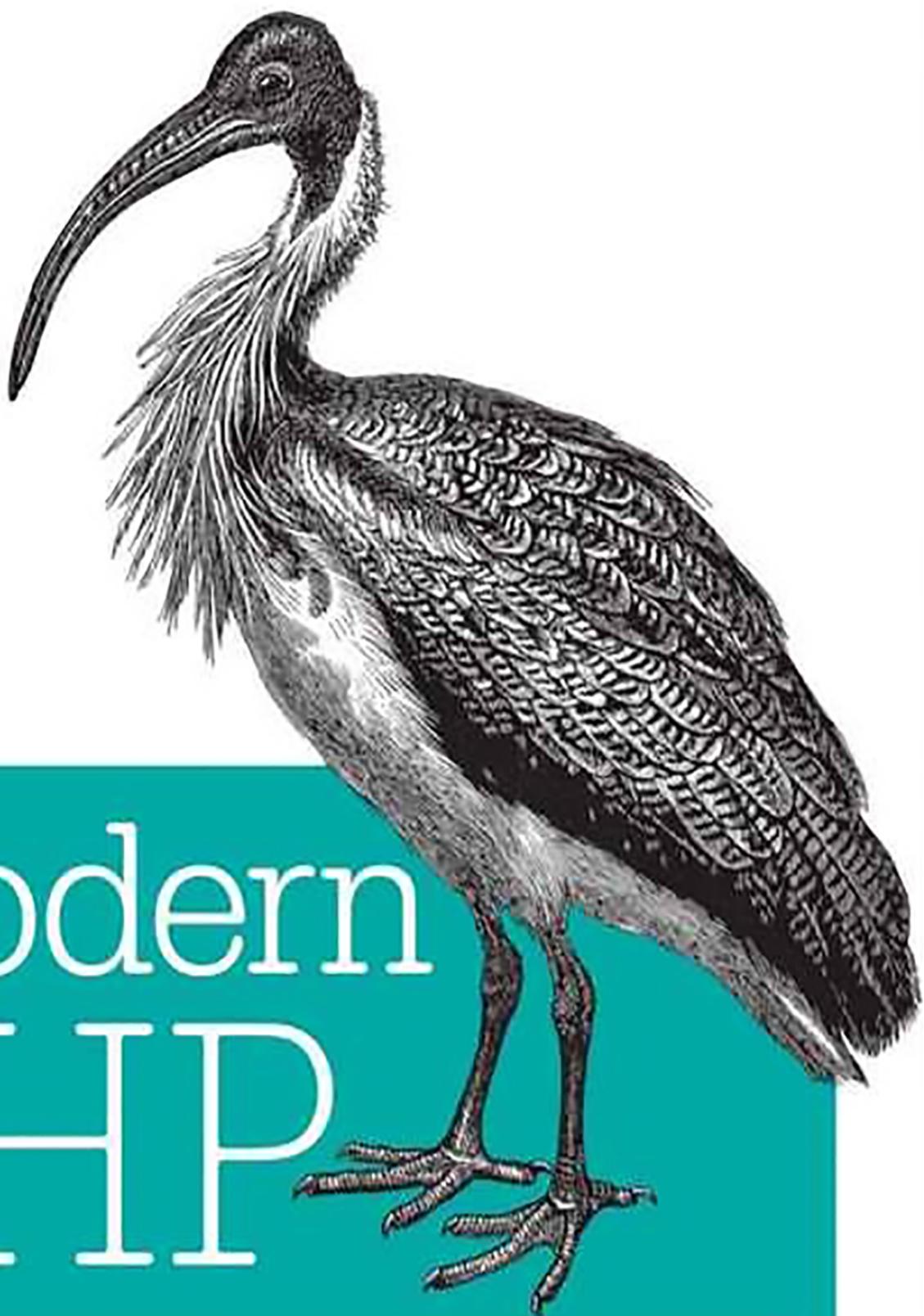


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# Modern PHP

NEW FEATURES AND GOOD PRACTICES

Josh Lockhart

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by Josh Lockhart

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[LSI]

For Laurel

# Preface

There are a million PHP tutorials online. Most of these tutorials are outdated and demonstrate obsolete practices. Unfortunately, these tutorials are still referenced today thanks to their Google immortality. Outdated information is dangerous to unaware PHP programmers who unknowingly create slow and insecure PHP applications. I recognized this issue in 2013, and it is the primary reason I began [PHP The Right Way](#), a community initiative to provide PHP programmers easy access to high-quality and up-to-date information from authoritative members of the PHP community.

*Modern PHP* is my next endeavor toward the same goal. This book is not a reference manual. Nope. This book is a friendly and fun conversation between you and me. I'll introduce you to the modern PHP programming language. I'll show you the latest PHP techniques that I use every day at work and on my open source projects. And I'll help you use the latest coding standards so you can share your PHP components and libraries with the PHP community.

You'll hear me say "community" over and over (and over). The PHP community is friendly and helpful and welcoming — although not without occasional drama. If you become curious about a specific feature mentioned in this book, reach out to your local PHP user group with questions. I guarantee you there are nearby PHP developers who would love to help you become a better PHP programmer. Your local PHP user group is an invaluable resource as you continue to improve your PHP skills long after you finish this book.

# What You Need to Know About This Book

Before we get started, I want to set a few expectations. First, it is impossible for me to cover *every* way to use PHP. There isn't enough time. Instead, I will show you *how I use PHP*. Yes, this is an opinionated approach, but I use the very same practices and standards adopted by many other PHP developers. What you take away from our brief conversation will be immediately applicable in your own projects.

Second, I assume you are familiar with variables, conditionals, loops, and so on; you don't have to know PHP, but you should at least bring a basic understanding of these fundamental programming concepts. You can also bring coffee (I love coffee). I'll supply everything else.

Third, I do not assume you are using a specific operating system. However, my code examples are written for Linux. Bash commands are provided for Ubuntu and CentOS and may also work on OS X. If you use Windows, I highly recommend you spin up a Linux virtual machine so you can run the example code in this book.

# How This Book Is Organized

[Part I](#) demonstrates new PHP features like namespaces, generators, and traits. It introduces you to the modern PHP language, and it exposes you to features you may not have known about until now.

[Part II](#) explores good practices that you should implement in your PHP applications. Have you heard the term *PSR*, but you're not entirely sure what it is or how to use it? Do you want to learn how to sanitize user input and use safe database queries? This chapter is for you.

[Part III](#) is more technical than the first two parts. It demonstrates how to deploy, tune, test, and profile PHP applications. We dive into deployment strategies with Capistrano. We talk about testing tools like PHPUnit and Travis CI. And we explore how to tune PHP so it performs as well as possible for your application.

[Appendix A](#) provides step-by-step instructions for installing and configuring PHP-FPM on your machine.

[Appendix B](#) explains how to build a local development environment that closely matches your production server. We explore Vagrant, Puppet, Chef, and alternative tools to help you get started quickly.

# Conventions Used in This Book

The following typographical conventions are used in this book:

## *Italic*

Indicates new terms, URLs, email addresses, filenames, and file extensions.

## `Constant width`

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

## `Constant width bold`

Shows commands or other text that should be typed literally by the user.

## *Constant width italic*

Shows text that should be replaced with user-supplied values or by values determined by context.

## **Tip**

This element signifies a tip or suggestion.

## **Note**

This element signifies a general note.

## **Warning**

This element indicates a warning or caution.

# Using Code Examples

Supplemental material (code examples, exercises, etc.) is available for download at <https://github.com/codeguy/modern-php>.

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# Acknowledgments

This is my first book. When O'Reilly approached me about writing *Modern PHP*, I was equally excited and scared to death. The first thing I did was a Walter Huston dance; I mean, *O'Reilly* wanted *me* to write a book. How cool is that!? Then I asked myself *can I really write that many pages?* A book isn't a quick or small task.

Of course, I immediately said “yes.” I knew I could write *Modern PHP* because I had family, friends, coworkers, editors, and reviewers supporting me the entire way. I want to acknowledge and thank my supporters for their invaluable feedback. Without them, this book would never have happened.

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I also want to thank my technical reviewers — Adam Fairholm ([@adamfairholm](#)) and Ed Finkler ([@funkatron](#)). Adam is a brilliant web developer at [Newfangled](#), and he is perhaps best known for his work on [IMVDb](#) — the popular music video database. Ed is well-known throughout the PHP community for his incredible PHP skills, his personality on the [/dev/hell podcast](#), and his commendable [Open Sourcing Mental Illness](#) campaign. Adam and Ed both pointed out everything dumb, illogical, and incorrect in my early drafts. This book is far better than anything I could write on my own thanks to their brutally honest feedback. I am forever indebted to them for their guidance and wisdom. If any faults or inaccuracies wriggled their way into the final manuscript, those faults are surely my own.

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# **Part I. Language Features**

# Chapter 1. The New PHP

The PHP language is experiencing a renaissance. PHP is transforming into a modern scripting language with helpful features like namespaces, traits, closures, and a built-in opcode cache. The modern PHP ecosystem is evolving, too. PHP developers rely less on monolithic frameworks and more on smaller specialized components. The Composer dependency manager is revolutionizing how we build PHP applications; it emancipates us from a framework's walled garden and lets us mix and match interoperable PHP components best suited for our custom PHP applications. Component interoperability would not be possible without community standards proposed and curated by the PHP Framework Interop Group.

*Modern PHP* is your guide to the new PHP, and it will show you how to build and deploy amazing PHP applications using community standards, good practices, and interoperable components.

# Past

Before we explore modern PHP, it is important to understand PHP's origin. PHP is an interpreted server-side scripting language. This means you write PHP code, upload it to a web server, and execute it with an interpreter. PHP is typically used with a web server like Apache or nginx to serve dynamic content. However, PHP can also be used to build powerful command-line applications (just like bash, Ruby, Python, and so on). Many PHP developers don't realize this and miss out on a really exciting feature. Not you, though.

You can read the official PHP history at <http://php.net/manual/history.php.php>. I won't repeat what has already been said so well by Rasmus Lerdorf (the creator of PHP). What I will tell you is that PHP has a tumultuous past. PHP began as a collection of CGI scripts written by Rasmus Lerdorf to track visits to his online resume. Lerdorf named his set of CGI scripts "Personal Home Page Tools." This early incarnation was completely different from the PHP we know today. Lerdorf's early PHP Tools were not a scripting language; they were tools that provided rudimentary variables and automatic form variable interpretation using an HTML embedded syntax.

Between 1994 and 1998, PHP underwent numerous revisions and even received a few ground-up rewrites. Andi Gutmans and Zeev Suraski, two developers from Tel Aviv, joined forces with Rasmus Lerdorf to transform PHP from a small collection of CGI tools into a full-fledged programming language with a more consistent syntax and basic support for object-oriented programming. They named their final product PHP 3 and released it in late 1998. The new PHP moniker was a departure from earlier names, and it is a recursive acronym for PHP: Hypertext Preprocessor. PHP 3 was the first version that most resembled the PHP we know today. It provided superior extensibility to various databases, protocols, and APIs. PHP 3's extensibility attracted many new developers to the project. By late 1998, PHP 3 was already installed on a staggering 10% of the world's web servers.

# Present

Today, the PHP language is quickly evolving and is supported by dozens of core team developers from around the world. Development practices have changed, too. In the past, it was common practice to write a PHP file, upload it to a production server with FTP, and hope it worked. This is a terrible development strategy, but it was necessary due to a lack of viable local development environments.

Nowadays, we eschew FTP and use version control instead. Version control software like Git helps maintain an auditable code history that can be branched, forked, and merged. Local development environments are identical to production servers thanks to virtualization tools like Vagrant and provisioning tools like Ansible, Chef, and Puppet. We leverage specialized PHP components with the Composer dependency manager. Our PHP code adheres to PSRs — community standards managed by the PHP Framework Interop Group. We thoroughly test our code with tools like PHPUnit. We deploy our applications with PHP’s FastCGI process manager behind a web server like nginx. And we increase application performance with an opcode cache.

Modern PHP encompasses many new practices that may be unfamiliar to those of you new to PHP, or to those upgrading from older PHP versions. Don’t feel overwhelmed. I’ll walk through each concept later in this book.

I’m also excited that PHP now has an official draft specification — something it lacked until 2014.

## Note

Most mature programming languages have a *specification*. In layman’s terms, a specification is a canonical blueprint that defines *what it means to be PHP*. This blueprint is used by developers who create programs that parse, interpret, and execute PHP code. It is not for developers who create applications and websites with PHP.

Sara Golemon and Facebook announced the first PHP specification draft at O’Reilly’s OSCON conference in 2014. You can read the official announcement on the [PHP internals mailing list](#), and you can read the [PHP specification](#) on GitHub.

An official PHP language specification is becoming more important given the introduction of multiple competing PHP engines. The original PHP engine is the [Zend Engine](#), a PHP interpreter written in C and introduced in PHP 4. The Zend Engine was created by Rasmus Lerdorf, Andi Gutmans, and Zeev Suraski. Today the Zend Engine is the Zend company’s main contribution to the PHP community. However, there is now a second major PHP engine — the HipHop Virtual Machine from Facebook. A language specification ensures that both engines maintain a baseline compatibility.

## Note

A *PHP engine* is a program that parses, interprets, and executes PHP code (e.g., the Zend Engine or Facebook’s HipHop Virtual Machine). This is not to be confused with *PHP*, which is a generic reference to the PHP language.

# Future

The Zend Engine is improving at a rapid pace with new features and improved performance. I attribute the Zend Engine's improvements to its new competition, specifically Facebook's *HipHop Virtual Machine* and *Hack* programming language.

Hack is a new programming language built on top of PHP. It introduces static typing, new data structures, and additional interfaces while maintaining backward compatibility with existing dynamically typed PHP code. Hack is targeted at developers who appreciate PHP's rapid development characteristics but need the predictability and stability from static typing.

## Note

We'll discuss *dynamic* versus *static* typing later in this book. The difference between the two is *when* PHP types are checked. Dynamic types are checked at runtime, whereas static types are checked at compile time. Jump ahead to [Chapter 12](#) for more information.

The HipHop Virtual Machine (HHVM) is a PHP and Hack interpreter that uses a *just in time* (JIT) compiler to improve application performance and reduce memory usage.

I don't foresee Hack and HHVM replacing the Zend Engine, but Facebook's new contributions are creating a giant splash in the PHP community. Increasing competition has prompted the Zend Engine core team to announce [PHP 7](#), an optimized Zend Engine said to be on par with HHVM. We'll discuss these developments further in [Chapter 12](#).

It's an exciting time to be a PHP programmer. The PHP community has never been this energized, fun, and innovative. I hope this book helps you firmly embrace modern PHP practices. There are a ton of new things to learn, and many more things on the horizon. Consider this your roadmap. Now let's get started.

# Chapter 2. Features

The modern PHP language has many exciting new features. Many of these features will be brand new to PHP programmers upgrading from earlier versions, and they'll be a nice surprise to programmers migrating to PHP from another language. These new features make the PHP language a powerful platform and provide a pleasant experience for building web applications and command-line tools.

Some of these features aren't essential, but they still make our lives easier. Some features, however, *are* essential. Namespaces, for example, are a cornerstone of modern PHP standards and enable development practices that modern PHP developers take for granted (e.g., autoloading). I'll introduce each new feature, explain why it is useful, and show you how to implement it in your own projects.

## Tip

I encourage you to follow along on your own computer. You can find all of the text's code examples in this book's companion [GitHub repository](#).

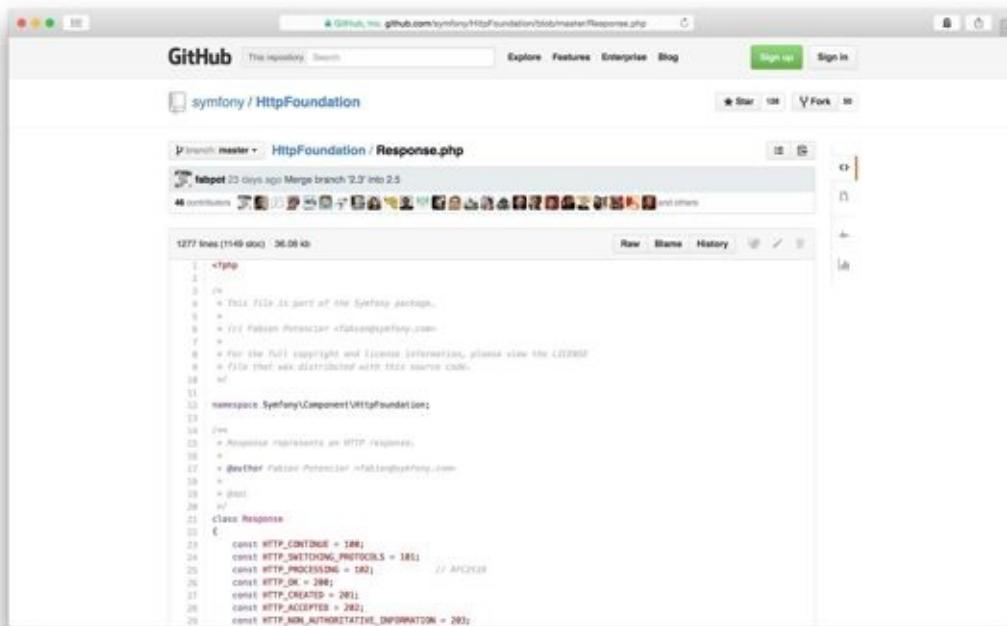
# Namespaces

If there is one modern PHP feature I want you to know, it is *namespaces*. Introduced in PHP 5.3.0, namespaces are an important tool that organizes PHP code into a virtual hierarchy, comparable to your operating system's filesystem directory structure. Each modern PHP component and framework organizes its code beneath its own globally unique vendor namespace so that it does not conflict with, or lay claim to, common class names used by other vendors.

## Note

Don't you hate it when you walk into a coffee shop and this one obnoxious person has a mess of books, cables, and whatnot spread across several tables? Not to mention he's sitting next to, but not using, the only available power outlet. He's wasting valuable space that could otherwise be useful to you. Figuratively speaking, this person is not using namespaces. Don't be this person.

Let's see how a real-world PHP component uses namespaces. The Symfony Framework's own [symfony/httpfoundation](#) is a popular PHP component that manages HTTP requests and responses. More important, the symfony/httpfoundation component uses common PHP class names like Request, Response, and Cookie. I guarantee you there are many other PHP components that use these same class names. How can we use the symfony/httpfoundation PHP component if other PHP code uses the same class names? We can safely use the symfony/httpfoundation component precisely because its code is sandboxed beneath the unique Symfony vendor namespace. Visit the [symfony/httpfoundation](#) component on GitHub and navigate to the [Response.php](#) file. It looks like [Figure 2-1](#).

A screenshot of a Mac OS X desktop showing a GitHub browser window. The window title is "GitHub - GitHub.com/symfony/HttpFoundation@master:Response.php". The page displays the contents of the Response.php file from the master branch of the symfony/HttpFoundation repository. The code is written in PHP and defines a class named Response. The file includes several constants at the top, such as HTTP\_CONTINUE (100), HTTP\_SWITCHING\_PROTOCOLS (101), HTTP\_PROCESSING (102), HTTP\_OK (200), HTTP\_CREATED (201), HTTP\_ACCEPTED (202), and HTTP\_NON\_AUTHORITATIVE\_INFORMATION (203). The code also includes annotations like // APC2018. The GitHub interface shows a commit from "fatspot" dated 23 days ago, merging branch '2.0' into '2.5'. The file has 1277 lines and is 36.08 kB in size. There are tabs for Raw, Blame, and History.

**Figure 2-1. GitHub symfony/httpfoundation screenshot**

Look closely at line 12. It contains this code:

```
namespace Symfony\Component\HttpFoundation;
```

This is a PHP namespace declaration, and it always appears on a new line immediately after the opening <?php tag. This particular namespace declaration tells us several things. First, we know the Response class lives beneath the `Symfony` vendor namespace (the vendor namespace is the topmost namespace). We know the Response class lives beneath the Component subnamespace. We also know the Response class lives beneath yet another subnamespace named `HttpFoundation`. You can view other files adjacent to `Response.php`, and you'll see they use the same namespace declaration. A namespace (or subnamespace) encapsulates and organizes related PHP classes, just as a filesystem directory contains related files.

## Tip

Subnamespaces are separated with a \ character.

Unlike your operating system's physical filesystem, PHP namespaces are a *virtual* concept and do not necessarily map 1:1 with filesystem directories. That being said, most PHP components do, in fact, map subnamespaces to filesystem directories for compatibility with the popular PSR-4 autoloader standard (we'll talk more about this in [Chapter 3](#)).

## Note

Technically speaking, namespaces are merely a PHP language notation referenced by the PHP interpreter to apply a common name prefix to a set of classes, interfaces, functions, and constants.

## Why We Use Namespaces

Namespaces are important because they let us create sandboxed code that works alongside other developers' code. This is the cornerstone concept of the modern PHP component ecosystem. Component and framework authors build and distribute code for a large number of PHP developers, and they have no way of knowing or controlling what classes, interfaces, functions, and constants are used alongside their own code. This problem applies to your own in-house projects, too. If you write custom PHP components or classes for a project, that code must work alongside your project's third-party dependencies.

As I mentioned earlier with the `symfony/httpfoundation` component, your code and other developers' code might use the same class, interface, function, or constant names. Without namespaces, a name collision causes PHP to fail. With namespaces, your code and other developers' code can use the same class, interface, function, or constant name assuming your code lives beneath a unique vendor namespace.

If you're building a tiny personal project with only a few dependencies, class name collisions probably won't be an issue. But when you're working on a team building a large project with numerous third-party dependencies, name collisions become a very real concern. You cannot control which classes, interfaces, functions, and constants are introduced into the global namespace by your project's dependencies. This is why namespacing your code is important.

# Declaration

Every PHP class, interface, function, and constant lives beneath a namespace (or subnamespace). Namespaces are declared at the top of a PHP file on a new line immediately after the opening `<?php` tag. The namespace declaration begins with `namespace`, then a space character, then the namespace name, and then a closing semicolon ; character.

Remember that namespaces are often used to establish a top-level vendor name. This example namespace declaration establishes the `Oreilly` vendor name:

```
<?php  
namespace Oreilly;
```

All PHP classes, interfaces, functions, or constants declared beneath this namespace declaration live in the `Oreilly` namespace and are, in some way, related to O'Reilly Media. What if we wanted to organize code related to this book? We use a subnamespace.

Subnamespaces are declared exactly the same as in the previous example. The only difference is that we separate namespace and subnamespace names with the \ character. The following example declares a subnamespace named `ModernPHP` that lives beneath the topmost `Oreilly` vendor namespace:

```
<?php  
namespace Oreilly\ModernPHP;
```

All classes, interfaces, functions, and constants declared beneath this namespace declaration live in the `Oreilly\ModernPHP` subnamespace and are, in some way, related to this book.

All classes in the same namespace or subnamespace don't have to be declared in the same PHP file. You can specify a namespace or subnamespace at the top of any PHP file, and that file's code becomes a part of that namespace or subnamespace. This makes it possible to write multiple classes in separate files that belong to a common namespace.

## Tip

The most important namespace is the *vendor namespace*. This is the topmost namespace that identifies your brand or organization, and it must be globally unique. Subnamespaces are less important, but they are helpful for organizing your project's code.

# Import and Alias

Before we had namespaces, PHP developers solved the name collision problem with Zend-style class names. This was a class-naming scheme popularized by the Zend Framework where PHP class names used underscores in lieu of filesystem directory separators. This convention accomplished two things: it ensured class names were unique, and it enabled a naive autoloader implementation that replaced underscores in PHP class names with filesystem directory separators to determine the class file path.

For example, the PHP class

`Zend_Cloud_DocumentService_Adapter_WindowsAzure_Query` corresponds to the PHP file `Zend/Cloud/DocumentService/Adapter/WindowsAzure/Query.php`. A side effect of the Zend-style naming convention, as you can see, is absurdly long class names. Call me lazy, but there's no way I'm typing that class name more than once.

Modern PHP namespaces present a similar problem. For example, the full `Response` class name in the `symfony\httpfoundation` component is

`\Symfony\Component\HttpFoundation\Response`. Fortunately, PHP lets us *import* and *alias* namespaced code.

By import, I mean that I tell PHP which namespaces, classes, interfaces, functions, and constants I will use in each PHP file. I can then use these *without typing their full namespaces*.

By alias, I mean that I tell PHP that I will reference an imported class, interface, function, or constant with a shorter name.

## Tip

You can import and alias PHP classes, interfaces, and other namespaces as of PHP 5.3. You can import and alias PHP functions and constants as of PHP 5.6.

The code shown in [Example 2-1](#) creates and sends a `400 Bad Request` HTTP response *without* importing and aliasing.

### Example 2-1. Namespace without alias

```
<?php
$response = new \Symfony\Component\HttpFoundation\Response('Oops', 400);
$response->send();
```

This isn't terrible, but imagine you have to instantiate a `Response` instance several times in a single PHP file. Your fingers will get tired quickly. Now look at [Example 2-2](#). It does the same thing *with* importing.

### Example 2-2. Namespace with default alias

```
<?php
use Symfony\Component\HttpFoundation\Response;

$response = new Response('Oops', 400);
$response->send();
```

We tell PHP we intend to use the `Symfony\Component\HttpFoundation\Response` class with the `use` keyword. We type the long, fully qualified class name once. Then we can instantiate the `Response` class without using its fully namespaced class name. How cool is

that?

Some days I feel really lazy. This is a good opportunity to use an alias. Let's extend [Example 2-2](#). Instead of typing Response, maybe I just want to type Res instead. [Example 2-3](#) shows how I can do that.

### Example 2-3. Namespace with custom alias

```
<?php
use Symfony\Component\HttpFoundation\Response as Res;

$r = new Res('Oops', 400);
$r->send();
```

In this example, I changed the import line to import the Response class. I also appended as Res to the end of the import line; this tells PHP to consider Res an alias for the Response class. If we don't append the as Res alias to the import line, PHP assumes a default alias that is the same as the imported class name.

#### Tip

You should import code with the use keyword at the top of each PHP file, immediately after the opening <?php tag or namespace declaration.

You don't need a leading \ character when importing code with the use keyword because PHP assumes imported namespaces are fully qualified.

The use keyword must exist in the global scope (i.e., not inside of a class or function) because it is used at compile time. It can, however, be located beneath a namespace declaration to import code into another namespace.

As of PHP 5.6, it's possible to import functions and constants. This requires a tweak to the use keyword syntax. To import a function, change use to use func:

```
<?php
use func Namespace\functionName;

functionName();
```

To import a constant, change use to use constant:

```
<?php
use constant Namespace\CONST_NAME;

echo CONST_NAME;
```

Function and constant aliases work the same as classes.

# Helpful Tips

## Multiple imports

If you import multiple classes, interfaces, functions, or constants into a single PHP file, you'll end up with multiple `use` statements at the top of your PHP file. PHP accepts a shorthand import syntax that combines multiple `use` statements on a single line like this:

```
<?php
use Symfony\Component\HttpFoundation\Request,
    Symfony\Component\HttpFoundation\Response,
    Symfony\Component\HttpFoundation\Cookie;
```

Don't do this. It's confusing and easy to mess up. I recommend you keep each `use` statement on its own line like this:

```
<?php
use Symfony\Component\HttpFoundation\Request;
use Symfony\Component\HttpFoundation\Response;
use Symfony\Component\HttpFoundation\Cookie;
```

You'll type a few extra characters, but your code is easier to read and troubleshoot.

## Multiple namespaces in one file

PHP lets you define multiple namespaces in a single PHP file like this:

```
<?php
namespace Foo {
    // Declare classes, interfaces, functions, and constants here
}

namespace Bar {
    // Declare classes, interfaces, functions, and constants here
}
```

This is confusing and violates the recommended *one class per file* good practice. Use only one namespace per file to make your code simpler and easier to troubleshoot.

## Global namespace

If you reference a class, interface, function, or constant *without a namespace*, PHP assumes the class, interface, function, or constant lives in the current namespace. If this assumption is wrong, PHP attempts to resolve the class, interface, function, or constant. If you need to reference a namespaced class, interface, function, or constant *inside another namespace*, you must use the fully qualified PHP class name (namespace + class name). You can type the fully qualified PHP class name, or you can import the code into the current namespace with the `use` keyword.

Some code might not have a namespace and, therefore, lives in the *global namespace*. The native `Exception` class is a good example. You can reference globally namespaced code inside another namespace by prepending a `\` character to the class, interface, function, or constant name. For example, the `\My\App\Foo::doSomething()` method in [Example 2-4](#) fails because PHP searches for a `\My\App\Exception` class that does not exist.

### Example 2-4. Unqualified class name inside another namespace

```
<?php
namespace My\App;
```

```
class Foo
{
    public function doSomething()
    {
        $exception = new Exception();
    }
}
```

Instead, add a \ prefix to the `Exception` class name, as shown in [Example 2-5](#). This tells PHP to look for the `Exception` class in the global namespace instead of the current namespace.

### Example 2-5. Qualified class name inside another namespace

```
<?php
namespace My\App;

class Foo
{
    public function doSomething()
    {
        throw new \Exception();
    }
}
```

## Autoloading

Namespaces also provide the bedrock for the PSR4 autoloader standard created by the PHP Framework Interop Group (PHP-FIG). This autoloader pattern is used by most modern PHP components, and it lets us autoload project dependencies using the Composer dependency manager. We'll talk about Composer and the PHP-FIG in [Chapter 4](#). For now, just understand that the modern PHP ecosystem and its emerging component-based architecture would be impossible without namespaces.

# Code to an Interface

Learning how to code to an interface changed my life as a PHP programmer, and it profoundly improved my ability to integrate third-party PHP components into my own applications. Interfaces are not a new feature, but they are an important feature that you should know about and use on a daily basis.

So what is a PHP interface? An interface is a contract between two PHP objects that lets one object depend not on what another object *is* but, instead, on what another object *can do*. An interface decouples our code from its dependencies, and it allows our code to depend on any third-party code that implements the expected interface. We don't care *how* the third-party code implements the interface; we care only that the third-party code *does* implement the interface. Here's a more down-to-earth example.

Let's pretend I just arrived in Miami, Florida for the Sunshine PHP Developer Conference. I need a way to get around town, so I head straight for the local car rental place. They have a tiny Hyundai compact, a Subaru wagon, and (much to my surprise) a Bugatti Veyron. I know I need a way to get around town, and all three vehicles can help me do that. But each vehicle does so differently. The Hyundai Accent is OK, but I'd like something with a bit more oomph. I don't have kids, so the wagon has more seating than I need. I'll take the Bugatti, please.

The reality is that I can drive any of these three cars because they all share a common and expected interface. Each car has a steering wheel, a gas pedal, a brake pedal, and turn signals, and each uses gasoline for fuel. The Bugatti is probably more power than I can handle, but the driving interface is the same as the Hyundai's. Because all three cars share the same expected interface, and I have the opportunity to choose my preferred vehicle (and if we're being honest, I'd probably go with the Hyundai).

This is the exact same concept in object-oriented PHP. If I write code that expects an object of a specific class (and therefore a specific implementation), my code's utility is inherently limited because it can only use objects of that one class, forever. However, if I write code that *expects an interface*, my code immediately knows how to use any object that implements that interface. My code does not care *how* the interface is implemented; my code cares only that the interface *is* implemented. Let's drive this home with a demo.

I have a hypothetical PHP class named `DocumentStore` that collects text from different sources: it fetches HTML from remote URLs; it reads stream resources; and it collects terminal command output. Each document stored in a `DocumentStore` instance has a unique ID. [Example 2-6](#) shows the `DocumentStore` class.

## Example 2-6. DocumentStore class definition

```
class DocumentStore
{
    protected $data = [];

    public function addDocument(Documentable $document)
    {
        $key = $document->getId();
        $value = $document->getContent();
        $this->data[$key] = $value;
    }
}
```

```

public function getDocuments()
{
    return $this->data;
}

```

How exactly does this work if the `addDocument()` method only accepts instances of the `Documentable` class? That's a good observation. However, `Documentable` is not a class. It's an interface, and it looks like [Example 2-7](#).

### Example 2-7. Documentable interface definition

```

interface Documentable
{
    public function getId();
    public function getContent();
}

```

This interface definition says that any object implementing the `Documentable` interface must provide a public `getId()` method and a public `getContent()` method.

So how exactly is this helpful? It's helpful because we can create separate document-fetching classes with wildly different implementations. [Example 2-8](#) shows an implementation that can fetch HTML from a remote URL with curl.

### Example 2-8. HtmlDocument class definition

```

class HtmlDocument implements Documentable
{
    protected $url;

    public function __construct($url)
    {
        $this->url = $url;
    }

    public function getId()
    {
        return $this->url;
    }

    public function getContent()
    {
        $ch = curl_init();
        curl_setopt($ch, CURLOPT_URL, $this->url);
        curl_setopt($ch, CURLOPT_RETURNTRANSFER, 1);
        curl_setopt($ch, CURLOPT_CONNECTTIMEOUT, 3);
        curl_setopt($ch, CURLOPT_FOLLOWLOCATION, 1);
        curl_setopt($ch, CURLOPT_MAXREDIRS, 3);
        $html = curl_exec($ch);
        curl_close($ch);

        return $html;
    }
}

```

Another implementation ([Example 2-9](#)) can read a stream resource.

### Example 2-9. StreamDocument class definition

```

class StreamDocument implements Documentable
{
    protected $resource;
    protected $buffer;

    public function __construct($resource, $buffer = 4096)
    {
        $this->resource = $resource;
        $this->buffer = $buffer;
    }
}

```

```

}

public function getId()
{
    return 'resource-' . (int)$this->resource;
}

public function getContent()
{
    $streamContent = '';
    rewind($this->resource);
    while (feof($this->resource) === false) {
        $streamContent .= fread($this->resource, $this->buffer);
    }

    return $streamContent;
}
}

```

And another implementation ([Example 2-10](#)) can fetch the result of a terminal command.

## Example 2-10. StreamDocument class definition

```

class CommandOutputDocument implements Documentable
{
    protected $command;

    public function __construct($command)
    {
        $this->command = $command;
    }

    public function getId()
    {
        return $this->command;
    }

    public function getContent()
    {
        return shell_exec($this->command);
    }
}

```

[Example 2-11](#) shows how we can use the DocumentStore class with our three document-collecting implementations.

## Example 2-11. DocumentStore

```

<?php
$documentStore = new DocumentStore();

// Add HTML document
$htmlDoc = new HtmlDocument('https://php.net');
$documentStore->addDocument($htmlDoc);

// Add stream document
$streamDoc = new StreamDocument(fopen('stream.txt', 'rb'));
$documentStore->addDocument($streamDoc);

// Add terminal command document
$cmdDoc = new CommandOutputDocument('cat /etc/hosts');
$documentStore->addDocument($cmdDoc);

print_r($documentStore->getDocuments());

```

This is really cool because the `HtmlDocument`, `StreamDocument`, and `CommandOutputDocument` classes have nothing in common other than a common interface.

At the end of the day, coding to an interface creates more-flexible code that delegates implementation concerns to others. Many more people (e.g., your office buddies, your open source project's users, or developers you've never met) can write code that works

seamlessly with your code by knowing nothing more than an interface.

# Traits

Many of my PHP developer friends are confused by *traits*, a new concept introduced in PHP 5.4.0. Traits behave like classes but look like interfaces. Which one are they? Neither and both.

A trait is a partial class implementation (i.e., constants, properties, and methods) that can be *mixed into* one or more existing PHP classes. Traits work double duty: they say what a class can do (like an interface), and they provide a modular implementation (like a class).

## Note

You may be familiar with traits in other languages. For example, PHP traits are similar to Ruby's composable modules, or *mixins*.

# Why We Use Traits

The PHP language uses a classical inheritance model. This means you start with a single generalized root class that provides a base implementation. You *extend* the root class to create more specialized classes that *inherit* their immediate parent's implementation. This is called an inheritance hierarchy, and it is a common pattern used by many programming languages.

## Tip

If it helps, picture yourself back in grade school Biology. Remember how you learned about the biological classification system? There are six kingdoms. Each kingdom is extended by phyla. Each phylum is extended by biological classes. Classes are extended by orders, orders by families, families by genera, and genera by species. Each hierarchy extension represents further specialization.

The classical inheritance model works well most of the time. However, what do we do if two unrelated PHP classes need to exhibit similar behavior? For example, a PHP class `RetailStore` and another PHP class `Car` are very different classes and don't share a common parent in their inheritance hierarchies. However, both classes should be geocodable into latitude and longitude coordinates for display on a map.

Traits were created for exactly this purpose. They enable modular implementations that can be injected into otherwise unrelated classes. Traits also encourage code reuse.

My first (bad) reaction is to create a common parent class `Geocodable` that both `RetailStore` and `Car` extend. This is a *bad* solution because it forces two otherwise unrelated classes to share a common ancestor that does not naturally belong in either inheritance hierarchy.

My second (better) reaction is to create a `Geocodable` interface that defines which methods are required to implement the geocoding behavior. The `RetailStore` and `Car` classes can both implement the `Geocodable` interface. This is a good solution that allows each class to retain its natural inheritance hierarchy, but it requires us to duplicate the same geocoding behavior in both classes. This is not a DRY solution.

## Note

DRY is an acronym for *Do not repeat yourself*. It's considered a good practice never to duplicate the same code in multiple locations. You should not need to change code in one location because you changed code in another location. Read more on [Wikipedia](#).

My third (best) reaction is to create a `Geocodable` trait that defines *and* implements the geocodable methods. I can then mix the `Geocodable` trait into both the `RetailStore` and `Car` classes without polluting their natural inheritance hierarchies.

# How to Create a Trait

Here's how you define a PHP trait:

```
<?php
trait MyTrait {
    // Trait implementation goes here
}
```

## Tip

It is considered a good practice to define only one trait per file, just like class and interface definitions.

Let's return to our Geocodable example to better demonstrate traits in practice. We agree both RetailStore and car classes need to provide geocodable behavior, and we've decided inheritance and interfaces are not the best solution. Instead, we create a Geocodable trait that returns latitude and longitude coordinates that we can plot on a map. Our complete Geocodable trait looks like [Example 2-12](#).

## Example 2-12. The Geocodable trait definition

```
<?php
trait Geocodable {
    /** @var string */
    protected $address;

    /** @var \Geocoder\Geocoder */
    protected $geocoder;

    /** @var \Geocoder\Result\Geocoded */
    protected $geocoderResult;

    public function setGeocoder(\Geocoder\GeocoderInterface $geocoder)
    {
        $this->geocoder = $geocoder;
    }

    public function setAddress($address)
    {
        $this->address = $address;
    }

    public function getLatitude()
    {
        if (isset($this->geocoderResult) === false) {
            $this->geocodeAddress();
        }

        return $this->geocoderResult->getLatitude();
    }

    public function getLongitude()
    {
        if (isset($this->geocoderResult) === false) {
            $this->geocodeAddress();
        }

        return $this->geocoderResult->getLongitude();
    }

    protected function geocodeAddress()
    {
        $this->geocoderResult = $this->geocoder->geocode($this->address);

        return true;
    }
}
```

The `Geocodable` trait defines only the properties and methods necessary to implement the geocodable behavior. It does not do anything else.

Our `Geocodable` trait defines three class properties: an address (string), a geocoder object (an instance of `\Geocoder\Geocoder` from the excellent [willdurand/geocoder](#) component by William Durand), and a geocoder result object (an instance of `\Geocoder\Result\Geocoded`). We also define four public methods and one protected method. The `setGeocoder()` method is used to inject the `Geocoder` object. The `setAddress()` method is used to set an address. The `getLatitude()` and `getLongitude()` methods return their respective coordinates. And the `geocodeAddress()` method passes the address string into the `Geocoder` instance to retrieve the geocoder result.

# How to Use a Trait

Using a PHP trait is easy. Add the code `use MyTrait;` inside a PHP class definition. Here's an example. Obviously, replace `MyTrait` with the appropriate PHP trait name:

```
<?php
class MyClass
{
    use MyTrait;

    // Class implementation goes here
}
```

## Tip

Both namespaces and traits are imported with the `use` keyword. *Where* they are imported is different. We import namespaces, classes, interfaces, functions, and constants *outside* of a class definition. We import traits *inside* a class definition. The difference is subtle but important.

Let's return to our `Geocodable` example. We defined the `Geocodable` trait in [Example 2-12](#). Let's update our `RetailStore` class so that it uses the `Geocodable` trait ([Example 2-13](#)). For the sake of brevity, I do not provide the complete `RetailStore` class implementation.

### Example 2-13. The `RetailStore` class definition

```
<?php
class RetailStore
{
    use Geocodable;

    // Class implementation goes here
}
```

That's all we have to do. Now each `RetailStore` instance can use the properties and methods provided by the `Geocodable` trait, as shown in [Example 2-14](#).

### Example 2-14. Traits

```
<?php
$geocoderAdapter = new \Geocoder\HttpAdapter\CurlHttpAdapter();
$geocoderProvider = new \Geocoder\Provider\GoogleMapsProvider($geocoderAdapter);
$geocoder = new \Geocoder\Geocoder($geocoderProvider);

$store = new RetailStore();
$store->setAddress('420 9th Avenue, New York, NY 10001 USA');
$store->setGeocoder($geocoder);

$latitude = $store->getLatitude();
$longitude = $store->getLongitude();
echo $latitude, ':', $longitude;
```

## Warning

The PHP interpreter copies and pastes traits into class definitions at compile time, and it does not protect against incompatibilities introduced by this action. If your PHP trait assumes a class property or method exists (that is *not* defined in the trait itself), be sure those properties and methods exist in the appropriate classes.

# Generators

PHP generators are an underutilized yet remarkably helpful feature introduced in PHP 5.5.0. I think many PHP developers are unaware of generators because their purpose is not immediately obvious. *Generators are simple iterators.* That's it.

Unlike your standard PHP iterator, PHP generators don't require you to implement the `Iterator` interface in a heavyweight class. Instead, generators *compute and yield iteration values on-demand*. This has profound implications for application performance. Think about it. A standard PHP iterator often iterates in-memory, precomputed data sets. This is inefficient, especially with large and formulaic data sets that can be computed instead. This is why we use generators to compute and yield subsequent values on the fly without commandeering valuable memory.

## Note

PHP generators are not a panacea for your iteration needs. Because generators never know the *next* iteration value until asked, it's impossible to rewind or fast-forward a generator. You can iterate in only one direction — forward. Generators are also a once-and-done deal. You can't iterate the same generator more than once. However, you are free to rebuild or clone a generator if necessary.

# Create a Generator

Generators are easy to create because they are just PHP functions that use the `yield` keyword one or more times. Unlike regular PHP functions, generators never return a value. They only *yield* values. [Example 2-15](#) shows a simple generator.

## Example 2-15. Simple generator

```
<?php
function myGenerator() {
    yield 'value1';
    yield 'value2';
    yield 'value3';
}
```

Pretty simple, huh? When you invoke the generator function, PHP returns an object that belongs to the `Generator` class. This object can be iterated with the `foreach()` function. During each iteration, PHP asks the `Generator` instance to compute and provide the next iteration value. What's neat is that the generator pauses its internal state whenever it yields a value. The generator resumes internal state when it is asked for the next value. The generator continues pausing and resuming until it reaches the end of its function definition or an empty `return;` statement. We can invoke and iterate the generator in [Example 2-15](#) like this:

```
<?php
foreach (myGenerator() as $yieldedValue) {
    echo $yieldedValue, PHP_EOL;
}
```

This outputs:

```
value1
value2
value3
```

# Use a Generator

I like to demonstrate how a PHP generator saves memory by implementing a simple `range()` function. First, let's do it the wrong way ([Example 2-16](#)).

## Example 2-16. Range generator (bad)

```
<?php
function makeRange($length) {
    $dataset = [];
    for ($i = 0; $i < $length; $i++) {
        $dataset[] = $i;
    }

    return $dataset;
}

$customRange = makeRange(1000000);
foreach ($customRange as $i) {
    echo $i, PHP_EOL;
}
```

[Example 2-16](#) makes poor use of memory. The `makeRange()` method in [Example 2-16](#) allocates one million integers into a precomputed array. A PHP generator can do the same thing while allocating memory for only *one* integer at any given time, as shown in [Example 2-17](#).

## Example 2-17. Range generator (good)

```
<?php
function makeRange($length) {
    for ($i = 0; $i < $length; $i++) {
        yield $i;
    }
}

foreach (makeRange(1000000) as $i) {
    echo $i, PHP_EOL;
}
```

This is a contrived example. However, just imagine all of the potential data sets that you can compute. Number sequences (e.g., Fibonacci) are an obvious candidate. You can also iterate a stream resource. Imagine you need to iterate a 4 GB comma-separated value (CSV) file and your virtual private server (VPS) has only 1 GB of memory available to PHP. There's no way you can pull the entire file into memory. [Example 2-18](#) shows how we can use a generator instead!

## Example 2-18. CSV generator

```
<?php
function getRows($file) {
    $handle = fopen($file, 'rb');
    if ($handle === false) {
        throw new Exception();
    }
    while (feof($handle) === false) {
        yield fgetcsv($handle);
    }
    fclose($handle);
}

foreach (getRows('data.csv') as $row) {
    print_r($row);
}
```

This example allocates memory for only one CSV row at a time instead of reading the

entire 4 GB CSV file into memory. It also encapsulates the iteration implementation into a tidy package; this lets us quickly change *how* we get data (e.g., CSV, XML, JSON) without interrupting our application code that iterates the data.

Generators are a tradeoff between versatility and simplicity. Generators are *forward-only* iterators. This means you cannot use a generator to rewind, fast-forward, or seek a data set. You can only ask a generator to compute and yield its next value. Generators are most useful for iterating large or numerically sequenced data sets with only a tiny amount of system memory. They are also useful for accomplishing the same simple tasks as larger iterators with less code.

Generators do not add functionality to PHP. You can do what generators do without a generator. However, generators greatly simplify certain tasks while using less memory. If you require more versatility to rewind, fast-forward, or seek through a data set, you're better off writing a custom class that implements the [Iterator interface](#), or using one of PHP's prebuilt [Standard PHP Library \(SPL\) iterators](#).

### Tip

For more generator examples, read [What Generators Can Do For You](#) by Anthony Ferrara ([@ircmaxell](#) on Twitter).

# Closures

*Closures* and *anonymous functions* were introduced in PHP 5.3.0, and they're two of my favorite and most used PHP features. They sound scary (at least I thought so when I first learned about them), but they're actually pretty simple to understand. They're extremely useful tools that every PHP developer should have in the toolbox.

A closure is a function that encapsulates its surrounding state at the time it is created. The encapsulated state exists inside the closure even when the closure lives after its original environment ceases to exist. This is a difficult concept to grasp, but once you do it'll be a life-changing moment.

An anonymous function is exactly that — a function without a name. Anonymous functions can be assigned to variables and passed around just like any other PHP object. But it's still a function, so you can invoke it and pass it arguments. Anonymous functions are especially useful as function or method callbacks.

## Note

Closures and anonymous functions are, in theory, separate things. However, PHP considers them to be one and the same. So when I say *closure*, I also mean *anonymous function*. And vice versa.

PHP closures and anonymous functions use the same syntax as a function, but don't let them fool you. They're actually objects *disguised* as PHP functions. If you inspect a PHP closure or anonymous function, you'll find they are instances of the `Closure` class. Closures are considered first-class value types, just like a string or integer.

# Create

So we know PHP closures look like functions. You should not be surprised, then, that you can create a PHP closure like [Example 2-19](#).

## Example 2-19. Simple closure

```
<?php
$closure = function ($name) {
    return sprintf('Hello %s', $name);
};

echo $closure("Josh");
// Outputs --> "Hello Josh"
```

That's it. [Example 2-19](#) creates a closure object and assigns it to the `$closure` variable. It looks like a standard PHP function: it uses the same syntax, it accepts arguments, and it returns a value. However, it does not have a name.

### Tip

We can invoke the `$closure` variable because the variable's value is a closure, and closure objects implement the `\__invoke()` magic method. PHP looks for and calls the `\__invoke()` method whenever `()` follows a variable name.

I typically use PHP closure objects as function and method callbacks. Many PHP functions expect callback functions, like `array_map()` and `preg_replace_callback()`. This is a perfect opportunity to use PHP anonymous functions! Remember, closures can be passed into other PHP functions as arguments, just like any other value. In [Example 2-20](#), I use a closure object as a callback argument in the `array_map()` function.

## Example 2-20. array\_map closure

```
<?php
$numbersPlusOne = array_map(function ($number) {
    return $number + 1;
}, [1, 2, 3]);
print_r($numbersPlusOne);
// Outputs --> [2, 3, 4]
```

OK, so that wasn't *that* impressive. But remember, before closures PHP developers had no choice but to create a separate named function and refer to that function by name. This was slightly slower to execute, and it segregated a callback's implementation from its usage. Old-school PHP developers used code like this:

```
<?php
// Named callback implementation
function incrementNumber ($number) {
    return $number + 1;
}

// Named callback usage
$numbersPlusOne = array_map('incrementNumber', [1, 2, 3]);
print_r($numbersPlusOne);
```

This code works, but it's not as succinct and tidy as [Example 2-20](#). We don't need a separate `incrementNumber()` named function if we use the function only once as a callback. Closures used as callbacks create more concise and legible code.

# Attach State

So far I've demonstrated nameless (or *anonymous*) functions used as callbacks. Let's explore how to attach and enclose state with a PHP closure. JavaScript developers might be confused by PHP closures because they do not automatically enclose application state like true JavaScript closures. Instead, you must manually attach state to a PHP closure with the closure object's `bindTo()` method or the `use` keyword.

It's far more common to attach closure state with the `use` keyword, so let's look at that first ([Example 2-21](#)). When you attach a variable to a closure via the `use` keyword, the attached variable retains the value assigned to it *at the time it is attached to the closure*.

## Example 2-21. Attaching closure state with use keyword

```
<?php
function enclosePerson($name) {
    return function ($doCommand) use ($name) {
        return sprintf('%s, %s', $name, $doCommand);
    };
}

// Enclose "Clay" string in closure
$clay = enclosePerson('Clay');

// Invoke closure with command
echo $clay('get me sweet tea!');
// Outputs --> "Clay, get me sweet tea!"
```

In [Example 2-21](#), the `enclosePerson()` named function accepts a `$name` argument, and it returns a closure object that *encloses* the `$name` argument. The returned closure object preserves the `$name` argument's value even after the closure exits the `enclosePerson()` function's scope. The `$name` variable still exists in the closure!

### Tip

You can pass multiple arguments into a closure with the `use` keyword. Separate multiple arguments with a comma, just as you do with any PHP function or method arguments.

Don't forget, PHP closures are objects. Each closure instance has its own internal state that is accessible with the `$this` keyword just like any other PHP object. A closure object's default state is pretty boring; it has a magic `__invoke()` method and a `bindTo()` method. That's it.

However, the `bindTo()` method opens the door to some interesting possibilities. This method lets us *bind* a closure object's internal state to a *different object*. The `bindTo()` method accepts an important second argument that specifies the PHP class of the object to which the closure is bound. This lets the closure access protected and private member variables of the object to which it is bound.

You'll find the `bindTo()` method is often used by PHP frameworks that map route URLs to anonymous callback functions. Frameworks accept an anonymous function and bind it to the application object. This lets you reference the primary application object inside the anonymous function with the `$this` keyword, as shown in [Example 2-22](#).

## Example 2-22. Attaching closure state with the bindTo method

```
01. <?php
02. class App
```

```

03. {
04.     protected $routes = array();
05.     protected $responseStatus = '200 OK';
06.     protected $responseContentType = 'text/html';
07.     protected $responseBody = 'Hello world';
08.
09.     public function addRoute($routePath, $routeCallback)
10.    {
11.        $this->routes[$routePath] = $routeCallback->bindTo($this, __CLASS__);
12.    }
13.
14.    public function dispatch($currentPath)
15.    {
16.        foreach ($this->routes as $routePath => $callback) {
17.            if ($routePath === $currentPath) {
18.                $callback();
19.            }
20.        }
21.
22.        header('HTTP/1.1 ' . $this->responseStatus);
23.        header('Content-type: ' . $this->responseContentType);
24.        header('Content-length: ' . mb_strlen($this->responseBody));
25.        echo $this->responseBody;
26.    }
27. }

```

Pay close attention to the `addRoute()` method. It accepts a route path (e.g., `/users/josh`) and a route callback. The `dispatch()` method accepts the current HTTP request path and invokes the matching route callback. The magic happens on line 11 when we bind the route callback to the current App instance. This lets us create a callback function that can manipulate the App instance state:

```

<?php
$app = new App();
$app->addRoute('/users/josh', function () {
    $this->responseContentType = 'application/json;charset=utf8';
    $this->responseBody = '{"name": "Josh"}';
});
$app->dispatch('/users/josh');

```

# Zend OPcache

Bytecode caches are not new to PHP. We've had optional standalone extensions like Alternative PHP Cache (APC), eAccelerator, ionCube, and XCache. But none of these was *built into* the PHP core distribution until now. As of PHP 5.5.0, PHP has its own built-in *bytecode cache* called Zend OPcache.

First, let me explain what a bytecode cache is and why it is important. PHP is an *interpreted* language. When the PHP interpreter executes a PHP script, the interpreter parses the PHP script code, compiles the PHP code into a set of existing [Zend Opcodes](#) (machine-code instructions), and executes the bytecode. This happens for each PHP file during every request. This is a lot of overhead, especially if PHP must parse, compile, and execute PHP scripts over and over again for every HTTP request. If only there were a way to *cache* precompiled bytecode to reduce application response times and reduce stress on our system resources. You're in luck.

A bytecode cache stores precompiled PHP bytecode. This means the PHP interpreter does not need to read, parse, and compile PHP code on every request. Instead, the PHP interpreter can read the precompiled bytecode from memory and execute it immediately. This is a huge timesaver and can drastically improve application performance.

# Enable Zend OPcache

Zend OPcache isn't enabled by default; you must explicitly enable Zend OPcache when you compile PHP.

## Note

If you choose a shared web host, be sure you choose a good hosting company that provides PHP 5.5.0 or newer with Zend OPcache enabled.

If you compile PHP yourself (i.e., on a VPS or dedicated server), you must include this option in your PHP `./configure` command:

```
--enable-opcache
```

After you compile PHP, you must also specify the path to the Zend OPcache extension in your `php.ini` file with this line:

```
zend_extension=/path/to/opcache.so
```

The Zend OPcache extension file path is displayed immediately after PHP compiles successfully. If you forget to look for this as I often do, you can also find the PHP extension directory with this command:

```
php-config --extension-dir
```

## Warning

If you use the popular [Xdebug](#) profiler by the incomparable Derick Rethans, your `php.ini` file must load the Zend OPcache extension *before* Xdebug.

After you update the `php.ini` file, restart the PHP process and you're ready to go. You can confirm Zend OPcache is working correctly by creating a PHP file with this content:

```
<?php  
phpinfo();
```

View this PHP file in a web browser and scroll down until you see the Zend OPcache extension section shown in [Figure 2-2](#). If you don't see this section, Zend OPcache is not running.

Zend OPcache		
	Local Value	Master Value
Opcache.Caching	Up and Running	
Optimization	Enabled	
Startup	OK	
Shared memory model	shmop	
Cache hits	0	
Cache misses	1	
Used memory	3440032	
Free memory	6184032	
Wasted memory	0	
Interned Strings Used memory	50232	
Interned Strings Free memory	5011672	
Cached scripts	1	
Cached keys	1	
Max keys	3007	
GC'd keys	0	
Heavily keys restarts	0	
Manual restarts	0	
<hr/>		
Directive	Local Value	Master Value
opcache.blacklist_filename	/var/www	/var/www
opcache.consistency_checks	0	0
opcache.dups_fix	Off	Off
opcache.enable	On	On
opcache.enable_cli	Off	Off
opcache.error_log	/var/www	/var/www
opcache.fast_shutdown	1	1
opcache.file_update_protection	0	0
opcache.force_restart_timeout	180	180
opcache.interned_strings_buffer	4	4
opcache.load_comments	1	1
opcache.log_verbosity_level	1	1
opcache.max_accelerated_files	3000	3000

**Figure 2-2. Zend OPcache INI settings**

# Configure Zend OPcache

When Zend OPcache is enabled, you should configure the Zend OPcache settings in your *php.ini* configuration file. Here are the OPcache settings I like to use:

```
opcache.validate_timestamps = 1 // "0" in production
opcache.revalidate_freq = 0
opcache.memory_consumption = 64
opcache.interned_strings_buffer = 16
opcache.max_accelerated_files = 4000
opcache.fast_shutdown = 1
```

## Tip

Learn more about these Zend OPcache settings in [Chapter 8](#). Find a complete list of Zend OPcache settings at [PHP.net](#).

## Use Zend OPcache

This part's easy because the Zend OPcache works automatically when enabled. Zend OPcache automatically caches precompiled PHP bytecode in memory and executes the bytecode if available.

Be careful if the `opcache.validate_timestamps` INI directive is false. When this setting is false, the Zend OPcache does not know about changes to your PHP scripts, and you must manually clear Zend OPcache's bytecode cache before it recognizes changes to your PHP files. This setting is good for production but inconvenient for development. You can enable automatic cache revalidation with these `php.ini` configuration settings:

```
opcache.validate_timestamps=1  
opcache.revalidate_freq=0
```

# Built-in HTTP server

Did you know that PHP has a built-in web server as of PHP 5.4.0? This is another hidden gem unknown to PHP developers who assume they need Apache or nginx to preview PHP applications. You shouldn't use it for production, but PHP's built-in web server is a perfect tool for local development.

I use PHP's built-in web server every day, whether I'm writing PHP or not. I use it to preview [Laravel](#) and [Slim Framework](#) applications. I use it while building websites with the Drupal content-management framework. I also use it to preview static HTML and CSS if I'm just building out markup.

## Tip

Remember, the PHP built-in server is a web server. It speaks HTTP, and it can serve static assets in addition to PHP files. It's a great way to write and preview HTML locally without installing MAMP, WAMP, or a heavyweight web server.

## Start the Server

It's easy to start the PHP web server. Open your terminal application, navigate to your project's document root directory, and execute this command:

```
php -S localhost:4000
```

This command starts a new PHP web server accessible at *localhost*. It listens on port 4000. Your current working directory is the web server's document root.

You can now open your web browser and navigate to <http://localhost:4000> to preview your application. As you browse your application in your web browser, each HTTP request is logged to standard out in your terminal application so you can see if your application throws 400 or 500 responses.

Sometimes it's useful to access the PHP web server from other machines on your local network (e.g., for previewing on your iPad or local Windows box). To do this, tell the PHP web server to listen on all interfaces by using `0.0.0.0` instead of `localhost`:

```
php -S 0.0.0.0:4000
```

When you are ready to stop the PHP web server, close your terminal application or press `Ctrl+C`.

# Configure the Server

It's not uncommon for an application to require its own PHP INI configuration file, especially if it has unique requirements for memory usage, file uploads, profiling, or bytecode caching. You can tell the PHP built-in server to use a specific INI file with the `-c` option:

```
php -S localhost:8000 -c app/config/php.ini
```

## Tip

It's a good idea to keep the custom INI file beneath the application's root directory and, optionally, version-control the INI file if it should be shared with other developers on your team.

# Router Scripts

The PHP built-in server has one glaring omission. Unlike Apache or nginx, it doesn't support `.htaccess` files. This makes it difficult to use *front controllers* that are common in many popular PHP frameworks.

## Note

A front controller is a single PHP file to which all HTTP requests are forwarded (via `.htaccess` files or rewrite rules). The front-controller PHP file is responsible for routing the request and dispatching the appropriate PHP code. This is a common pattern used by Symfony and other popular frameworks.

The PHP built-in server mitigates this omission with *router scripts*. The router script is executed before every HTTP request. If the router script returns false, the static asset referenced by the current HTTP request URI is returned. Otherwise, the output of the router script is returned as the HTTP response body. In other words, if you use a router script you're effectively hardcoding the same functionality as an `.htaccess` file.

Using a router script is easy. Just pass the PHP script file path as a argument when you start up the PHP built-in server:

```
php -S localhost:8000 router.php
```

## Detect the Built-in Server

Sometimes it's helpful to know if your PHP script is served by PHP's built-in web server versus a traditional web server like Apache or nginx. Perhaps you need to set specific headers for nginx (e.g., `Status:`) that should not be set for the PHP web server. You can detect the PHP web server with the `php_sapi_name()` function. This function returns the string `cli-server` if the current script is served with the PHP built-in server:

```
<?php
if (php_sapi_name() === 'cli-server') {
    // PHP web server
} else {
    // Other web server
}
```

## Drawbacks

PHP's built-in web server should not be used for production. It is for local development only. If you use the PHP built-in web server on a production machine, be prepared for a lot of disappointed users and a flood of [Pingdom](#) downtime notifications.

- The built-in server performs suboptimally because it handles one request at a time, and each HTTP request is blocking. Your web application will stall if a PHP file must wait on a slow database query or remote API response.
- The built-in server supports only a [limited number of mimetypes](#).
- The built-in server has limited URL rewriting with router scripts. You'll need Apache or nginx for more advanced URL rewrite behavior.

# What's Next

The modern PHP language has a lot of powerful features that can improve your applications. I've talked about my favorite features in this chapter. You can learn more about PHP's latest features on the [PHP website](#).

I'm sure you're excited to start using these fun features in your applications. However, it's important that you use these features correctly according to PHP community standards. And that's exactly what we talk about in the next chapter.

## **Part II. Good Practices**

# Chapter 3. Standards

There is a mind-boggling number of PHP components and frameworks. There are macro frameworks like [Symfony](#) and [Laravel](#). There are micro frameworks like [Silex](#) and [Slim](#). And there are legacy frameworks like [CodeIgniter](#) that were built long before modern PHP components existed. The modern PHP ecosystem is a veritable melting pot of code that helps us developers build amazing applications.

Unfortunately, older PHP frameworks were developed in isolation and do not share code with other PHP frameworks. If your project uses one of these older PHP frameworks, you're stuck with the framework and must live inside the framework's ecosystem. This centralized environment is OK if you are happy with the framework's tools. However, what if you use the CodeIgniter framework but want to cherry-pick a helper library from the Symfony framework? You're probably out of luck unless you write a one-off adapter specifically for your project.

What we've got here is a failure to communicate.

Cool Hand Luke

Do you see the problem? Frameworks created in isolation were not designed to communicate with other frameworks. This is extremely inefficient, both for developers (creativity is limited by framework choice) and for frameworks themselves (they re-invent code that already exists elsewhere). I have good news, though. The PHP community has evolved from a centralized framework model to a distributed ecosystem of efficient, interoperable, and specialized components.

# PHP-FIG to the Rescue

Several PHP framework developers recognized this problem and began a conversation at [php|tek](#) (a popular PHP conference) in 2009. They discussed how to improve intraframework communication and efficiency. Instead of writing a new and tightly coupled logging class, for example, what if a PHP framework could share a decoupled logging class like [monolog](#)? Instead of writing its own HTTP request and response classes, what if a PHP framework could instead cherry-pick the excellent HTTP request and response classes from the Symfony Framework's [symfony/httpfoundation](#) component? For this to work, PHP frameworks must speak a common language that allows them to communicate and share with other frameworks. They need *standards*.

The PHP framework developers who serendipitously met at [php|tek](#) eventually created the [PHP Framework Interop Group](#) (PHP-FIG). The PHP-FIG is a group of PHP framework representatives who, according to the PHP-FIG website, "talk about the commonalities between our projects and find ways we can work together." The PHP-FIG creates recommendations that PHP frameworks can voluntarily implement to improve communication and sharing with other frameworks.

The PHP-FIG is a self-appointed group of framework representatives. Its members are not elected, and they are not special in any way other than their willingness to improve the PHP community. Anyone can request membership. And anyone can submit feedback to PHP-FIG recommendations that are in the proposal process. Final PHP-FIG recommendations are typically adopted and implemented by many of the largest and most popular PHP frameworks. I highly encourage you to get involved with the PHP-FIG, if only to send feedback and help shape the future of your favorite PHP frameworks.

## Note

It is very important to understand the PHP-FIG provides *recommendations*. These are not rules. These are not requirements. These are carefully crafted suggestions that make our lives as PHP developers (and PHP framework authors) easier.

# **Framework Interoperability**

The PHP-FIG's mission is framework interoperability. And framework interoperability means working together via interfaces, autoloading, and style.

# Interfaces

PHP frameworks work together via shared interfaces. PHP interfaces allow frameworks to assume what methods are provided by third-party dependencies without worrying about *how* the dependencies implement the interface.

## Note

Refer to [Chapter 2](#) for an in-depth explanation of PHP interfaces.

For example, a framework is happy to share a third-party logger object *assuming* the shared logger object implements the `emergency()`, `alert()`, `critical()`, `error()`, `warning()`, `notice()`, `info()`, and `debug()` methods. Exactly how these methods are implemented is irrelevant. Each framework cares only that the third-party dependency does implement these methods.

Interfaces enable PHP developers to build, share, and use specialized components instead of monolithic frameworks.

## Autoloading

PHP frameworks work together via autoloading. Autoloading is the process by which a PHP class is automatically located and loaded *on-demand* by the PHP interpreter during runtime.

Before PHP standards, PHP components and frameworks implemented their own unique autoloaders using the magic `\__autoload()` method or the more recent `spl_autoload_register()` method. This required us to learn and use a unique autoloader for each component and framework. Nowadays, most modern PHP components and frameworks are compatible with a common autoloader standard. This means we can mix and match multiple PHP components with only one autoloader.

## Style

PHP frameworks work together via code style. Your code style determines spacing, capitalization, and bracket placement (among other things). If PHP frameworks agree on a standard code style, PHP developers don't need to learn a new style every time they use a new PHP framework. Instead, PHP framework code is immediately familiar. A standard code style also lowers the barrier for new project contributors, who can spend more time squashing bugs and less time learning an unfamiliar style.

Standard code style also improves our own projects. Every developer has a unique style with more than a few idiosyncrasies, and these become a problem when multiple developers work on the same codebase. A standard code style helps all team members immediately understand the same codebase regardless of its author.

# What Is a PSR?

PSR is an acronym for *PHP standards recommendation*. If you've recently read a PHP-related blog, you have probably seen the terms PSR-1, PSR-2, PSR-3, and so on. These are PHP-FIG recommendations. Their names begin with PSR- and end with a number. Each PHP-FIG recommendation solves a specific problem that is frequently encountered by most PHP frameworks. Instead of PHP frameworks continually re-solving the same problems, frameworks can instead adopt the PHP-FIG's recommendations and build upon shared solutions.

The PHP-FIG has published five recommendations as of this book's publication:

- [PSR-1: Basic code style](#)
- [PSR-2: Strict code style](#)
- [PSR-3: Logger interface](#)
- [PSR-4: Autoloading](#)

## Note

If you counted only four recommendations, you are correct. The PHP-FIG deprecated its first [PSR-0](#) recommendation. This first recommendation was replaced by the newer [PSR-4](#) recommendation.

Notice how the PHP-FIG recommendations coincide nicely with the three interoperability methods I mentioned earlier: interfaces, autoloading, and code style. This is not a coincidence.

I'm really excited about the PHP-FIG recommendations. They are the bedrock beneath the modern PHP ecosystem. They define the means with which PHP components and frameworks interoperate. I admit, PHP standards are not the most scintillating of topics, but they are (in my mind) prerequisite to understanding modern PHP.

# PSR-1: Basic Code Style

If you want to write PHP code that is compatible with community standards, start with PSR-1. It's the easiest PHP standard to use. It's so easy, you're probably already using it without even trying. PSR-1 provides simple guidelines that are easy to implement with minimal effort. The point of PSR-1 is to provide a baseline code style for participating PHP frameworks. You must satisfy these requirements to be compatible with PSR-1:

## PHP tags

You must surround your PHP code with either the `<?php ?>` or `<?= ?>` tags. You must not use any other PHP tag syntax.

## Encoding

All PHP files must be encoded with the UTF-8 character set without a byte order mark (BOM). This sounds complicated, but your text editor or IDE can do this for you automatically.

## Objective

A single PHP file can either define symbols (a class, trait, function, constant, etc.) or perform an action that has side effects (e.g., create output or manipulate data). A PHP file should not do both. This is a simple task and requires only a little foresight and planning on your part.

## Autoloading

Your PHP namespaces and classes must support the PSR-4 autoloader standard. All you have to do is choose appropriate names for your PHP symbols and make sure their definition files are in the expected location. We'll chat about PSR-4 soon.

## Class names

Your PHP class names must use the common `CamelCase` format. This format is also called `TitleCase`. Examples are `CoffeeGrinder`, `CoffeeBean`, and `PourOver`.

## Constant names

Your PHP constants must use all uppercase characters. They may use underscores to separate words if necessary. Examples are `WOOT`, `LET OUR POWERS COMBINE`, and `GREAT_SCOTT`.

## Method names

Your PHP method names must use the common `camelCase` format. This means the method name's first character is lowercase, and the first letter of each subsequent word in the method name is uppercase. Examples are `phpIsAwesome`, `iLoveBacon`, and `tenantIsMyFavoriteDoctor`.

# PSR-2: Strict Code Style

After you implement PSR-1, the next step is to implement PSR-2. The PSR-2 standard further defines PHP code style with stricter guidelines.

The PSR-2 code style is a godsend for PHP frameworks that have many contributors from around the world, all of whom bring their own unique style and preferences. A common strict code style lets developers write code that is easily and quickly understood by other contributors.

Unlike PSR-1, the PSR-2 recommendation contains stricter guidelines. Some of PSR-2's guidelines may not be what you prefer. However, PSR-2 is the preferred code style of many popular PHP frameworks. You don't have to use PSR-2, but doing so will drastically improve the ability for other developers to read, use, and contribute to your PHP code.

## Tip

You should use the stricter PSR-2 code style. Even though I call it *strict*, it's easy enough to write. Eventually it'll become second nature. Also, there are tools available to automatically format existing PHP code into the PSR-2 style.

## Implement PSR-1

The PSR-2 code style requires that you implement the PSR-1 code style.

### Indentation

This is a hot topic that is typically divided into two camps. The first camp prefers to indent code with a single tab character. The second (and much cooler) camp prefers to indent code with several space characters. The PSR-2 recommendation says PHP code should be indented with four space characters.

## Tip

From personal experience, space characters are better suited for indentation because a space is a definitive measure that largely renders the same in different code editors. A tab, however, can vary in width and renders differently in different code editors. Use four space characters to indent code to ensure the best visual continuity for your code.

### Files and lines

Your PHP files must use Unix linefeed (LF) endings, must end with a single blank line, and must not include a trailing ?> PHP tag. Each line of code *should not* exceed 80 characters. Ultimately, each line of code *must not* exceed 120 characters. Each line must not have trailing white space. This sounds like a lot of work, but it's really not. Most code editors can automatically wrap code to a specific width, strip trailing whitespace, and use Unix line endings. All of these should happen automatically with little to no thought on your part.

## Tip

Omitting the trailing ?> PHP tag was odd to me at first. However, it is good practice to omit the closing tag to avoid unexpected output errors. If you do include the ?> closing

tag, and also a blank line *after* the closing tag, the blank line is considered output and can cause errors (e.g., when you set HTTP headers).

## Keywords

I know many PHP developers who type TRUE, FALSE, and NULL in uppercase characters. If you do this, try to unlearn this practice and instead use only lowercase characters from now on. The PSR-2 recommendation says that you should type all PHP keywords in lowercase.

## Namespaces

Each namespace declaration must be followed by one blank line. Likewise, when you import or alias namespaces with the use keyword, you must follow the block of use declarations with one blank line. Here's an example:

```
<?php
namespace My\Component;

use Symfony\Components\HttpFoundation\Request;
use Symfony\Components\HttpFoundation\Response;

class App
{
    // Class definition body
}
```

## Classes

Like indentation, class definition bracket placement is another topic that attracts heated debate. Some prefer the opening bracket to reside on the same line as the class name. Others prefer the opening bracket to reside on a new line after the class name. The PSR-2 recommendation says a class definition's opening bracket must reside on a new line immediately after the class definition name as shown in the following example. The class definition's closing bracket must reside on a new line after the end of the class definition body. This is probably what you have been doing already so it's not as big a deal. If your class extends another class or implements an interface, the extends and implements keywords must appear on the same line as the class name:

```
<?php
namespace My\App;

class Administrator extends User
{
    // Class definition body
}
```

## Methods

Method definition bracket placement is the same as class definition bracket placement. The method definition's opening bracket resides on a new line immediately after the method name. The method definition's closing bracket resides on a new line immediately after the method definition body. Pay close attention to the method arguments. The first parenthesis does not have a trailing space, and the last parenthesis does not have a preceding space. Each method argument (except the last) is followed immediately by a comma and one space character:

```
<?php
namespace Animals;

class StrawNeckedIbis
```

```

{
    public function flapWings($number0fTimes = 3, $speed = 'fast')
    {
        // Method definition body
    }
}

```

## Visibility

You must declare a *visibility* for each class property and method. A visibility is one of `public`, `protected`, or `private`; visibility determines how a property or method is accessible within and outside of its class. Old-school PHP developers may be accustomed to prefixing class properties with the `var` keyword and prefixing private methods with the underscore `_` character. *Do not do this.* Use one of the visibilities listed previously instead. If you declare a class property or method as `abstract` or `final`, the `abstract` and `final` qualifiers must appear *before* the visibility. If you declare a property or method as `static`, the `static` qualifier must appear *after* the visibility:

```

<?php
namespace Animals;

class StrawNeckedIbis
{
    // Static property with visibility
    public static $numberOfBirds = 0;

    // Method with visibility
    public function __construct()
    {
        static::$numberOfBirds++;
    }
}

```

## Control structures

This is probably the one guideline that trips me up the most. All *control structure keywords* must be followed by a single space character. A control structure keyword is `if`, `elseif`, `else`, `switch`, `case`, `while`, `do while`, `for`, `foreach`, `try`, or `catch`. If the control structure keyword requires a set of parentheses, make sure the first parenthesis is not followed by a space character, and make sure the last parenthesis is not preceded by a space character. Unlike in class and method definitions, opening brackets that appear after a control structure keyword must remain on the same line as the control structure keyword. The control structure keyword's closing bracket must reside on a new line. Here's a brief example that demonstrates these guidelines:

```

<?php
$gorilla = new \Animals\Gorilla;
$ibis = new \Animals\StrawNeckedIbis;

if ($gorilla->isAwake() === true) {
    do {
        $gorilla->beatChest();
    } while ($ibis->isAsleep() === true);

    $ibis->flyAway();
}

```

## Tip

You can automate PSR-1 and PSR-2 code style compatibility. Many code editors automatically format your code according to PSR-1 and PSR-2. There are tools available to help you audit and format your code against PHP standards, too. One such tool is the

[PHP Code Sniffer](#), also called `phpcs`. This tool (used directly on the command line or via your IDE) reports inconsistencies between your code and a given PHP code standard. You can install `phpcs` with most package managers (e.g., PEAR, Homebrew, Aptitude, or Yum).

You can also use Fabien Potencier's [PHP-CS-Fixer](#) to correct most incompatibilities automatically. This tool is not perfect, but it'll get you most of the way toward PSR compatibility with little or no effort on your part.

# PSR-3: Logger Interface

The third PHP-FIG recommendation is not a set of guidelines like its predecessors. PSR-3 is an interface, and it prescribes methods that can be implemented by PHP logger components.

## Note

A *logger* is an object that writes messages of varying importance to a given output. Logged messages are used to diagnose, inspect, and troubleshoot application operation, stability, and performance. Examples include writing debug information to a text file during development, capturing website traffic statistics into a database, or emailing fatal error diagnostics to a website administrator. The most popular PHP logger component is [monolog/monolog](#), created by Jordi Boggiano.

Many PHP frameworks implement logging in some capacity. Before the PHP-FIG, each framework solved logging differently, often with a proprietary implementation. In the spirit of interoperability and specialization — recurring motifs in modern PHP — the PHP-FIG established the PSR-3 logger interface. Frameworks that accept PSR-3 compatible loggers accomplish two important things: logging concerns are delegated to a third party, and end users can provide their preferred logger component. It's a win-win for everyone.

# Write a PSR-3 Logger

A PHP logger component compatible with the PSR-3 recommendation must include a PHP class that implements the interface named `Psr\Log\LoggerInterface`. The PSR-3 interface replicates the [RFC 5424 syslog protocol](#) and prescribes nine methods:

```
<?php
namespace Psr\Log;

interface LoggerInterface
{
    public function emergency($message, array $context = array());
    public function alert($message, array $context = array());
    public function critical($message, array $context = array());
    public function error($message, array $context = array());
    public function warning($message, array $context = array());
    public function notice($message, array $context = array());
    public function info($message, array $context = array());
    public function debug($message, array $context = array());
    public function log($level, $message, array $context = array());
}
```

Each interface method maps to a corresponding RFC 5424 protocol level and accepts two arguments. The first `$message` argument must be a string or an object with a `__toString()` method. The second `$context` argument is optional and provides an array of placeholder values that replace tokens in the first argument.

## Tip

Use the `$context` argument to construct complicated logger messages. You use *placeholders* in the message text. A placeholder looks like `{placeholder_name}`; it contains a {, the placeholder name, and a }. A placeholder does not contain spaces. The `$context` argument is an associative array; its keys are placeholder names (without brackets), and its values replace the related placeholders in the message text.

To write a PSR-3 logger, create a new PHP class that implements the `Psr\Log\LoggerInterface` interface and provide a concrete implementation for each interface method.

# Use a PSR-3 Logger

If you are creating your own PSR-3 logger, stop and reconsider if you are spending your time wisely. I strongly discourage you from writing your own logger. Why? Because there are some truly amazing PHP logger components already available!

If you need a PSR-3 logger, just use [monolog/monolog](#). Don't waste time looking elsewhere. The Monolog PHP component fully implements the PSR-3 interface, and it's easily extended with custom message formatters and handlers. Monolog's message handlers let you send log messages to text files, syslog, email, HipChat, Slack, networked servers, remote APIs, databases, and pretty much anywhere else you can imagine. In the very unlikely event Monolog does not provide a handler for your desired output destination, it's super-easy to write and integrate your own Monolog message handler.

[Example 3-1](#) demonstrates how easy it is to setup Monolog and log messages to a text file.

## Example 3-1. Using Monolog

```
<?php
use Monolog\Logger;
use Monolog\Handler\StreamHandler;

// Prepare logger
$log = new Logger('myApp');
$log->pushHandler(new StreamHandler('logs/development.log', Logger::DEBUG));
$log->pushHandler(new StreamHandler('logs/production.log', Logger::WARNING));

// Use logger
$log->debug('This is a debug message');
$log->warning('This is a warning message');
```

## PSR-4: Autoloaders

The fourth PHP-FIG recommendation describes a standardized *autoloader* strategy. An autoloader is a strategy for finding a PHP class, interface, or trait and loading it into the PHP interpreter on-demand at runtime. PHP components and frameworks that support the PSR-4 autoloader standard can be located by and loaded into the PHP interpreter with only *one* autoloader. This is a big deal given the modern PHP ecosystem's affinity for many interoperable components.

# Why Autoloaders Are Important

How often have you seen code like this at the top of your PHP files?

```
<?php
include 'path/to/file1.php';
include 'path/to/file2.php';
include 'path/to/file3.php';
```

All too often, right? You're probably familiar with the `require()`, `require_once()`, `include()`, and `include_once()` functions. These functions load an external PHP file into the current script, and they work wonderfully if you have only a few PHP scripts. However, what if you need to include a hundred PHP scripts? What if you need to include a thousand PHP scripts? The `require()` and `include()` functions do not scale well, and this is why PHP autoloaders are important. An autoloader is a strategy for finding a PHP class, interface, or trait and loading it into the PHP interpreter on-demand at runtime, without explicitly including files as the example does.

Before the PHP-FIG introduced its PSR-4 recommendation, PHP component and framework authors used the `__autoload()` and `spl_autoload_register()` functions to register custom autoloader strategies. Unfortunately, each PHP component and framework used a unique autoloader, and every autoloader used different logic to locate and load PHP classes, interfaces, and traits. Developers using these components and frameworks were obliged to invoke each component's autoloader when bootstrapping a PHP application. I use Sensio Labs' [Twig](#) template component all the time. It's awesome. Without PSR-4, however, I have to read Twig's documentation and figure out how to register its custom autoloader in my application's bootstrap file, like this:

```
<?php
require_once '/path/to/lib/Twig/Autoloader.php';
Twig_Autoloader::register();
```

Imagine having to research and register unique autoloaders for every PHP component in your application. The PHP-FIG recognized this problem and proposed the PSR-4 autoloader recommendation to facilitate component interoperability. Thanks to PSR-4, we can autoload all of our application's PHP components with only one autoloader. This is amazing. Most modern PHP components and frameworks are compatible with PSR-4. If you write and distribute your own components, make sure they are compatible with PSR-4, too! Participating components include Symfony, Doctrine, Monolog, Twig, Guzzle, SwiftMailer, PHPUnit, Carbon, and many others.

# The PSR-4 Autoloader Strategy

Like any PHP autoloader, PSR-4 describes a strategy to locate and load PHP classes, interfaces, and traits during runtime. The PSR-4 recommendation does not require you to change your code's implementation. Instead, PSR-4 only suggests how your code is organized into filesystem directories and PHP namespaces. The PSR-4 autoloader strategy relies on PHP namespaces and filesystem directories to locate and load PHP classes, interfaces, and traits.

The essence of PSR-4 is mapping a top-level namespace prefix to a specific filesystem directory. For example, I can tell PHP that classes, interfaces, or traits beneath the `\Oreilly\ModernPHP` namespace live beneath the `src/` physical filesystem directory. PHP now knows that any classes, interfaces, or traits that use the `\Oreilly\ModernPHP` namespace prefix correspond to directories and files beneath the `src/` directory. For example, the `\Oreilly\ModernPHP\Chapter1` namespace corresponds to the `src/Chapter1` directory, and the `\Oreilly\ModernPHP\Chapter1\Example` class corresponds to the `src/Chapter1/Example.php` file.

## Tip

PSR-4 lets you map a namespace *prefix* to a filesystem directory. The namespace prefix can be one top-level namespace. The namespace prefix can also be a top-level namespace *and any number of subnamespaces*. It's quite flexible.

Remember when we talked about vendor namespaces in [Chapter 2](#)? The PSR-4 autoloader strategy is most relevant to component and framework authors who distribute code to other developers. A PHP component's code lives beneath a unique vendor namespace, and the component's author specifies which filesystem directory corresponds to the component's vendor namespace — exactly as I demonstrated earlier. We'll explore this concept more in [Chapter 4](#).

# How to Write a PSR-4 Autoloader (and Why You Shouldn't)

We know that PSR-4 compatible code has a namespace prefix that maps to a base filesystem directory. We also know that subnamespaces beneath the namespace prefix map to subdirectories beneath the base filesystem directory. [Example 3-2](#) shows an autoloader implementation, borrowed from the [PHP-FIG website](#), that finds and loads classes, interfaces, and traits based on the PSR-4 autoloader strategy.

## Example 3-2. PSR-4 autoloader

```
<?php
/**
 * An example of a project-specific implementation.
 *
 * After registering this autoload function with SPL, the following line
 * would cause the function to attempt to load the \Foo\Bar\Baz\Qux class
 * from /path/to/project/src/Baz/Qux.php:
 *
 *     new \Foo\Bar\Baz\Qux;
 *
 * @param string $class The fully qualified class name.
 * @return void
 */
spl_autoload_register(function ($class) {

    // project-specific namespace prefix
    $prefix = 'Foo\\Bar\\';

    // base directory for the namespace prefix
    $base_dir = __DIR__ . '/src/';

    // does the class use the namespace prefix?
    $len = strlen($prefix);
    if (strncmp($prefix, $class, $len) !== 0) {
        // no, move to the next registered autoloader
        return;
    }

    // get the relative class name
    $relative_class = substr($class, $len);

    // replace the namespace prefix with the base directory, replace namespace
    // separators with directory separators in the relative class name, append
    // with .php
    $file = $base_dir . str_replace('\\', '/', $relative_class) . '.php';

    // if the file exists, require it
    if (file_exists($file)) {
        require $file;
    }
});
```

Copy and paste this into your application, change the `$prefix` and `$base_dir` variables, and you have yourself a working PSR-4 autoloader. However, if you find yourself writing your own PSR-4 autoloader, stop and ask yourself if what you are doing is really necessary. Why? Because we can use PSR-4 autoloaders that are automagically generated by the Composer dependency manager. Conveniently enough, that's exactly what we'll talk about next in [Chapter 4](#).

# Chapter 4. Components

Modern PHP is less about monolithic frameworks and more about composing solutions from specialized and interoperable components. When I build a new PHP application, rarely do I reach straight for Laravel or Symfony. Instead, I think about which existing PHP components I can combine to solve my problem.

# Why Use Components?

Modern PHP components are a new concept to many PHP programmers. I had no idea about PHP components until a few years ago. Before I knew better, I instinctually started PHP applications with a massive framework like Symfony or CodeIgniter without considering other options. I invested in a single framework's closed ecosystem and used the tools it provided. If the framework did not provide what I needed, I was out of luck and I built additional functionality on my own. It was also difficult to integrate custom or third-party libraries into larger frameworks because they did not share common interfaces. I am relieved to inform you that times have changed, and we are no longer beholden to monolithic frameworks and their walled gardens.

Today, we choose from a vast and continually growing collection of specialized components to create custom applications. Why waste time coding an HTTP request and response library when the [guzzle/http](#) component already exists? Why create a new router when the [aura/router](#) and [orno/route](#) components work great? Why spend time coding an adapter to Amazon's S3 online storage service when the [aws/aws-sdk-php](#) and [league/flysystem](#) components can be used instead? You get my drift. Other developers have spent countless development hours creating, perfecting, and testing specialized components that do one thing really well. It's silly not to take advantage of these components to build better applications more quickly instead of wasting time reinventing the wheel.

# What Are Components?

A component is a bundle of code that helps solve a specific problem in your PHP application. For example, if your PHP application sends and receives HTTP requests, there's a component to do that. If your PHP application parses comma-delimited data, there's a PHP component to do that. If your PHP application needs a way to log messages, there's a component for that. Instead of rebuilding already-solved functionality, we use PHP components and spend more time solving our project's larger objectives.

## Note

Technically speaking, a PHP component is a collection of related classes, interfaces, and traits that solve a single problem. A component's classes, interfaces, and traits usually live beneath a common namespace.

In any marketplace, there are good products and there are bad products. The same concept applies to PHP components. Just as you inspect an apple at the grocery store, you can use a few tricks to spot a good PHP component. Here are a few characteristics of good PHP components:

### Laser-focused

A PHP component is laser-focused and exists only to solve a single problem very well. It is not a jack-of-all-trades and master of none; it is a master of one. It is obsessed with solving a single problem, and it encapsulates its genius beneath a simple user interface.

### Small

A PHP component is no larger than it needs to be. It contains the least amount of PHP code necessary to solve one problem. The amount of code varies. A PHP component can have one PHP class. It can also have several PHP classes organized into subnamespaces. There is no correct number of classes in a PHP component. It uses however many are necessary to solve its one problem.

### Cooperative

A PHP component plays well with others. After all, this is the point of PHP components — their existence depends on their cooperation with other components to build larger solutions. A PHP component does not pollute the global namespace with its own code. Instead, a PHP component lives beneath its own namespace to avoid name collisions with other components.

### Well-tested

A PHP component is well-tested. This is easy to accomplish thanks to its small size. If a PHP component is small and laser-focused, it is very likely easily tested. Its concerns are few, and its dependencies can be easily identified and mocked. The best PHP components provide their own tests and have sufficient test coverage.

### Well-documented

A PHP component is well-documented. It should be easy for developers to install, understand, and use. Good documentation makes this possible. The PHP component should have a *README* file that says what the component does, how to install it, and how to use it. The component may also have its own website with more in-depth information. And good documentation should also extend into the PHP component's source code. Its classes, methods, and properties should have inline docblocks that describe the code, its parameters, its return values, and its potential exceptions.

# Components Versus Frameworks

The problem with frameworks (particularly older frameworks) is that they are an expensive investment. When we choose a framework, we invest in that framework's tools. Frameworks usually provide a smorgasbord of tools. But sometimes we need a specific something that the framework does not provide, and it becomes our burden to find and integrate a custom PHP library. Integrating third-party code into a framework is difficult because the third-party code and the PHP framework probably don't share common interfaces.

When we choose a framework, we invest in that framework's future. We put our faith behind the framework's core development team. We assume the framework's developers will continue investing their own time into developing the framework and ensuring that its code remains up-to-date with modern standards. And often this does not happen. Frameworks are very large, and they require a lot of time and effort to maintain. Project maintainers have their own lives, jobs, and interests. And lives, jobs, and interests change.

## Note

To be fair, larger PHP components are also at risk of abandonment, especially if a component only has one core developer.

Also, who's to say that a particular framework will remain the best tool for the job? Large projects that exist for many years must perform well and be well-tuned now and into the future. The wrong PHP framework may hinder this ability. Older PHP frameworks that have fallen out of fashion may become slower and outmoded as they lose community support. Older frameworks are often written with procedural code instead of modern object-oriented code. Your newer team members may be unfamiliar with an older framework's codebase. There is a lot to consider when deciding whether or not to use a PHP framework.

# Not All Frameworks Are Bad

So far I've spoken only about the downsides of frameworks. Frameworks are not all bad. [Symfony](#) is an excellent example of a modern PHP framework. Fabien Potencier and [Sensio Labs](#) built the Symfony Framework as an amalgam of smaller and decoupled [Symfony components](#). These components can be used together as a framework or piecemeal in custom applications.

Other, older frameworks are making a similar transition to modern PHP components. The [Drupal content management framework](#) is another example. Drupal 7 is written with procedural PHP code that lives in the global PHP namespace. It ignores modern PHP practices to support its legacy codebase. However, Drupal 8 is a ginormous and commendable leap into modern PHP. Drupal 8 leverages the comparative advantages of many different PHP components to build a modern content management platform.

[Laravel](#) is also a popular PHP framework written by Taylor Otwell. Like Symfony, Laravel is built atop its own [Illuminate](#) component library. However (at time of publishing), Laravel's components are not easily decoupled for use in non-Laravel applications. Laravel does not use the PSR-2 community standards, and Laravel does not adhere to the [Semantic Versioning scheme](#). Don't let this dissuade you though. Laravel is still an amazing framework that can create very powerful applications.

## Tip

The most popular modern PHP frameworks include:

- [Aura](#)
- [Laravel](#)
- [Symfony](#)
- [Yii](#)
- [Zend](#)

## Use the Right Tool for the Job

Should you use components or a framework? *Use the right tool for the job.* Most modern PHP frameworks are only a set of conventions built atop smaller PHP components.

If you are working on a smaller project that can be solved with a precise collection of PHP components, then use components. Components make it super-easy to shop for and use existing tools so we can focus less on boilerplate and more on the larger task at hand. Components also help our code remain lightweight and nimble. We use only the code we need, and it's super-easy to swap one component with another that may be better suited for our project.

If you are working on a large project with multiple team members and can benefit from the conventions, discipline, and structure provided by a framework, then use a framework. However, frameworks make many decisions for us and require us to adhere to its set of conventions. Frameworks are less flexible, but we do get far more out-of-the-box than we do with a collection of PHP components. If these tradeoffs are acceptable, by all means use a framework to guide and expedite your project development.

# Find Components

You can find modern PHP components on [Packagist](#) ([Figure 4-1](#)), the de facto PHP component directory. This website aggregates PHP components and makes them searchable by keyword. The best PHP components are listed on Packagist. I tip my hat to [Jordi Boggiano](#) and [Igor Wiedler](#) for creating such an invaluable community resource.

## Tip

I'm often asked which components I believe are the best PHP components. This is a subjective question. However, I largely agree with the PHP components listed at [Awesome PHP](#). This is a list of good PHP components curated by [Jamie York](#).

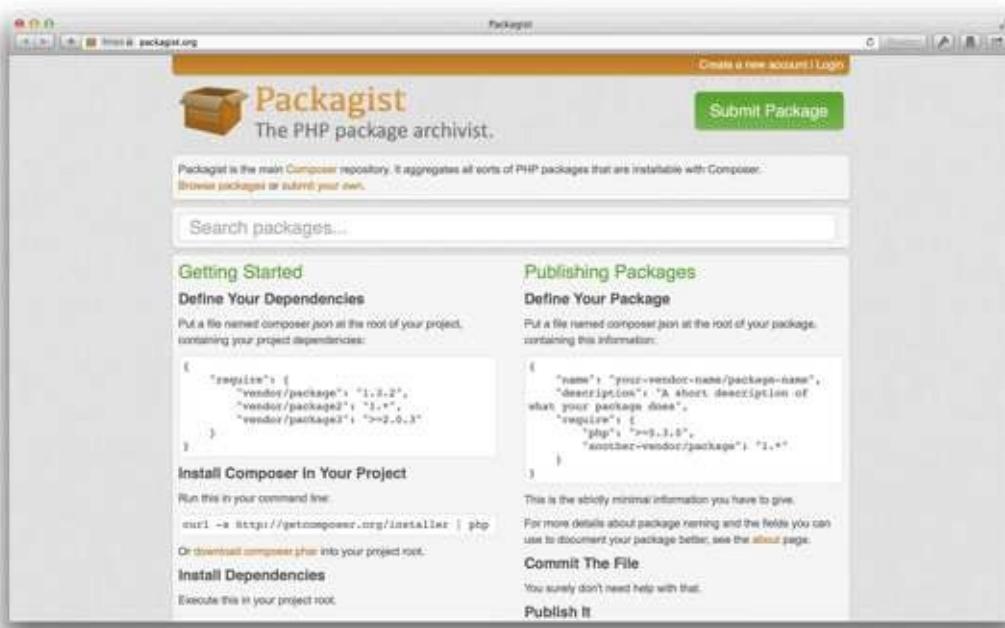


Figure 4-1. Packagist website

## Shop

Do not waste your time solving problems that are already solved. Do you need to send or receive HTTP messages? Go to Packagist and search for `http`; Guzzle is the first result. Use it. Do you need to parse a CSV file? Go to Packagist and search for `csv`; pick a CSV component and use it. Think of Packagist as a grocery store for PHP components where you can shop for the best ingredients. Packagist probably has a PHP component that solves your problem.

## Choose

What if there are multiple PHP components on Packagist that do what you need? How do you pick the best one? Packagist keeps statistics about each PHP component. Packagist tells you how many times each PHP component has been downloaded and starred ([Figure 4-2](#)). More downloads and stars indicate a component may be a good option (this is not always true). That being said, don't discount newer packages with fewer downloads. Many new components are added every day.

It can be difficult to find the perfect PHP component if your Packagist keyword search returns a large number of results. You can't always rely on download statistics, because crowds are not always right. This is a problem that Packagist must address as it becomes more popular. I recommend you rely on word of mouth and peer recommendations to confirm your PHP component selection.



**Figure 4-2. Packagist website search results**

## Leave Feedback

If you find a PHP component that you like, star the PHP component on Packagist and share it with your fellow PHP developers on Twitter, Facebook, IRC, Slack, and your other communication channels. This helps the best PHP components bubble up so they are discovered by other developers.

# Use PHP Components

Packagist is where you find PHP components. [Composer](#) is how you install PHP components. Composer is a dependency manager for PHP components that runs on the command line. You tell Composer which PHP components you need, and Composer downloads and autoloads the components into your project. It's as simple as that. Because Composer is a dependency manager, it also resolves and downloads your components' dependencies (and their dependencies, *ad infinitum*).

Composer works hand-in-hand with Packagist, too. When you tell Composer you want to use the `guzzlehttp/guzzle` component, Composer fetches the `guzzlehttp/guzzle` component listing on Packagist, finds the component's repository URL, determines the appropriate version to use, and discovers the component's dependencies. Composer then downloads the `guzzlehttp/guzzle` component and its dependencies into your project.

Composer is important because dependency management and autoloading are hard problems to solve. Autoloading is the process of automatically loading PHP classes on-demand without explicitly loading them with the `require()`, `require_once()`, `include()`, or `include_once()` functions. Older PHP versions let us write custom autoloaders with the `\__autoload()` function; this function is automatically invoked by the PHP interpreter when we instantiate a class that has not already been loaded. PHP later introduced the more flexible `spl_autoload_register()` function in its SPL library. Exactly how a PHP class is autoloaded is entirely up to the developer. Unfortunately, the lack of a common autoloader standard often necessitates a unique autoloader implementation for every project. This makes it difficult to use code created and shared by other developers if each developer provides a unique autoloader.

The PHP Framework Interop Group recognized this problem and created the PSR-0 standard (superseded by the PSR-4 standard). The PSR-0 and PSR-4 standards suggest how to organize code into namespaces and filesystem directories so it is compatible with one standard autoloader implementation. As I alluded to in [Chapter 3](#), we don't have to write a PSR-4 autoloader on our own. Instead, the Composer dependency manager automatically generates a PSR-compatible autoloader for *all* of our project's PHP components. Composer effectively abstracts away dependency management and autoloading.

## Note

I believe Composer is the most important addition to the PHP community, period. It changed the way I create PHP applications. I use Composer for *every* PHP project because it drastically simplifies integrating and using third-party PHP components in my applications. If you haven't used Composer yet, you should start researching Composer today.

# How to Install Composer

Composer is easy to install. Open a terminal and execute this command:

```
curl -sS https://getcomposer.org/installer | php
```

This command downloads the Composer installer script with `curl`, executes the installer script with `php`, and creates a `composer.phar` file in the current working directory. The `composer.phar` file is the Composer binary.

## Warning

Never execute code that you blindly download from a remote URL. Be sure you review the remote code first so you know exactly what it will do. Also make sure you download the remote code over HTTPS.

I prefer to move and rename the downloaded Composer binary to `/usr/local/bin/composer` with this command:

```
sudo mv composer.phar /usr/local/bin/composer
```

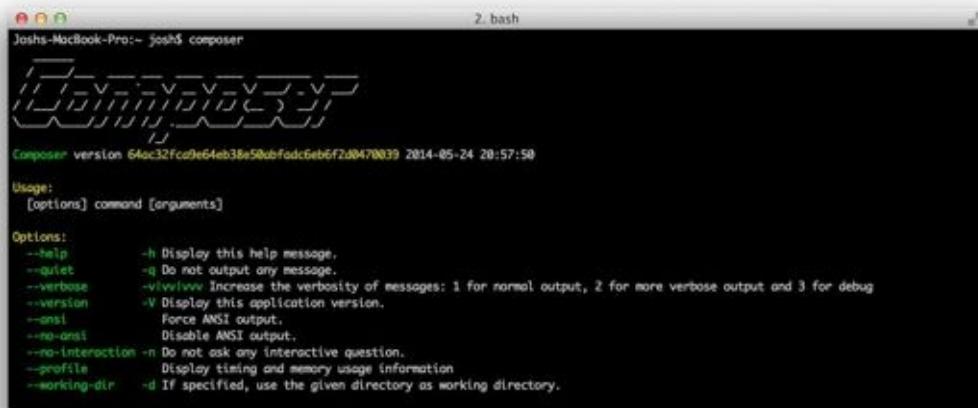
Be sure you run this command to make the `composer` binary executable:

```
sudo chmod +x /usr/local/bin/composer
```

Finally, add the `/usr/local/bin` directory to your environment PATH by appending this line to your `~/.bash_profile` file:

```
PATH=/usr/local/bin:$PATH
```

You should now be able to execute `composer` in your terminal application to see a list of Composer options ([Figure 4-3](#)).



The screenshot shows a terminal window titled "zsh" running on a Mac OS X system. The command `josh$ composer` has been entered. The output displays the version of Composer (version 640c32fc09e64eb38e58dbfadc6eb6f2d0470039, dated 2014-05-24 20:57:59), followed by usage instructions and a detailed list of command-line options. The options listed include `--help`, `--quiet`, `--verbose`, `--version`, `--ansi`, `--no-ansi`, `--no-interaction`, `--profile`, and `--working-dir`.

```
Composer version 640c32fc09e64eb38e58dbfadc6eb6f2d0470039 2014-05-24 20:57:59
Usage:
  [options] command [arguments]

Options:
  --help      -h Display this help message.
  --quiet     -q Do not output any message.
  --verbose   -vVVVvvv Increase the verbosity of messages: 1 for normal output, 2 for more verbose output and 3 for debug
  --version   -V Display this application version.
  --ansi      Force ANSI output.
  --no-ansi    Disable ANSI output.
  --no-interaction -n Do not ask any interactive question.
  --profile    Display timing and memory usage information
  --working-dir -d If specified, use the given directory as working directory.
```

**Figure 4-3. Composer command-line options**

# How to Use Composer

Now that Composer is installed, let's download some PHP components. Composer is typically used to download PHP components on a per-project basis.

## Component names

First, you should make a list of the components you need for your project. Specifically, note each component's vendor and package names. Each PHP component has a vendor name and a package name. For example, the popular [league/flysystem](#) component's vendor name is league and its package name is flysystem. The vendor and package names are separated with a / character. Together, the vendor and package names form the full component name league/flysystem.

The vendor name is globally unique and provides the global identity to which its encompassed packages belong. The package name uniquely identifies a single package beneath a given vendor name. Composer and Packagist use the vendor/package naming convention to avoid name collisions among PHP components from different vendors. You can find a PHP component's vendor and package names on the component's Packagist directory listing ([Figure 4-4](#)).

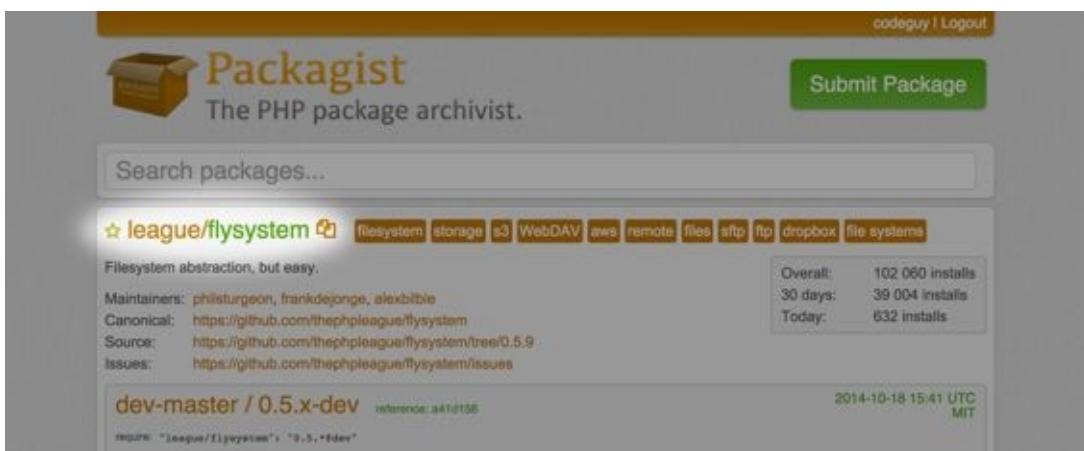


Figure 4-4. Packagist vendor and package name

## Component installation

Each PHP component can have many available versions (e.g., 1.0.0, 1.5.0, or 2.15.0). All available versions are listed on the component's Packagist directory listing.

# Semantic Versioning

Modern PHP components use the [Semantic Versioning scheme](#) and contain three numbers separated with a period (.) character (e.g., 1.13.2). The first number is the *major release* number; the major release number is incremented whenever the PHP component is updated with changes that break backward compatibility. The second number is the *minor release* number; the minor release number is incremented whenever the PHP component is updated with minor features that do not break backward compatibility. The third and final number is the *patch release* number; the patch release number is incremented when the PHP component receives backward-compatible bug fixes.

Fortunately, we don't have to figure out each component's most stable version number. Composer does this for us. Navigate to your project's topmost directory in your terminal application and run this command once for each PHP component:

```
composer require vendor/package
```

Replace *vendor/package* with the component's vendor and package names. To install the Flysystem component, for example, run this command:

```
composer require league/flysystem
```

This command instructs Composer to find and install the PHP component's most stable version. It also instructs Composer to update the component up to, but not including, the component's next major version. The previous example, as of October 2014, installs Flysystem version 0.5.9, and it will update the Flysystem component up to, but not including, version 1.\*.

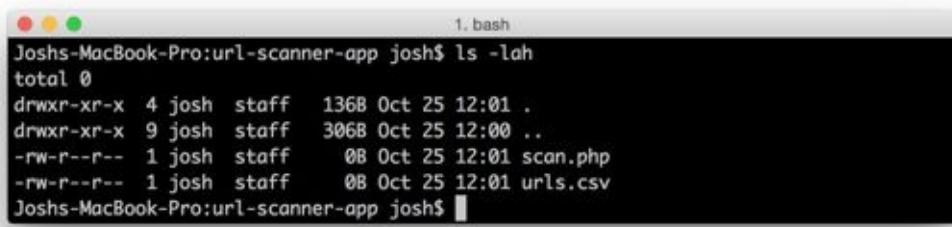
You can review the result of this command in the newly created or updated *composer.json* file in your project's topmost directory. This command also creates a *composer.lock* file. Commit both of these files into your version control system.

## Example Project

Let's reinforce our Composer skills by building an example PHP application that scans URLs from a CSV file and reports all inaccessible URLs. Our project will send an HTTP request to each URL. If a URL returns an HTTP response with a status code greater than or equal to 400, we'll send the inaccessible URL to standard out. Our project will be a command-line application, and the path to the CSV file will be the first and only command-line argument. Ultimately, we'll execute our script, pass it the CSV file path, and see a list of inaccessible URLs on standard out:

```
php scan.php /path/to/urls.csv
```

Our project directory looks like [Figure 4-5](#).



```
1. bash
Josh-MacBook-Pro:url-scanner-app josh$ ls -lah
total 0
drwxr-xr-x  4 josh  staff  1368 Oct 25 12:01 .
drwxr-xr-x  9 josh  staff  3068 Oct 25 12:00 ..
-rw-r--r--  1 josh  staff   0B Oct 25 12:01 scan.php
-rw-r--r--  1 josh  staff   0B Oct 25 12:01 urls.csv
Josh-MacBook-Pro:url-scanner-app josh$
```

**Figure 4-5. Component directory structure**

The first thing I do when starting a new PHP project is determine what tasks can be solved with existing PHP components. The *scan.php* script opens and iterates a CSV file, so we'll need a PHP component that can read and iterate CSV data. The *scan.php* script also sends an HTTP request to each URL in the CSV file, so we'll need a PHP component that can send HTTP requests and inspect HTTP responses. It is certainly possible to write our own code to iterate a CSV file or send HTTP requests, but why should we waste our time if these problems are already solved? Remember, our goal is to scan a list of URLs. Our job is not to build HTTP and CSV parser libraries.

After browsing Packagist, I find the `guzzlehttp/guzzle` and `league/csv` PHP components. The former handles HTTP messages and the latter parses and iterates CSV data. Let's install these components with Composer using these commands in the project's topmost directory:

```
composer require guzzlehttp/guzzle;
composer require league/csv;
```

These commands instruct Composer to download these two components into a new `vendor/` directory in the project's topmost directory. It also creates a `composer.json` file and a `composer.lock` file.

## The `composer.lock` file

After you install project dependencies with Composer, you'll notice that Composer creates a `composer.lock` file. This file lists all of the PHP components used by our project and the components' exact version numbers (including major, minor, and patch numbers). This effectively locks our project to these specific PHP component versions.

Why is this important? If a `composer.lock` file is present, Composer downloads the specific PHP component versions listed in the `composer.lock` file regardless of the component's latest available version on Packagist. You should version control the `composer.lock` file and distribute it to your team members so they can use the same PHP component versions as you. If your team members, your staging server, and your production server all use the same PHP component versions, you minimize the risk of bugs caused by component version discrepancies.

The one downside with the `composer.lock` file is that `composer install` will not install versions newer than those listed in the `composer.lock` file. If you do need to download newer component versions *and* update your `composer.lock` file, use `composer update`. The `composer update` command updates your components to their latest stable versions and also updates the `composer.lock` file with new PHP component version numbers.

## Autoloading PHP components

Now that our project's PHP components are installed with Composer, how do we use them? Luckily for us, when Composer downloads the PHP components it also creates a single PSR-compatible autoloader for all of our project dependencies. All we have to do is require Composer's autoloader at the top of the `scan.php` file:

```
<?php
require 'vendor/autoload.php';
```

Composer's autoloader is just a PHP file named `autoload.php` located inside the `vendor/` directory. When Composer downloads each PHP component, Composer inspects each component's own `composer.json` file to determine how the component prefers to be autoloaded and, with this information, creates a local PSR-compatible autoloader for it. Ultimately, we can instantiate any of our project's PHP components and they are autoloaded on-demand! Pretty neat, huh?

## Implement `scan.php`

Let's finish the `scan.php` script using the Guzzle and CSV components. Remember, the path to the CSV file is provided as the first command-line argument (accessible in the `$argv` array) when our PHP script is executed. The `scan.php` script looks like [Example 4-1](#).

### Example 4-1. URL scanner app

```
<?php
// 1. Use Composer autoloader
require 'vendor/autoload.php';

// 2. Instantiate Guzzle HTTP client
$client = new \GuzzleHttp\Client();

// 3. Open and iterate CSV
$csv = new \League\Csv\Reader($argv[1]);
foreach ($csv as $csvRow) {
    try {
        // 4. Send HTTP OPTIONS request
        $httpResponse = $client->options($csvRow[0]);

        // 5. Inspect HTTP response status code
        if ($httpResponse->getStatusCode() >= 400) {
            throw new \Exception();
        }
    } catch (\Exception $e) {
```

```
// 6. Send bad URLs to standard out
echo $csvRow[0] . PHP_EOL;
}
```

## Tip

Pay attention to how we use the `\League\CSV` and `\GuzzleHttp` namespaces when we instantiate the `guzzlehttp/guzzle` and `league/csv` components. How do we know to use these particular namespaces? I read the `guzzlehttp/guzzle` and `league/csv` documentation. Remember, good PHP components have documentation.

Add a few URLs to the `urls.csv` file, one URL per line. *Make sure at least one URL is invalid.* Next, open a terminal and execute the `scan.php` script:

```
php scan.php urls.csv
```

We execute the `php` binary and pass it two arguments. The first argument is the path to the `scan.php` script. The second argument is the path to the CSV file that contains a list of URLs. If any of the URLs return an unsuccessful HTTP response, they are output to the terminal screen.

# Command-Line Scripts with PHP

Did you know you can write command-line scripts with PHP? This is a great way to automate maintenance tasks for your web application. Learn more about writing PHP command line scripts here:

- <http://php.net/manual/wrappers.php.php>
- <https://php.net/manual/reserved.variables.argv.php>
- <https://php.net/manual/reserved.variables argc.php>

# Composer and Private Repositories

So far I've assumed you are using open source PHP components that are publicly available. As much as I create and use open source software, I recognize that using *only* open source PHP components may not always be possible. Sometimes we have to mix open source and proprietary components in the same application. This is especially true for companies that use internally developed PHP components that cannot be open sourced due to licensing or security concerns. Composer makes this a nonissue.

Composer can manage private PHP components whose repositories require authentication. When you run `composer install` or `composer update`, Composer prompts you if a component's repository requires authentication credentials. Composer also asks if you want to save the repository authentication credentials in a local `auth.json` file (created adjacent to the `composer.json` file). An example `auth.json` file looks like this:

```
{  
    "http-basic": {  
        "example.org": {  
            "username": "your-username",  
            "password": "your-password"  
        }  
    }  
}
```

In most cases, you should not version control the `auth.json` file. Instead, let project developers create their own `auth.json` file with their own authentication credentials.

If you'd rather not wait for Composer to request authentication credentials, you can manually tell Composer your authentication credentials for a remote machine with this command:

```
composer config http-basic.example.org your-username your-password
```

In this example, `http-basic` lets Composer know we are adding authentication details for a given domain. The `example.org` hostname identifies the remote machine that contains the private component repository. The final two arguments are the username and password credentials. By default, this command saves credentials in the current project's `auth.json` file.

You can also save authentication credentials system-wide by using the `--global` flag. This flag lets Composer use your credentials for all projects on your local machine:

```
composer config --global http-basic.example.org your-username your-password
```

Global credentials are saved in the `~/.composer/auth.json` file. If you are using Windows, global credentials are saved in `%APPDATA%/Composer`.

## Tip

Learn more about Composer and private repositories in [Authentication management in Composer](#).

# Create PHP Components

By this point you should be able to find and use PHP components. Let's switch gears and talk about *creating* PHP components. Specifically, we'll convert the URL scanner application into a PHP component and submit it to the Packagist component directory.

Creating PHP components is a great way to share your work with the greater PHP community. The PHP community is built on a foundation of sharing and helping others. If you use open source components in your applications, it's always nice to return the favor with a new and innovative open source component.

## Tip

Be careful that you do not rewrite components that already exist. If you improve upon an existing component, consider sending your improvements to the original component as a pull request. Otherwise, you risk confusing and fragmenting the PHP component ecosystem with duplicate components.

# Vendor and Package Names

Before I build a PHP component, I choose the component's vendor and package name. Remember, each PHP component uses a globally unique vendor and package name combination to avoid name collisions with other components. I recommend you use only lowercase letters for your vendor and package names.

A vendor name is the brand or identity to which a component belongs. Many of my own PHP components use the `codeguy` vendor name because this is my online identity. Choose a vendor name that best represents you or your component's brand.

## Tip

Search Packagist before you choose a vendor name to make sure it is not already claimed by another developer.

A package name identifies a PHP component beneath a given vendor name. Many components can live beneath a single vendor name. For this example, I'll use `modernphp` as the vendor name and `scanner` as the package name.

## Namespaces

As we discussed in [Chapter 2](#), each component lives beneath its own PHP namespace so that it does not pollute the global namespace or collide with other components that use the same PHP class names.

A common misconception is that the component's PHP namespace must match the component's vendor and package names. This is not true. The component's PHP namespace is unrelated to the component's vendor and package names. The vendor and package names are only used by Packagist and Composer to identify a component. You use the component's namespace when using the component in your PHP code.

For this tutorial, we'll create our component beneath the PHP namespace `oreilly\ModernPHP`. This namespace does not exist yet. I just pulled this out of thin air for this particular component.

# Filesystem Organization

PHP components have largely standardized on this filesystem structure:

src/

This directory contains the component's source code (e.g., PHP class files).

tests/

This directory contains the component's tests. We will not use this directory in this example.

composer.json

This is the Composer configuration file. This file describes the component and tells Composer's autoloader to map your component's PSR-4 namespace to the `src/` directory.

README.md

This Markdown file provides helpful information about this component, including its name, description, author, usage, contributor guidelines, software license, and credits.

CONTRIBUTING.md

This Markdown file describes how others can contribute to this component.

LICENSE

This plain-text file contains the component's software license.

CHANGELOG.md

This Markdown file lists changes introduced in each new component version.

## Tip

If you're having trouble starting your own PHP component, have a look at the PHP League's [excellent PHP component boilerplate repository](#).

# The composer.json File

The *composer.json* file is *required* and must contain valid JSON. It includes information used by Composer to find, install, and autoload the PHP component. It also contains information for the component's Packagist directory listing.

[Example 4-2](#) shows a *composer.json* file for our URL scanner component. It includes all of the *composer.json* properties that I use most often for my own PHP components.

## Example 4-2. The URL Scanner component composer.json file

```
{  
    "name": "modernphp/scanner",  
    "description": "Scan URLs from a CSV file and report inaccessible URLs",  
    "keywords": ["url", "scanner", "csv"],  
    "homepage": "http://example.com",  
    "license": "MIT",  
    "authors": [  
        {  
            "name": "Josh Lockhart",  
            "homepage": "https://github.com/codeguy",  
            "role": "Developer"  
        }  
    ],  
    "support": {  
        "email": "help@example.com"  
    },  
    "require": {  
        "php": ">=5.4.0",  
        "guzzlehttp/guzzle": "~5.0"  
    },  
    "require-dev": {  
        "phpunit/phpunit": "~4.3"  
    },  
    "suggest": {  
        "league/csv": "~6.0"  
    },  
    "autoload": {  
        "psr-4": {  
            "Oreilly\\ModernPHP\\": "src/"  
        }  
    }  
}
```

This is admittedly a lot to digest, so let's step through each *composer.json* property in detail:

### name

This is the component's vendor and package name, separated with a / character. This value is displayed on Packagist.

### description

This contains a few sentences that succinctly describe the component. This description is displayed on Packagist.

### keywords

This contains an appropriate number of keywords that describe the component. These keywords help others find this component on Packagist.

### homepage

This is the URL of the component's website.

## license

This is the software license with which the PHP component is released. I prefer to use the MIT Public License. You can read more about software licenses at <http://choosealicense.com>. Remember to *always* release your code with a license.

## authors

This is an array of information for each project author. You should include at least a name and URL for each author.

## support

This is how the component's users find technical support. I prefer to include an email address and support forum URL. You could also list an IRC channel, for example.

## require

This lists the PHP component's own component dependencies. You should list each dependency's vendor/package name and minimum version number. I also like to list the minimum PHP version required by this component. All dependencies listed beneath this property are installed for both development and production project installations.

## require-dev

This acts like the require property, but it lists only the dependencies required to develop this component. For example, I often list `phpunit` as a dev dependency so that other component contributors can write and run tests. These dependencies are installed only during development. They are not installed in production projects.

## suggest

This acts like the require property, but it merely suggests other components because they may be useful when used with our component. Unlike the require property, this object's values are free text fields that describe each suggested component. Composer does not install suggested components.

## autoload

This tells the Composer autoloader how to autoload this component. I recommend you use the PSR-4 autoloader, as demonstrated in [Example 4-2](#). Beneath the `psr-4` property, you map the component's namespace prefix to a filesystem path relative to the component's root directory. This makes our component compatible with a standard PSR-4 autoloader. In [Example 4-2](#), I map the `Oreilly\ModernPHP` namespace to the `src/` directory. The mapping's namespace must end with two back slash characters (`\\"`) to avoid conflicts with other components that use a namespace with a similar sequence of characters. Based on the example mapping, if we instantiate a hypothetical `Oreilly\ModernPHP\Url\Scanner` class, Composer will autoload the PHP class file at `src\Url\Scanner.php`.

## Tip

Learn more about the complete `composer.json` schema at [getcomposer.org](http://getcomposer.org).

## The **README** file

The *README* file is often the component's first introduction to its users. This is especially true for components hosted on GitHub and Bitbucket. Therefore, it's important that the component's *README* file provides, at a minimum, this information:

- Component name and description
- Install instructions
- Usage instructions
- Testing instructions
- Contributing instructions
- Support resources
- Author credits
- Software license

### Tip

GitHub and Bitbucket can render *README* files in Markdown format. This means you can write well-formatted *README* files with headers, lists, links, and images. Use this to your advantage! All you have to do is add the *.md* or *.markdown* file extension to the *README* file. The same principle applies to the *CONTRIBUTING* and *CHANGELOG* files. Learn more about the Markdown format at [Daring Fireball](#).

# Component Implementation

And now we arrive at the component's meat and potatoes — its implementation. This is where you write the PHP classes, interfaces, and traits that form the PHP component. What classes you write, and how many, depends entirely on the PHP component's purpose. However, all component classes, interfaces, and traits must live in the `src/` directory and exist beneath the component's namespace prefix listed in the `composer.json` file.

For this demonstration, I'll create a single PHP class named `Scanner` that exists beneath the `Url` subnamespace beneath the `Oreilly\ModernPHP` namespace listed in the `composer.json` file. The `Scanner` class file lives at `src/Url/Scanner.php`. The `Scanner` class implements the same logic as our earlier URL scanner example application, except it encapsulates the URL scanning behavior in a PHP class ([Example 4-3](#)).

## Example 4-3. The URL Scanner component class

```
<?php
namespace Oreilly\ModernPHP\Url;

class Scanner
{
    /**
     * @var array An array of URLs
     */
    protected $urls;

    /**
     * @var \GuzzleHttp\Client
     */
    protected $httpClient;

    /**
     * Constructor
     * @param array $urls An array of URLs to scan
     */
    public function __construct(array $urls)
    {
        $this->urls = $urls;
        $this->httpClient = new \GuzzleHttp\Client();
    }

    /**
     * Get invalid URLs
     * @return array
     */
    public function getInvalidUrls()
    {
        $invalidUrls = [];
        foreach ($this->urls as $url) {
            try {
                $statusCode = $this->getStatusCodeForUrl($url);
            } catch (\Exception $e) {
                $statusCode = 500;
            }

            if ($statusCode >= 400) {
                array_push($invalidUrls, [
                    'url' => $url,
                    'status' => $statusCode
                ]);
            }
        }
        return $invalidUrls;
    }
}
```

```

/**
 * Get HTTP status code for URL
 * @param string $url The remote URL
 * @return int The HTTP status code
 */
protected function getStatusCodeForUrl($url)
{
    $httpResponse = $this->httpClient->options($url);

    return $httpResponse->getStatusCode();
}

```

Instead of parsing and iterating a CSV file, we inject an array of URLs into the Scanner class constructor. We want our URL scanner class to be as generic as possible. If we demand a CSV file, we inherently limit our component's usefulness. If we accept an array of URLs, we let the end user decide how to fetch an array of URLs (from a PHP array, a CSV file, an iterator, etc). That being said, we still *recommend* the league/csv component because it can be helpful for developers using our component. We include the league/csv component in the *composer.json* manifest's suggest property.

The Scanner class has a hard dependency on the guzzlehttp/guzzle component. However, we isolate each URL's HTTP request in the `getStatusCodeForUrl()` method. This lets us stub (or *override*) this method's implementation in our component's unit tests so that our tests do not rely on a working Internet connection.

## Version Control

We're almost done. Before we submit our component to Packagist, we must publish it to a public code repository. I prefer to publish my open source PHP components to GitHub. However, any public Git repository is fine (I have [published this component to GitHub](#)).

It's also a good idea to *tag* each component release using the Semantic Versioning scheme. This lets component consumers request specific versions of your component (e.g., `~1.2`). I'll create a `1.0.0` tag for the URL scanner component.

# Packagist Submission

Now we're ready to submit the component to Packagist. If you don't use GitHub, go ahead and [create a Packagist account](#). You can also log in to Packagist with your GitHub credentials.

Once logged in, click the big green Submit Package button at the top right of the website. Enter the full Git repository URL into the Repository URL text field and click the Check button. Packagist verifies the repository URL and prompts you to confirm your submission. Click Submit to finalize your component submission. Packagist creates and redirects you to the component listing, which looks [Figure 4-6](#).



**Figure 4-6. Packagist component listing**

You'll notice it pulls the component name, description, keywords, dependencies, and suggestions from the component's *composer.json* file. You'll also notice that it shows the repository branches and tags, too. Packagist establishes a direct correlation between repository tags and semantic version numbers. This is why I recommend your repository tags be valid version numbers like 1.0.0, 1.1.0, and so on. However, we still have that big red alert message that reads:

This package is not auto-updated. Please set up the GitHub Service Hook for Packagist so that it gets updated whenever you push!

We can activate a GitHub or Bitbucket hook that notifies Packagist whenever the component repository is updated. Learn how to setup this repository hook at <https://packagist.org/profile/>.

# Using the Component

We're done! Now anyone can install the URL scanner component with Composer and use it in their PHP applications. Run this command in your terminal to install the URL scanner component with Composer:

```
composer require modernphp/scanner
```

Then you can use the URL scanner component, as shown in [Example 4-4](#).

## Example 4-4. URL Scanner component usage

```
<?php
require 'vendor/autoload.php';

$urls = [
    'http://www.apple.com',
    'http://php.net',
    'http://sdfssdwerw.org'
];
$scanner = new \Oreilly\ModernPHP\Url\Scanner($urls);
print_r($scanner->getInvalidUrls());
```

# Chapter 5. Good Practices

This chapter contains an assortment of good practices that you should apply when building PHP applications. Following good practices makes your applications faster, more secure, and more stable. The PHP language is an accumulation of tools introduced piecemeal over a long period of time, and we use these tools to apply good practices. Tools change with the passage of time as newer and better solutions are introduced in newer PHP versions. Unfortunately, the PHP language still contains outdated tools from its past, and it's possible to build slow and insecure applications with these outmoded tools if you're not careful. The trick is knowing which tools to use and which to ignore. That's what this chapter is all about.

I'm not preaching "best practices" from atop an academic ivory tower. This chapter contains good and practical advice that I use every day in all of my own projects. You can immediately apply this knowledge to your own projects.

## Note

Good practices demonstrated in this chapter have always been possible with past and present PHP versions. However, *how* you implement these practices changes as the PHP language evolves. Newer PHP versions introduce tools that make it easier to apply good practices. This chapter demonstrates how to apply good practices with the latest tools in PHP 5.3+.

# Sanitize, Validate, and Escape

Fox Mulder is correct — *trust no one*. Never trust *any* data that originates from a source not under your direct control. A few external sources are:

- `$_GET`
- `$_POST`
- `$_REQUEST`
- `$_COOKIE`
- `$argv`
- `php://stdin`
- `php://input`
- `file_get_contents()`
- Remote databases
- Remote APIs
- Data from your clients

All of these external data sources are potential attack vectors that can inject malicious data into your PHP scripts (intentionally or accidentally). Writing a PHP script that receives user input and renders output is easy. Doing so *safely* requires a bit more thought. The simplest advice I can give you is this: *sanitize* input, *validate* data, and *escape* output.

# Sanitize Input

When you *sanitize* input (i.e., data from any of the sources listed previously), you escape or remove unsafe characters. It's important to sanitize input data *before* it reaches your application's storage layer (e.g., Redis or MySQL). This is your first line of defense. For example, assume your website comment form accepts HTML. By default, nothing prevents a visitor from adding a devious `<script>` tag to the comment text like this:

```
<p>
    This was a helpful article!
</p>
<script>window.location.href='http://example.com';</script>
```

If you don't sanitize this comment, you'll inject malevolent code into your database that can be rendered into your website's markup. When your website visitors go to a page with this unsanitized comment, they're redirected to a website that does bad things. This is one example why you must sanitize input data that you do not control. In my experience, there are several types of input data that you'll run into most often: HTML, SQL queries, and user profile information (i.e., email addresses and phone numbers).

## HTML

You sanitize HTML special characters (e.g., `&`, `>`, `&#x2033;`) into their HTML entity equivalents with the `htmlentities()` function ([Example 5-1](#)). This function escapes *all* HTML characters in a given string and renders the string safe for your application's storage layer.

The `htmlentities()` function is dumb, though. It does not validate HTML input. It does not escape single quotes by default. And it cannot detect the input string's character set. Here's how to use the `htmlentities()` function correctly. The first argument is the input string. The second argument is the `ENT_QUOTES` constant, which prompts the function to encode single quotes. The third argument specifies the input string's character set.

### Example 5-1. Sanitize input with the `htmlentities()` function

```
<?php
$input = '<p><script>alert("You won the Nigerian lottery!");</script></p>';
echo htmlentities($input, ENT_QUOTES, 'UTF-8');
```

If you require more finesse when sanitizing HTML input, use the [HTML Purifier](#) library. HTML Purifier is a very robust and secure PHP library that sanitizes HTML input according to rules that you provide. The HTML Purifier library's downside is that it is slow and potentially difficult to configure.

### Warning

Do not sanitize HTML with regular-expression functions such as `preg_replace()`, `preg_replace_all()` and `preg_replace_callback()`. Regular expressions are complicated, the HTML input can be invalid, and the risk of error is high.

## SQL queries

There are times when you must build a SQL query based on input data. Sometimes this input data arrives in an HTTP request query string (e.g., `?user=1`). Other times this input

data arrives as an HTTP request URI segment (e.g., /users/1). If you’re not careful, bad people can purposefully malform your SQL queries and wreak havoc on your database. For example, I see many beginner PHP programmers build SQL queries by concatenating raw \$\_GET and \$\_POST input data, as in [Example 5-2](#).

## Example 5-2. Bad SQL query

```
$sql = sprintf(
    'UPDATE users SET password = "%s" WHERE id = %s',
    $_POST['password'],
    $_GET['id']
);
```

*This is bad!* What if someone sends this HTTP request to your PHP script?

```
POST /user?id=1 HTTP/1.1
Content-Length: 17
Content-Type: application/x-www-form-urlencoded

password=abc"; --
```

This HTTP request sets *every* user’s password to abc because many SQL databases consider -- to be the beginning of a comment causing subsequent text to be ignored. *Never use unsanitized input data in a SQL query.* If you need to integrate input data in a SQL query, use a *PDO prepared statement*. PDO is a database abstraction layer built into PHP that presents a single interface to multiple databases. PDO prepared statements are a PDO tool that sanitizes and safely embeds external data into a SQL query to avoid problems like [Example 5-2](#). I consider PDO and PDO statements extremely important tools, so I’ve given them their own section later in this chapter.

## User profile information

If your application has user accounts, you’ll likely encounter email addresses, telephone numbers, zip codes, and other profile-related information. PHP anticipates this scenario with the filter\_var() and filter\_input() functions. These two functions accept a variety of flags to sanitize different forms of input: emails, URL-encoded strings, integers, floats, HTML characters, URLs, and specific ASCII character ranges.

[Example 5-3](#) demonstrates how to sanitize an email address by removing all characters except letters, digits, and !#\$%&'\*+-=?^\_`{|}~@.[].

### Example 5-3. Sanitize user profile email address

```
<?php
$email = 'john@example.com';
$emailSafe = filter_var($email, FILTER_SANITIZE_EMAIL);
```

[Example 5-4](#) demonstrates how to sanitize a user’s bio by removing characters below ASCII 32 and escaping characters above ASCII 127.

### Example 5-4. Sanitize user profile international characters

```
<?php
$string = "\nInternationalization\t";
$safeString = filter_var(
    $string,
    FILTER_SANITIZE_STRING,
    FILTER_FLAG_STRIP_LOW|FILTER_FLAG_ENCODE_HIGH
);
```

## Note

Discover more `filter_var()` flags and options at <http://php.net/manual/function.filter-var.php>.

# Validate Data

It is also important to *validate* data. Unlike sanitization, validation does not remove information from input data. Validation only confirms that input data meets your expectations. If you expect an email address, make sure the input data is an email address. If you expect a phone number, make sure the input data is a phone number. That's all there is to it. Validation ensures that you persist accurate and well-formatted information in your application's storage layer. If you encounter invalid data, you can abort the data persistence operation and surface an appropriate error message to your application's user. Validation also prevents potential database errors. For example, if MySQL expects a DATETIME value but is given the string next year, MySQL will either error out or use a default (and incorrect) value. Either way, your application's data integrity is compromised by invalid data.

You can validate user input with the `filter_var()` function with any of the `FILTER_VALIDATE_*` flags. PHP provides flags to validate Booleans, emails, floats, integers, IP addresses, regular expressions, and URLs. [Example 5-5](#) demonstrates how to validate an email address.

## Example 5-5. Validate email address

```
<?php
$input = 'john@example.com';
$isEmail = filter_var($input, FILTER_VALIDATE_EMAIL);
if ($isEmail !== false) {
    echo "Success";
} else {
    echo "Fail";
}
```

Pay close attention to the `filter_var()` function's return value. If the validation succeeds, the return value is the original validated value. If the validation fails, the return value is `false`.

Although the `filter_var()` function provides a number of validation flags, it cannot validate everything. I recommend these additional validation components, too:

- [aura/filter](#)
- [respect/validation](#)
- [symfony/validator](#)

## Tip

You should validate *and* sanitize input data to make sure input data is safe *and* what you expect.

# Escape Output

When it's time to render output to a web page or API response, it is very important that you *escape* your output. This is one more layer of protection that prevents malicious code from being rendered and inadvertently executed by your application's users.

Escape output with the PHP `htmlentities()` function that we mentioned earlier. Be sure you use `ENT_QUOTES` as the second argument so that it escapes both single and double quotes. Specify the appropriate character encoding (usually `UTF-8`) as the third argument. [Example 5-6](#) demonstrates how to escape HTML output before it is rendered.

## Example 5-6. Escape output with the `htmlentities` function

```
<?php  
$output = '<p><script>alert("NSA backdoor installed");</script>';  
echo htmlentities($output, ENT_QUOTES, 'UTF-8');
```

Some PHP template engines like [twig/twig](#) (my favorite) or [smarty/smarty](#) escape output automatically. The Twig template engine by Sensio Labs, for example, escapes all output by default unless you tell it otherwise. This is a brilliant default and provides a nice safety net for your PHP web applications.

# Passwords

Password security is monumentally important given the growing number of online attacks. How often have you cancelled a credit card because a major retailer was hacked? Many retailers have (and will) fall victim to malicious hackers because they do not protect their systems with best security practices. Your PHP applications are no different, and they are vulnerable to the same attacks unless you use appropriate precautions.

One important precaution is password security. It is your duty to safely manage, hash, and store user passwords. It doesn't matter if your application is a trivial game or a vault for top-secret business documents. Your users entrust you with their information and expect you to guard their information with the best security practices available. I meet many PHP developers who don't understand how to safely manage passwords. After all, securely managing passwords is hard. Fortunately, PHP provides built-in tools that make password security fairly easy. This section demonstrates how to use these tools with modern security practices.

## Never Know User Passwords

You should never know your users' passwords. You should never *be able* to know your users' passwords. If your application's database is hacked, you don't want plain-text or decryptable passwords sitting in your database. Leaked passwords are a serious breach of trust, and they dump a mountain of legal liability on you or your company. The less you know, the safer you are.

## Never Restrict User Passwords

It frustrates me when a website requires my account password to satisfy a specific format. It makes me even angrier when my account password cannot be longer than {N} number of characters. *Why!?* I understand that password formats may be restricted for compatibility with legacy applications or databases, but this is not an excuse for poor security practices.

Never restrict your users' passwords. If you require passwords to fit a particular pattern, you are effectively providing a roadmap for bad guys to hack your application. If you must restrict user passwords, I recommend you only require a minimum length. It is not unreasonable to blacklist commonly used or dictionary-based passwords, too.

## Never Email User Passwords

Never send passwords via email. If you send my password via email, I know three things: you know my password; you are storing my password in plain text or in a decryptable format; and you have no qualms sending my password over the Internet in plain text.

Instead, send an email with a URL where I can choose or change my own password. Web applications often generate a unique token that can only be used once to choose or change a password. For example, suppose I forget my account password for your web application. I click the “Forgot password” link on your login form, and I am directed to a form where I enter my email address to request a new password. Your application generates a unique token, and it associates this token with the account identified by my email address. Your application sends an email to the account’s email address with a URL that includes the unique token as a URL segment or a query-string parameter. When I visit the URL, your application validates the token and, if the token is valid, allows me to choose a new password for my account. After I choose a new password, your application invalidates the token.

# Hash User Passwords with bcrypt

You should *hash* user passwords. Do not *encrypt* user passwords. Encryption and hashing are not synonymous. Encryption is a two-way algorithm, meaning what is encrypted can later be decrypted by design. Hashing is a one-way algorithm. Hashed data cannot be reverted to its original form, and identical data always produces the same hash values.

When you store a user password in your database, you hash the password first and store the *password hash* in your database. If hackers break into your database, they see only meaningless password hashes that require a massive amount of time and NSA resources to crack.

Many hashing algorithms are available (e.g., MD5, SHA1, bcrypt, scrypt). Some are fast and designed to verify data integrity. Others are slow and designed to be safe and secure. Slow, safe, and secure are what we want when it comes to password generation and storage.

The most secure peer-reviewed hashing algorithm known today is bcrypt. Unlike MD5 and SHA1, bcrypt is designed to be very slow. The bcrypt algorithm automatically salts data to foil potential rainbow table attacks. The bcrypt algorithm also consumes a large amount of time (measured in seconds) while iteratively hashing data to generate a super-secure final hash value. The number of hash iterations is called the *work factor*. A higher work factor makes it exponentially more expensive for a bad guy to crack password hashes. The bcrypt algorithm is future-proof, too, because you can simply increase its work factor as computers become faster.

The bcrypt algorithm is extensively peer-reviewed. Minds far greater than my own have reviewed the bcrypt algorithm for potential exploits, and so far none has been found. It is very important that you rely on peer-reviewed hashing algorithms. Never create your own. There is safety in numbers, and odds are you are not a cryptography expert (unless you are, in which case tell Bruce Schneier I said hello).

# Password Hashing API

As you can see, there are a lot of considerations to make when working with user passwords. However, [Anthony Ferrara](#) was kind enough to build the native [password hashing API](#) available in PHP 5.5.0. PHP's native password hashing API provides easy-to-use functions that drastically simplify password hashing and verification. The password hashing API also uses the bcrypt hashing algorithm by default.

## Note

Anthony Ferrara (also known as [@ircmaxell](#) on Twitter) is a Developer Advocate at Google, and he is an authoritative source for all things related to PHP performance and security. Anthony is also the author of the PHP password hashing API. I encourage you to follow Anthony on [Twitter](#) and read his [blog](#). I want to say a big thank you to Anthony. His contributions to PHP have single-handedly improved PHP application security by making best security practices more accessible.

You'll encounter two scenarios when building web applications: user registration and user login. Let's explore how the PHP password hashing API simplifies both scenarios.

## User registration

A web application can't exist without users, and users need a way to sign up for an account. Let's assume our hypothetical application has a PHP file available at the URL `/register.php`. This PHP file receives a URL-encoded HTTP POST request with an email address and password. We create a user account if the email address is valid and the password contains at least eight characters. This is an example HTTP POST request:

```
POST /register.php HTTP/1.1
Content-Length: 43
Content-Type: application/x-www-form-urlencoded

email=john@example.com&password=sekritshhh!
```

[Example 5-7](#) is the `register.php` file that receives the HTTP POST request.

### Example 5-7. User registration script

```
01 <?php
02 try {
03     // Validate email
04     $email = filter_input(INPUT_POST, 'email', FILTER_VALIDATE_EMAIL);
05     if (!$email) {
06         throw new Exception('Invalid email');
07     }
08
09     // Validate password
10    $password = filter_input(INPUT_POST, 'password');
11    if (!$password || mb_strlen($password) < 8) {
12        throw new Exception('Password must contain 8+ characters');
13    }
14
15    // Create password hash
16    $passwordHash = password_hash(
17        $password,
18        PASSWORD_DEFAULT,
19        ['cost' => 12]
20    );
21    if ($passwordHash === false) {
22        throw new Exception('Password hash failed');
23    }
24
```

```

25 // Create user account (THIS IS PSEUDO-CODE)
26 $user = new User();
27 $user->email = $email;
28 $user->password_hash = $passwordHash;
29 $user->save();
30
31 // Redirect to login page
32 header('HTTP/1.1 302 Redirect');
33 header('Location: /login.php');
34 } catch (Exception $e) {
35 // Report error
36 header('HTTP/1.1 400 Bad request');
37 echo $e->getMessage();
38 }

```

In [Example 5-7](#):

- Lines 4–7 validate the user email address. We toss an exception if the email is invalid.
- Lines 10–13 validate the plain-text user password pulled from the HTTP request body. We toss an exception if the plain-text user password contains fewer than eight characters.
- Lines 16–23 create a password hash with the PHP password hashing API’s `password_hash()` function. The `password_hash()` function’s first argument is the plain-text user password. The second argument is the `PASSWORD_DEFAULT` constant, which tells PHP to use the bcrypt hashing algorithm. The final argument is an array of hashing options. The `cost` array key specifies the bcrypt work factor. A work factor of `10` is used by default, but you should increase the cost factor for your particular hardware so that password hashing requires 0.1 to 0.5 seconds to finish. We toss an exception if the password hashing fails.
- Lines 26–29 demonstrate saving a hypothetical user account. These lines contain pseudocode; you should replace these lines with code appropriate for your own application. The point is that you persist the user record with the password hash — not the plain-text password pulled from the HTTP request body. We also persist the email address that is used to locate and log in a user account.

## Tip

Store password hashes in a `VARCHAR(255)` database column. This gives you flexibility to continue storing future passwords that may require more characters than the current bcrypt algorithm.

## User login

Our hypothetical application also has a PHP file available at URL `/login.php`. This file accepts an HTTP POST request that contains an email address and password used to identify, authenticate, and log in a user. This is an example HTTP POST request:

```

POST /login.php HTTP/1.1
Content-Length: 43
Content-Type: application/x-www-form-urlencoded

email=john@example.com&password=sekritshhh!

```

The `login.php` file finds the user account identified by the email address, it verifies the submitted password with the user account’s password hash, and it logs in the user account. [Example 5-8](#) shows the `login.php` file.

## Example 5-8. User login script

```
01 <?php
02 session_start();
03 try {
04     // Get email address from request body
05     $email = filter_input(INPUT_POST, 'email');
06
07     // Get password from request body
08     $password = filter_input(INPUT_POST, 'password');
09
10    // Find account with email address (THIS IS PSEUDO-CODE)
11    $user = User::findByEmail($email);
12
13    // Verify password with account password hash
14    if (password_verify($password, $user->password_hash) === false) {
15        throw new Exception('Invalid password');
16    }
17
18    // Re-hash password if necessary (see note below)
19    $currentHashAlgorithm = PASSWORD_DEFAULT;
20    $currentHashOptions = array('cost' => 15);
21    $passwordNeedsRehash = password_needs_rehash(
22        $user->password_hash,
23        $currentHashAlgorithm,
24        $currentHashOptions
25    );
26    if ($passwordNeedsRehash === true) {
27        // Save new password hash (THIS IS PSEUDO-CODE)
28        $user->password_hash = password_hash(
29            $password,
30            $currentHashAlgorithm,
31            $currentHashOptions
32        );
33        $user->save();
34    }
35
36    // Save login status to session
37    $_SESSION['user_logged_in'] = 'yes';
38    $_SESSION['user_email'] = $email;
39
40    // Redirect to profile page
41    header('HTTP/1.1 302 Redirect');
42    header('Location: /user-profile.php');
43 } catch (Exception $e) {
44     header('HTTP/1.1 401 Unauthorized');
45     echo $e->getMessage();
46 }
```

In [Example 5-8](#):

- Line 5 and 8 retrieve the email address and password from the HTTP request body.
- Line 11 locates the user record associated with the email address submitted in the HTTP request body. I use pseudocode in [Example 5-8](#), and you should replace this line with code specific to your own application.
- Lines 14–16 compare the plain-text password submitted in the HTTP request body with the password hash stored in the user record. We compare the password and password hash with the `password_verify()` function. If verification fails, we toss an exception.
- Lines 19–34 make sure the user record's password hash value is up-to-date with the most current password algorithm options by invoking the `password_needs_rehash()` function. If the user record's password hash is out of date, we create a new hash value using the most current algorithm options, and we update the user record with the new hash value.

## Verify password

The `password_verify()` function compares the plain-text password from the HTTP request body to the password hash stored in the user record. This function accepts two arguments. The first argument is the plain-text password. The second argument is the existing password hash in the user record. If the `password_verify()` function returns `true`, the plain-text password is valid and we log in the user. Otherwise, the plain-text password is invalid and we abort the login process.

## Rehash password

After line 17 in [Example 5-8](#), authentication is successful and we can log in the user. Before we do, however, it is important to check if the existing password hash in the user record is outdated. If it is outdated, we create a new password hash.

Why should we create a new password hash? Pretend our application was created two years ago when we used a bcrypt work factor of 10. Today we use a bcrypt work factor of 20 because hackers are smarter and computers are faster. Unfortunately, there are some user accounts whose password hashes were generated with a bcrypt work factor of 10. After we verify the login request's authenticity, we check if the existing user record's password hash needs to be updated with the `password_needs_rehash()` function. This function makes sure a given password hash is created with the most current hashing algorithm options. If a password hash *does* need to be rehashed, rehash the plain-text password from the HTTP request body using the current algorithm options and update the user record with the new hash value.

### Tip

It's easiest to employ the `password_needs_rehash()` function in the user login script because I have access to the old password hash *and* the plain-text password at the same time.

## Password Hashing API for PHP < 5.5.0

If you cannot use PHP 5.5.0 or newer, fear not. You can use Anthony Ferrara's [ircmaxell/password-compat](https://github.com/ircmaxell/password-compat) component. It implements all of these PHP password hashing API functions:

- `password_hash()`
- `password_get_info()`
- `password_needs_rehash()`
- `password_verify()`

Ferrara's `ircmaxell/password-compat` component is a drop-in replacement for the modern PHP password hashing API. Include the component in your application with Composer and you're off and running.

# Dates, Times, and Time Zones

Working with dates and times is hard. Pretty much every PHP developer has, at one time or another, made a mistake working with dates and times. This is precisely why I recommend you do not manage dates and times on your own. There are too many considerations to juggle, including date formats, time zones, daylight saving, leap years, leap seconds, and months with variable numbers of days. It's too easy for your own calculations to become inaccurate. Instead, use the `DateTime`, `DateInterval`, and `DateTimeZone` classes introduced in PHP 5.2.0. These helpful classes provide a simple object-oriented interface to accurately create and manipulate dates, times, and timezones.

# Set a Default Time Zone

The first thing you should do is declare a default time zone for PHP's date and time functions. If you don't set a default time zone, PHP shows an E\_WARNING message. There are two ways to set the default time zone. You can declare the default time zone in the *php.ini* file like this:

```
date.timezone = 'America/New_York';
```

You can also declare the default time zone during runtime with the `date_default_timezone_set()` function ([Example 5-9](#)).

## Example 5-9. Set default timezone

```
<?php  
date_default_timezone_set('America/New_York');
```

Either solution requires a valid time-zone identifier. You can find a complete list of PHP time-zone identifiers at <http://php.net/manual/timezones.php>.

# The DateTime Class

The `DateTime` class provides an object-oriented interface to manage date and time values. A single `DateTime` instance represents a specific date and time. The `DateTime` class constructor ([Example 5-10](#)) is the simplest way to create a new `DateTime` instance.

## Example 5-10. The DateTime class

```
<?php  
$datetime = new DateTime();
```

Without arguments, the `DateTime` class constructor creates an instance that represents the current date and time. You can pass a string argument into the `DateTime` class constructor to specify a custom date and time ([Example 5-11](#)). The string argument must use one of the valid date and time formats listed at <http://php.net/manual/datetime.formats.php>.

## Example 5-11. DateTime class with argument

```
<?php  
$datetime = new DateTime('2014-04-27 5:03 AM');
```

In an ideal world, you are given date and time data in a format that PHP understands. Unfortunately, this is not always the case. Sometimes you must work with date and time values in different and unexpected formats. I experience this problem on a daily basis. Many of my clients send Excel spreadsheets with data to import into an application, and each client provides date and time values in wildly different formats. The `DateTime` class makes this a nonissue.

Use the `DateTime::createFromFormat()` static method to create a `DateTime` instance with a date and time string that uses a custom format. This method's first argument is the date and time string *format*. The second argument is the date and time string that uses said format ([Example 5-12](#)).

## Example 5-12. DateTime class with static constructor

```
<?php  
$datetime = DateTime::createFromFormat('M j, Y H:i:s', 'Jan 2, 2014 23:04:12');
```

### Note

The `DateTime::createFromFormat()` static method accepts the same date and time formats as the `date()` function. Valid date and time formats are available at <http://php.net/manual/datetime.createfromformat.php>.

# The DateInterval Class

The `DateInterval` class is pretty much prerequisite knowledge for manipulating `DateTime` instances. A `DateInterval` instance represents a fixed length of time (e.g., “two days”) or a relative length of time (e.g., “yesterday”). You use `DateInterval` instances to modify `DateTime` instances. For example, the `DateTime` class provides `add()` and `sub()` methods to manipulate a `DateTime` instance’s value. Both methods accept a `DateInterval` argument that specifies the amount of time added to or subtracted from a `DateTime` instance.

Instantiate the `DateInterval` class with its constructor. The `DateInterval` class constructor accepts a string argument that provides an *interval specification*. Interval specifications are a little tricky at first, but there’s not much to them. First, an interval specification is a string that begins with the letter `P`. Next, you append an integer. And last, you append a *period designator* that qualifies the preceding integer value. Valid period designators are:

- `Y` (years)
- `M` (months)
- `D` (days)
- `w` (weeks)
- `H` (hours)
- `m` (minutes)
- `s` (seconds)

An interval specification can include both date and time values. If you include a time value, separate the date and time parts with the letter `T`. For example, the interval specification `P2D` means *two days*. The interval specification `P2DT5H2M` means *two days, five hours, and two minutes*.

[Example 5-13](#) demonstrates how to modify a `DateTime` instance by a given interval of time using the `add()` method.

## Example 5-13. The DateInterval class

```
<?php
// Create DateTime instance
$datetime = new DateTime('2014-01-01 14:00:00');

// Create two weeks interval
$interval = new DateInterval('P2W');

// Modify DateTime instance
$datetime->add($interval);
echo $datetime->format('Y-m-d H:i:s');
```

You can create an *inverted* `DateInterval`, too ([Example 5-14](#)). This lets you traverse a `DatePeriod` instance in reverse chronology!

## Example 5-14. An inverted DateInterval class

```
$dateStart = new \DateTime();
$dateInterval = \DateInterval::createFromString('-1 day');
$datePeriod = new \DatePeriod($dateStart, $dateInterval, 3);
foreach ($datePeriod as $date) {
    echo $date->format('Y-m-d'), PHP_EOL;
}
```

This outputs:

2014-12-08  
2014-12-07  
2014-12-06  
2014-12-05

# The DateTimeZone Class

If your application caters to an international clientele, you've probably wrestled with time zones. Time zones are tricky, and they are a constant source of confusion for many PHP developers.

PHP represents time zones with the `DateTimeZone` class. All you have to do is pass a valid time-zone identifier into the `DateTimeZone` class constructor:

```
<?php  
$timezone = new DateTimeZone('America/New_York');
```

## Note

Find a complete list of valid time-zone identifiers at <http://php.net/manual/timezones.php>.

You often use `DateTimeZone` instances when creating `DateTime` instances. The `DateTime` class constructor's optional second argument is a `DateTimeZone` instance. The `DateTime` instance's value, and all modifications to its value, are now relative to the specified time zone. If you omit the constructor's second argument, the time zone is determined by your default time-zone setting:

```
<?php  
$timezone = new DateTimeZone('America/New_York');  
$datetime = new DateTime('2014-08-20', $timezone);
```

You can change a `DateTime` instance's time zone after instantiation with the `setTimezone()` method ([Example 5-15](#)).

## Example 5-15. DateTimeZone usage

```
<?php  
$timezone = new DateTimeZone('America/New_York');  
$datetime = new \DateTime('2014-08-20', $timezone);  
$datetime->setTimezone(new DateTimeZone('Asia/Hong_Kong'));
```

I find it easiest if I always work in the UTC time zone. My server's time zone is UTC, and my PHP default time zone is UTC. If I persist date and time values into a database, I save them as the UTC time zone. I convert the UTC date and time values to the appropriate time zone when I display the data to application users.

# The DatePeriod Class

Sometimes you need to iterate a sequence of dates and times that recur over a specific interval of time. Repeating calendar events are a good example. The `DatePeriod` class solves this problem. The `DatePeriod` class constructor accepts three required arguments:

- A `DateTime` instance that represents the date and time from which iteration begins
- A `DateInterval` instance that represents the interval of time between subsequent dates and times
- An integer that represents the number of total iterations

A `DatePeriod` instance is an iterator, and each iteration yields a `DateTime` instance.

[Example 5-16](#) yields three dates and times separated by two-week intervals.

## Example 5-16. DatePeriod class usage

```
<?php
$start = new DateTime();
$interval = new DateInterval('P2W');
$period = new DatePeriod($start, $interval, 3);

foreach ($period as $nextDateTime) {
    echo $nextDateTime->format('Y-m-d H:i:s'), PHP_EOL;
}
```

The `DatePeriod` class constructor accepts an optional fourth argument that specifies the period's explicit end date and time. If you want to exclude the start date from the period's iteration, pass the `DatePeriod::EXCLUDE_START_DATE` constant as the final constructor argument ([Example 5-17](#)).

## Example 5-17. DatePeriod class usage with options

```
<?php
$start = new DateTime();
$interval = new DateInterval('P2W');
$period = new DatePeriod(
    $start,
    $interval,
    3,
    DatePeriod::EXCLUDE_START_DATE
);

foreach ($period as $nextDateTime) {
    echo $nextDateTime->format('Y-m-d H:i:s'), PHP_EOL;
}
```

## The nesbot/carbon Component

If you work with dates and times more often than not, you should use Brian Nesbitt's [nesbot/carbon](#) PHP component. Carbon provides a simple user interface with many useful methods for working with date and time values.

# Databases

Many PHP applications persist information in a wide assortment of databases like MySQL, PostgreSQL, SQLite, MSSQL, and Oracle. Each database provides its own PHP extension to establish communication between PHP and the database. MySQL, for example, uses the `mysqli` extension, which adds various `mysqli_*`() functions to the PHP language. SQLite3 uses the `SQLite3` extension, which adds the `SQLite3`, `SQLite3Stmt`, and `SQLite3Result` classes to the PHP language. If you work with different databases in one or more projects, you have to install and learn various PHP database extensions and interfaces. This increases your cognitive and technical overhead.

# The PDO Extension

This is exactly why PHP provides the native PDO extension. PDO (or *PHP data objects*) is a collection of PHP classes that communicate with many different SQL databases via a single user interface. Database implementations are abstracted away. Instead, we can write and execute database queries with a single interface regardless of the particular database system we happen to be using at the time.

## Warning

Even though the PDO extension provides a single interface to different databases, we still must write our own SQL statements. This is the downside to PDO. Each database provides proprietary features, and these features often require unique SQL syntax. I recommend you write ANSI/ISO SQL when using PDO so that your SQL doesn't break if/when you change database systems. If you absolutely must use a proprietary database feature, keep in mind you must update your SQL statements if you change database systems.

# Database Connections and DSNs

First, select the database system most appropriate for your application. Install the database, create the schema, and optionally load an initial dataset. Next, instantiate the PDO class in PHP. The PDO instance establishes a connection between PHP and the database.

The PDO class constructor accepts a string argument called a DSN, or data source name, that provides database connection details. A DSN begins with the database driver name (e.g., mysql or sqlite), a :, and the remainder of the connection string. The DSN connection string is different for each database, but it typically includes:

- Hostname or IP address
- Port number
- Database name
- Character set

## Note

Learn more about your database's DSN format at <http://php.net/manual/pdo.drivers.php>.

The PDO class constructor's second and third arguments are a username and password for your database. Provide these arguments if your database requires authentication.

[Example 5-18](#) establishes a PDO connection to a MySQL database named acme. The database is available at IP address 127.0.0.1, and it listens on the standard MySQL port 3306. The database username is josh, and the database password is sekrit. The connection character set is utf8.

## Example 5-18. PDO constructor

```
<?php
try {
    $pdo = new PDO(
        'mysql:host=127.0.0.1;dbname=books;port=3306;charset=utf8',
        'USERNAME',
        'PASSWORD'
    );
} catch (PDOException $e) {
    // Database connection failed
    echo "Database connection failed";
    exit;
}
```

The PDO class constructor's first argument is the DSN. The DSN begins with mysql:. This instructs PDO to use the PDO MySQL driver to connect to a MySQL database. After the : character, we specify a semicolon-delimited list of keys and values. Specifically, we specify the host, dbname, port, and charset settings.

## Tip

The PDO constructor throws a PDOException instance if the database connection fails. It's important that you anticipate and catch this exception when creating PDO connections.

## Keep your database credentials secret

[Example 5-18](#) is fine for demonstration purposes, but it isn't safe. *Never hard-code database credentials into PHP files*, especially PHP files served to the public. If PHP

exposes raw PHP code to HTTP clients due to a bug or server misconfiguration, your database credentials are naked for the world to see. Instead, move your database credentials into a configuration file *above* the document root and include them into your PHP files when necessary.

## Tip

Do not version control your credentials, either. Protect your credentials with a `.gitignore` file. Otherwise, you will publish your secret credentials into your code repository for others to see. This is especially bad if you are using a public repository.

In this example, the `settings.php` file contains our database connection credentials. It lives beneath the project root directory but above the document root. The `index.php` file lives beneath the document root directory, and it is served to the public with a web server. The `index.php` file uses the credentials in the `settings.php` file:

```
[project_root]
    settings.php
    public_html/ <-- document root
        index.php
```

This is the `settings.php` file:

```
<?php
$settings = [
    'host' => '127.0.0.1',
    'port' => '3306',
    'name' => 'acme',
    'username' => 'USERNAME',
    'password' => 'PASSWORD',
    'charset' => 'utf8'
];
```

[Example 5-19](#) shows the `index.php` file. It includes the `settings.php` file and establishes a PDO database connection.

### Example 5-19. PDO constructor with external settings

```
<?php
include('../settings.php');

$pdo = new PDO(
    sprintf(
        'mysql:host=%s;dbname=%s;port=%s;charset=%s',
        $settings['host'],
        $settings['name'],
        $settings['port'],
        $settings['charset']
    ),
    $settings['username'],
    $settings['password']
);
```

This is much safer. If the `index.php` code leaks to the public, our database credentials remain secret.

# Prepared Statements

We now have a PDO connection to a database, and we can use this connection to read from and write to the database with SQL statements. We're not done yet. When I build PHP applications, I often need to customize SQL statements with dynamic information from the current HTTP request. For example, the URL `/user?email=john@example.com` shows profile information for a specific user account. The SQL statement for this URL might be:

```
SELECT id FROM users WHERE email = "john@example.com";
```

A beginner PHP developer might build the SQL statement like this:

```
$sql = sprintf(
    'SELECT id FROM users WHERE email = "%s"',
    filter_input(INPUT_GET, 'email')
);
```

This is bad because the SQL string uses raw input from the HTTP request query string. It provides a welcome mat for hackers to do bad things to your PHP application. Haven't you heard of [little Bobby Tables](#)? It is extremely important to sanitize user input that is used in a SQL statement. Fortunately, the PDO extension makes input sanitization super-easy with *prepared statements* and *bound parameters*.

A prepared statement is a `PDOStatement` instance. However, I rarely instantiate the `PDOStatement` class directly. Instead, I fetch a prepared statement object with the `PDO` instance's `prepare()` method. This method accepts a SQL statement string as its first argument, and it returns a `PDOStatement` instance:

```
<?php
$sql = 'SELECT id FROM users WHERE email = :email';
$statement = $pdo->prepare($sql);
```

Pay close attention to the SQL statement. The `:email` is a *named placeholder* to which I can safely bind any value. In [Example 5-20](#), I bind the HTTP request query string to the `:email` placeholder with the `$statement` instance's `bindValue()` method.

## Example 5-20. Prepared statement with email address

```
<?php
$sql = 'SELECT id FROM users WHERE email = :email';
$statement = $pdo->prepare($sql);

$email = filter_input(INPUT_GET, 'email');
$statement->bindValue(':email', $email);
```

The prepared statement automatically sanitizes the `$email` value, and it protects our database from SQL injection attacks. You can include multiple named placeholders in a SQL statement string and invoke the prepared statement's `bindValue()` method for each placeholder.

In [Example 5-20](#), the `:email` named placeholder represents a string value. What if we change our SQL statement to find a user by a numeric ID? In this case, we must pass a third argument to the prepared statement's `bindValue()` method to specify the type of data bound to the placeholder. Without the third argument, a prepared statement assumes bound data is a string.

[Example 5-21](#) shows a modification of [Example 5-20](#) that finds a user by numeric ID

instead of an email address. The numeric ID is pulled from the HTTP query string parameter named `id`.

### Example 5-21. Prepared statement with ID

```
<?php
$sql = 'SELECT email FROM users WHERE id = :id';
$statement = $pdo->prepare($sql);

$userId = filter_input(INPUT_GET, 'id');
$statement->bindValue(':id', $userId, PDO::PARAM_INT);
```

We use the `PDO::PARAM_INT` constant as the third argument. This tells PDO that the bound data is an integer. There are several PDO constants you can use to specify various data types:

```
PDO::PARAM_BOOL
PDO::PARAM_NULL
PDO::PARAM_INT
PDO::PARAM_STR (default)
```

#### Note

See all PDO constants at <http://php.net/manual/pdo.constants.php>.

# Query Results

We now have a prepared statement, and we're ready to execute SQL queries against the database. The prepared statement's `execute()` method executes the statement's SQL statement with any bound data. If you are executing `INSERT`, `UPDATE`, or `DELETE` statements, invoke the `execute()` method and you're done. If you execute a `SELECT` statement, you probably expect the database to return matching records. You can fetch query results with the prepared statement's `fetch()`, `fetchAll()`, `fetchColumn()`, and `fetchObject()` methods.

The `PDOStatement` instance's `fetch()` method returns the next row from the result set. I use this method to iterate large result sets, especially if the entire result set cannot fit in available memory ([Example 5-22](#)).

## Example 5-22. Prepared statement results as associative array

```
<?php
// Build and execute SQL query
$sql = 'SELECT id, email FROM users WHERE email = :email';
$statement = $pdo->prepare($sql);
$email = filter_input(INPUT_GET, 'email');
$statement->bindValue(':email', $email, PDO::PARAM_INT);
$statement->execute();

// Iterate results
while (($result = $statement->fetch(PDO::FETCH_ASSOC)) !== false) {
    echo $result['email'];
}
```

In this example, I use the `PDO::FETCH_ASSOC` constant as the first argument in the statement instance's `fetch()` method. This argument determines how the `fetch()` and `fetchAll()` methods return query results. You can use any of these constants:

### `PDO::FETCH_ASSOC`

Prompts the `fetch()` or `fetchAll()` method to return an associative array. The array keys are database column names.

### `PDO::FETCH_NUM`

Prompts the `fetch()` or `fetchAll()` method to return a numeric array. The array keys are the numeric index of database columns in your query result.

### `PDO::FETCH_BOTH`

Prompts the `fetch()` or `fetchAll()` method to return an array that contains both associative and numeric array keys. This is a combination of `PDO::FETCH_ASSOC` and `PDO::FETCH_NUM`.

### `PDO::FETCH_OBJ`

Prompts the `fetch()` or `fetchAll()` method to return an object whose properties are database column names.

## Note

Learn more about fetching PDO statement results at  
<http://php.net/manual/pdostatement.fetch.php>.

If you are working with smaller result sets, you can fetch *all* query results with the prepared statement's `fetchAll()` method ([Example 5-23](#)). I typically discourage this method unless you are absolutely sure the complete query result is small enough to fit in available memory.

### Example 5-23. Prepared statement fetch all results as associative array

```
<?php
// Build and execute SQL query
$sql = 'SELECT id, email FROM users WHERE email = :email';
$statement = $pdo->prepare($sql);
$email = filter_input(INPUT_GET, 'email');
$statement->bindValue(':email', $email, PDO::PARAM_INT);
$statement->execute();

// Iterate results
$results = $statement->fetchAll(PDO::FETCH_ASSOC);
foreach ($results as $result) {
    echo $result['email'];
}
```

If you are concerned only with a single column in your query result, you can use the prepared statement's `fetchColumn()` method. This method, similar to the `fetch()` method, returns the value of a single column from the next row of the query result ([Example 5-24](#)). The `fetchColumn()` method's one and only argument is the index of the desired column.

#### Tip

The query result column order matches the column order specified in the SQL query.

### Example 5-24. Prepared statement fetch one column, one row at a time as associative array

```
<?php
// Build and execute SQL query
$sql = 'SELECT id, email FROM users WHERE email = :email';
$statement = $pdo->prepare($sql);
$email = filter_input(INPUT_GET, 'email');
$statement->bindValue(':email', $email, PDO::PARAM_INT);
$statement->execute();

// Iterate results
while (($email = $statement->fetchColumn(1)) !== false) {
    echo $email;
}
```

In [Example 5-24](#), the `email` column is listed second in the SQL query. It therefore becomes the second column in each query result row, and I pass the number `1` into the `fetchColumn()` method (columns are zero-indexed).

You can also use the prepared statement's `fetchObject()` method to fetch the next query result row as an object whose property names are the SQL query result columns ([Example 5-25](#)).

### Example 5-25. Prepared statement fetch row as object

```
<?php
// Build and execute SQL query
$sql = 'SELECT id, email FROM users WHERE email = :email';
$statement = $pdo->prepare($sql);
$email = filter_input(INPUT_GET, 'email');
$statement->bindValue(':email', $email, PDO::PARAM_INT);
$statement->execute();

// Iterate results
```

```
while (($result = $statement->fetchObject()) !== false) {  
    echo $result->name;  
}
```

# Transactions

The PDO extension also supports *transactions*. A transaction is a set of database statements that execute *atomically*. In other words, a transaction is a collection of SQL queries that are either all executed successfully or not executed at all. Transaction atomicity encourages data consistency, safety, and durability. A nice side effect of transactions is improved performance, because you are effectively queuing multiple queries to be executed together at one time.

## Note

Not all databases support transactions. Check your database's documentation and its associated PHP PDO driver for more information.

Transactions are simple to use with the PDO extension. You build and execute SQL statements exactly as demonstrated in [Example 5-25](#). There is only one difference. You surround SQL statement executions with the PDO instance's `beginTransaction()` and `commit()` methods. The `beginTransaction()` method causes PDO to queue subsequent SQL query executions rather than execute them immediately. The `commit()` method executes queued queries in an atomic transaction. If a single query in the transaction fails, none of the transaction queries is applied. Remember, a transaction is all or nothing.

Atomicity is important when data integrity is paramount. Let's explore example code that handles bank account transactions. Our code can deposit funds into an account. It can also withdraw funds from an account assuming there are sufficient funds. The code in [Example 5-26](#) transfers \$50 from one account to another account. It does not use a database transaction.

## Example 5-26. Database query without transaction

```
<?php
require 'settings.php';

// PDO connection
try {
    $pdo = new PDO(
        sprintf(
            'mysql:host=%s;dbname=%s;port=%s;charset=%s',
            $settings['host'],
            $settings['name'],
            $settings['port'],
            $settings['charset']
        ),
        $settings['username'],
        $settings['password']
    );
} catch (PDOException $e) {
    // Database connection failed
    echo "Database connection failed";
    exit;
}

// Statements
$stmtSubtract = $pdo->prepare('
    UPDATE accounts
    SET amount = amount - :amount
    WHERE name = :name
');
$stmtAdd = $pdo->prepare('
    UPDATE accounts
    SET amount = amount + :amount
');
```

```

        WHERE name = :name
');

// Withdraw funds from account 1
$fromAccount = 'Checking';
$withdrawal = 50;
$stmtSubtract->bindParam(':name', $fromAccount);
$stmtSubtract->bindParam(':amount', $withdrawal, PDO::PARAM_INT);
$stmtSubtract->execute();

// Deposit funds into account 2
$toAccount = 'Savings';
$deposit = 50;
$stmtAdd->bindParam(':name', $toAccount);
$stmtAdd->bindParam(':amount', $deposit, PDO::PARAM_INT);
$stmtAdd->execute();

```

This seems fine, right? It's not. What happens if our server suddenly shuts down after we withdraw \$50 from account 1 and before we deposit \$50 into account 2? Perhaps our hosting company had a power outage or a fire or a flood or was afflicted by some other calamity. What happens to the \$50 withdrawn from account 1? The funds are not deposited into account 2. The funds disappear. We can protect data integrity with a database transaction ([Example 5-27](#)).

## Example 5-27. Database query with transaction

```

<?php
require 'settings.php';

// PDO connection
try {
    $pdo = new PDO(
        sprintf(
            'mysql:host=%s;dbname=%s;port=%s;charset=%s',
            $settings['host'],
            $settings['name'],
            $settings['port'],
            $settings['charset']
        ),
        $settings['username'],
        $settings['password']
    );
} catch (PDOException $e) {
    // Database connection failed
    echo "Database connection failed";
    exit;
}

// Statements
$stmtSubtract = $pdo->prepare('
    UPDATE accounts
    SET amount = amount - :amount
    WHERE name = :name
');
$stmtAdd = $pdo->prepare('
    UPDATE accounts
    SET amount = amount + :amount
    WHERE name = :name
');

// Start transaction
$pdo->beginTransaction();

// Withdraw funds from account 1
$fromAccount = 'Checking';
$withdrawal = 50;
$stmtSubtract->bindParam(':name', $fromAccount);
$stmtSubtract->bindParam(':amount', $withdrawal, PDO::PARAM_INT);
$stmtSubtract->execute();

// Deposit funds into account 2
$toAccount = 'Savings';

```

```
$deposit = 50;
$stmtAdd->bindParam(':name', $toAccount);
$stmtAdd->bindParam(':amount', $deposit, PDO::PARAM_INT);
$stmtAdd->execute();

// Commit transaction
$pdo->commit();
```

[Example 5-27](#) wraps the withdrawal and deposit into a single database transaction. This ensures that both execute successfully or not at all. Our data remains consistent.

# Multibyte Strings

PHP assumes each character in a string is an 8-bit character that occupies a single byte of memory. Unfortunately, this is a naive assumption that breaks down as soon as you work with non-English characters. You might localize your PHP application for international users. Your blog might receive comments written in Spanish, German, or Norwegian. Your users' names might contain accented characters. My point is that you'll often encounter *multibyte* characters, and you must accommodate them correctly.

When I say *multibyte character*, I mean any character that is not one of the 128 characters in the traditional ASCII character set. Some examples are ñ, è, â, ô, à, æ, and ø. There are many others. PHP's default string-manipulation functions assume all strings use only 8-bit characters. If you manipulate a Unicode string that contains multibyte characters with PHP's native string functions, you will get incorrect and unexpected results.

## Note

Unicode is an international standard that assigns a number to each unique character from many different languages. It is maintained by the [Unicode Consortium](#).

You can avoid multibyte string errors by installing the [mbstring](#) PHP extension. This extension introduces multibyte-aware string functions that replace most of PHP's native string-manipulation functions. For example, use the multibyte-aware `mb_strlen()` function instead of PHP's native `strlen()` function.

To this day I'm still training myself to use the `mbstring` multibyte string functions instead of PHP's default string functions. It's a tough habit to form, but you must use the multibyte string functions if you work with Unicode strings. Otherwise, it's easy for multibyte Unicode data to become malformed.

## Tip

I use the `Iñternâtiònàlizætiøn` string when testing my PHP applications for multibyte character support.

## Character Encoding

Use UTF-8. If you leave this section with one piece of advice, this is it. All modern web browsers understand UTF-8 character encoding. A character encoding is a method of packaging Unicode data in a format that can be stored in memory or sent over the wire between a server and client. The UTF-8 character encoding is just one of many available character encodings. UTF-8, however, is the most popular character encoding and is supported by all modern web browsers.

# Unicode and UTF-8 Explained

Tom Scott provides [the best explanation of Unicode and UTF-8 that I've seen](#). Joel Spolsky also [writes a nice explanation of character encodings on his website](#).

Character encoding is complex and confuses a lot of developers. When you work with multibyte strings, keep this advice in mind:

1. Always know the character encoding of your data.
2. Store data with the UTF-8 character encoding.
3. Output data with the UTF-8 character encoding.

The `mbstring` extension doesn't just manipulate Unicode strings. It also converts multibyte strings between various character encodings. This is useful when clients export Excel spreadsheet data with a Windows-specific character encoding when what I really want is UTF-8 encoded data. Use the `mb_detect_encoding()` and `mb_convert_encoding()` functions to convert Unicode strings from one character encoding to another.

# Output UTF-8 Data

When you work with multibyte characters, it is important that you tell PHP you are working with the UTF-8 character encoding. It's easiest to do this in your *php.ini* file like this:

```
default_charset = "UTF-8";
```

The default character set is used by many PHP functions, including `htmlentities()`, `html_entity_decode()`, `htmlspecialchars()`, and the `mbstring` functions. This value is also added to the default Content-Type header returned by PHP unless explicitly specified with the `header()` function like this:

```
<?php  
header('Content-Type: application/json; charset=utf-8');
```

## Warning

You cannot use the `header()` function after *any* output is returned from PHP.

I also recommend you include this `meta` tag in your HTML document header:

```
<meta charset="UTF-8"/>
```

# Streams

Streams are probably the most amazing and least used modern PHP feature. Even though streams were introduced in PHP 4.3.0, many developers still don't know about streams because they are rarely mentioned, and they are poorly documented.

Streams were introduced with PHP 4.3.0 as a way of generalizing file, network, data compression, and other operations which share a common set of functions and uses. In its simplest definition, a stream is a resource object which exhibits streamable behavior. That is, it can be read from or written to in a linear fashion, and may be able to `fseek()` to an arbitrary location within the stream.

## PHP Manual

That's a mouthful, right? Let's reduce this into something more understandable. A stream is a transfer of data between an origin and destination. That's it. The origin and destination can be a file, a command-line process, a network connection, a ZIP or TAR archive, temporary memory, standard input or output, or any other resource available via PHP's [stream wrappers](#).

If you've read from or written to a file, you've used streams. If you've read from `php://stdin` or written to `php://stdout`, you've used streams. Streams provide the underlying implementation for many of PHP's IO functions like `file_get_contents()`, `fopen()`, `fgets()`, and `fwrite()`. PHP's stream functions help us manipulate different stream resources (origins and destinations) with a single interface.

## Tip

I think of *streams* as a pipe that carries water from one location to another. As water flows through the pipe from origin to destination, we can filter the water, we can transform the water, we can add water, and we can remove water. (*Hint:* The water is a metaphor for data.)

# Stream Wrappers

There are different types of streamable data that require unique *protocols* for reading and writing data. We call these protocols [stream wrappers](#). For example, we can read and write data to the filesystem. We can talk with remote web servers via HTTP, HTTPS, or SSH (secure shell). We can open, read, and write ZIP, RAR, or PHAR archives. All of these communication methods imply the same generic process:

1. Open communication.
2. Read data.
3. Write data.
4. Close communication.

Although the process is the same, reading and writing a filesystem file is different from sending or receiving HTTP messages. Stream wrappers, however, encapsulate these differences behind a common interface.

Every stream has a *scheme* and a *target*. We specify the scheme and target in the stream's *identifier* using this familiar format:

```
<scheme>://<target>
```

The `<scheme>` identifies the stream's wrapper. The `<target>` identifies the stream data source. [Example 5-28](#) creates a PHP stream to/from the Flickr API. It uses the HTTP stream wrapper.

## Example 5-28. Flickr API with HTTP stream wrapper

```
<?php
$json = file_get_contents(
    'http://api.flickr.com/services/feeds/photos_public.gne?format=json'
);
```

Don't be fooled by what appears to be a traditional website URL. The `file_get_contents()` function's string argument is actually a stream identifier. The `http` scheme prompts PHP to use the HTTP stream wrapper. The argument's remainder is the stream target. The stream target looks like a traditional website URL only because that's what the HTTP stream wrapper expects. This may not be true for other stream wrappers.

### Note

Reread this paragraph several times until it becomes ingrained in your memory. Many PHP developers don't understand that a traditional URL is actually a PHP stream wrapper identifier in disguise.

## The `file://` stream wrapper

We use the `file_get_contents()`, `fopen()`, `fwrite()`, and `fclose()` methods to read from and write to the filesystem. We rarely consider these functions as using PHP streams, because the default PHP stream wrapper is `file://`. We're using PHP streams and we don't even realize it! [Example 5-29](#) creates a stream to/from the `/etc/hosts` file using the `file://` stream wrapper.

## Example 5-29. Implicit `file://` stream wrapper

```
<?php
$handle = fopen('/etc/hosts', 'rb');
while (feof($handle) !== true) {
    echo fgets($handle);
}
fclose($handle);
```

[Example 5-30](#) accomplishes the same task. This example, however, explicitly specifies the `file://` stream wrapper in the stream identifier.

### Example 5-30. Explicit `file://` stream wrapper

```
<?php
$handle = fopen('file:///etc/hosts', 'rb');
while (feof($handle) !== true) {
    echo fgets($handle);
}
fclose($handle);
```

We usually omit the `file://` stream wrapper because PHP assumes this is the default value.

## The `php://` stream wrapper

PHP developers who write command-line scripts will appreciate the `php://` stream wrapper. This stream wrapper communicates with the PHP script's standard input, standard output, and standard error file descriptors. You can open, read from, and write to these four streams with PHP's filesystem functions:

`php://stdin`

This read-only PHP stream exposes data provided via standard input. For example, a PHP script can use this stream to receive information piped into the script on the command line.

`php://stdout`

This PHP stream lets you write data to the current output buffer. This stream is write-only and cannot be read or seeked.

`php://memory`

This PHP stream lets you read and write data to system memory. The downside to this PHP stream is that available memory is finite. It's safer to use the `php://temp` stream instead.

`php://temp`

This PHP stream acts just like `php://memory`, except that when available memory is gone, PHP instead writes to a temporary file.

## Other stream wrappers

PHP and PHP extensions provide many other stream wrappers. For example, there are stream wrappers to communicate with ZIP and TAR archives, FTP servers, data-compression libraries, Amazon APIs, and more. A popular misconception is that the `fopen()`, `fgets()`, `fputs()`, `feof()`, `fclose()`, and other PHP filesystem functions are for filesystem files only. *This is not true.* PHP's filesystem functions work with *all* stream wrappers that support them. For example, we can use `fopen()`, `fgets()`, `fputs()`, `feof()`, and `fclose()` to interact with a ZIP archive, Amazon S3 (with the custom [S3 wrapper](#)), or

even Dropbox (with the custom [Dropbox wrapper](#)).

### Note

Learn more about the `php://` stream wrapper at [PHP.net](#).

## Custom stream wrappers

It's also possible to write your own custom PHP stream wrapper. PHP provides an example `streamwrapper` class that demonstrates how to write a custom stream wrapper that supports some or all of the PHP filesystem functions. Learn more about custom PHP stream wrappers at:

- <http://php.net/manual/class.streamwrapper.php>
- <http://php.net/manual/stream.streamwrapper.example-1.php>

# Stream Context

Some PHP streams accept an optional set of parameters, or a *stream context*, to customize the stream's behavior. Different stream wrappers expect different context parameters. You create a stream context with the `stream_context_create()` function. The returned context object can be passed into and used by most PHP filesystem and stream functions.

For example, did you know that you can send an HTTP POST request with the `file_get_contents()` function? You can with a stream context object ([Example 5-31](#)).

## Example 5-31. Stream context

```
<?php
$requestBody = '{"username":"josh"}';
$context = stream_context_create(array(
    'http' => array(
        'method' => 'POST',
        'header' => "Content-Type: application/json; charset=utf-8;\r\n".
                      "Content-Length: " . mb_strlen($requestBody),
        'content' => $requestBody
    )
));
$response = file_get_contents('https://my-api.com/users', false, $context);
```

The stream context is an associative array whose topmost array key is the stream wrapper name. The stream context's array values are specific to each stream wrapper. Consult the appropriate PHP stream wrapper's documentation for a list of valid settings.

# Stream Filters

So far we've talked about opening, reading from, and writing to PHP streams. However, the true power of PHP streams is filtering, transforming, adding, or removing stream data in transit. Imagine opening a stream to a Markdown file and converting it into HTML *automatically* as you read the file into memory.

## Note

PHP provides several built-in stream filters, including `string.rot13`, `string.toupper`, `string.toLowerCase`, and `string.strip_tags`. These are not useful. Use custom stream filters, instead.

You attach a filter to an existing stream with the `stream_filter_append()` function.

[Example 5-32](#) uses the `string.toupper` filter to read data from a text file on the local filesystem and convert its content to uppercase characters. I don't encourage using this particular stream filter. I'm only demonstrating how to attach a filter to a stream.

### Example 5-32. Stream filter `string.toupper` example

```
<?php
$handle = fopen('data.txt', 'rb');
stream_filter_append($handle, 'string.toupper');
while(feof($handle) !== true) {
    echo fgets($handle); // <-- Outputs all uppercase characters
}
fclose($handle);
```

You can also attach a filter to a stream with the `php://filter` stream wrapper. This only works if you attach the filter *when you first open the PHP stream*. [Example 5-33](#) accomplishes the same task as the previous example, except it attaches the filter with `php://filter` strategy.

### Example 5-33. Stream filter `string.toupper` example with `php://filter`

```
<?php
$handle = fopen('php://filter/read=string.toupper/resource=data.txt', 'rb');
while(feof($handle) !== true) {
    echo fgets($handle); // <-- Outputs all uppercase characters
}
fclose($handle);
```

Pay close attention to the `fopen()` function's first argument. The argument is a stream identifier that uses the `php://` stream wrapper. This is the stream identifier target:

```
filter/read=<filter_name>/resource=<scheme>://<target>
```

This strategy may appear superfluous compared to the `stream_filter_append()` function. However, some PHP filesystem functions like `file()` or `fpassthru()` do not give you the opportunity to attach filters after the function is called. The `php://filter` stream wrapper is the only way to attach stream filters with these functions.

Let's look at a more realistic stream filter example. At [New Media Campaigns](#), our in-house content management system archives nginx access logs to [rsync.net](#). We keep one log file per day, and each log file is compressed with bzip2. Log filenames use the format `YYYY-MM-DD.log.bz2`. I was asked to extract access data for a specific domain for the past 30 days. This seems like a lot of work, right? I need to calculate a date range, determine log filenames, FTP into rsync.net, download files, decompress files, iterate each

file line-by-line, extract appropriate lines, and write access data to an output destination. Believe it or not, PHP streams let me do all of this in fewer than 20 lines of code ([Example 5-34](#)).

### Example 5-34. Iterate bzipped log files with DateTime and stream filters

```
01 <?php
02 $dateStart = new \DateTime();
03 $dateInterval = \DateInterval::createFromString('-1 day');
04 $datePeriod = new \DatePeriod($dateStart, $dateInterval, 30);
05 foreach ($datePeriod as $date) {
06     $file = 'sftp://USER:PASS@rsync.net/' . $date->format('Y-m-d') . '.log.bz2';
07     if (file_exists($file)) {
08         $handle = fopen($file, 'rb');
09         stream_filter_append($handle, 'bzip2.decompress');
10         while (feof($handle) !== true) {
11             $line = fgets($handle);
12             if (strpos($line, 'www.example.com') !== false) {
13                 fwrite(STDOUT, $line);
14             }
15         }
16     }
17 }
18 }
```

In [Example 5-34](#):

- Lines 2–4 create a DatePeriod instance that spans the past 30 days using an inverted, one-day interval.
- Line 6 creates a log filename using the DateTime instance returned by each DatePeriod iteration.
- Lines 8–9 open a stream resource to the log file on rsync.net with the SFTP stream wrapper. We decompress the bzip2 log file on the fly by appending the bzip2.decompress stream filter to the log file stream resource.
- Lines 10–15 iterate the decompressed log file contents using PHP’s standard filesystem functions.
- Lines 12–14 inspect each line for a given domain. If the domain is present, the line is written to standard output.

The bzip2.decompress stream filter lets us *automatically* decompress log files as we read them. The alternative solution is manually decompressing log files into a temporary directory with shell\_exec() or bzdecompress(), iterating the decompressed files, and cleaning up the decompressed files when our PHP script completes. PHP streams are a simpler, more elegant solution.

## Custom Stream Filters

It's possible to write custom stream filters, too. In fact, custom stream filters are the primary reason you use stream filters. Custom stream filters are PHP classes that extend the [php\\_user\\_filter](#) built-in class. The custom stream class must implement the `filter()`, `onCreate()`, and `onClose()` methods. You must register custom stream filters with the `stream_filter_register()` function.

# Here Comes the Bucket Brigade!

A PHP stream subdivides data into sequential *buckets*, and each bucket contains a fixed amount of stream data (e.g., 4,096 bytes). If we use our pipe metaphor, water is carried from origin to destination in individual buckets that float through the pipe and pass through stream filters. Each stream filter receives and manipulates one or more buckets at a time. The bucket or buckets received by a filter at any given time is called a *bucket brigade*.

Let's create a custom stream filter that censors dirty words from a stream as its data is read into memory ([Example 5-35](#)). First, we must create a PHP class that extends `php_user_filter`. This class must implement a `filter()` method that acts as a sieve through which stream buckets pass. It receives a bucket brigade from upstream, it manipulates each bucket object in the brigade, and it sends each bucket into the downstream bucket brigade toward the stream destination. This is our `DirtyWordsFilter` custom stream class.

## Tip

Each bucket object in a bucket brigade has two public properties: `data` and `datalen`. These are the bucket content and content length, respectively.

### Example 5-35. Custom DirtyWordsFilter stream filter

```
class DirtyWordsFilter extends php_user_filter
{
    /**
     * @param resource $in      Incoming bucket brigade
     * @param resource $out     Outgoing bucket brigade
     * @param int      $consumed Number of bytes consumed
     * @param bool     $closing  Last bucket brigade in stream?
     */
    public function filter($in, $out, &$consumed, $closing)
    {
        $words = array('grime', 'dirt', 'grease');
        $wordData = array();
        foreach ($words as $word) {
            $replacement = array_fill(0, mb_strlen($word), '*');
            $wordData[$word] = implode('', $replacement);
        }
        $bad = array_keys($wordData);
        $good = array_values($wordData);

        // Iterate each bucket from incoming bucket brigade
        while ($bucket = stream_bucket_make_writeable($in)) {
            // Censor dirty words in bucket data
            $bucket->data = str_replace($bad, $good, $bucket->data);

            // Increment total data consumed
            $consumed += $bucket->datalen;

            // Send bucket to downstream brigade
            stream_bucket_append($out, $bucket);
        }

        return PSFS_PASS_ON;
    }
}
```

The `filter()` method receives, manipulates, and forwards buckets of stream data. Inside the `filter()` function, we iterate the buckets in the `$in` bucket brigade and replace dirty words with their censored values. This method returns the `PSFS_PASS_ON` constant to

indicate successful operation. This method accepts four arguments:

`$in`

A brigade of one or more upstream buckets that contains stream data from the stream origin

`$out`

A brigade of one or more buckets that continue downstream toward the stream destination

`&$consumed`

The total number of stream bytes consumed by our custom filter

`$closing`

Is the `filter()` method receiving the last available bucket brigade?

We must register the `DirtyWordsFilter` custom stream filter with the `stream_filter_register()` function ([Example 5-36](#)).

### Example 5-36. Register custom `DirtyWordsFilter` stream filter

```
<?php
stream_filter_register('dirty_words_filter', 'DirtyWordsFilter');
```

The first argument is the filter name that identifies our custom filter. The second argument is our custom filter's class name. We can now use our custom stream filter ([Example 5-37](#)).

### Example 5-37. Use `DirtyWordsFilter` stream filter

```
<?php
$handle = fopen('data.txt', 'rb');
stream_filter_append($handle, 'dirty_words_filter');
while (feof($handle) !== true) {
    echo fgets($handle); // <-- Outputs censored text
}
fclose($handle);
```

### Tip

If you want to learn more about PHP streams, watch Elizabeth Smith's [Nomad PHP presentation](#). It's not free, but it's worth the admission price. You can also read more about PHP streams in the [PHP documentation](#).

# Errors and Exceptions

Things go wrong. It's a fact of life. No matter how hard we concentrate or how much time we pour into a project, there are always bugs and errors that we overlook. For example, have you ever used a PHP application that displays only a blank white page? Have you ever visited a PHP website that spits out an indecipherable stack trace? These unfortunate situations indicate an application error or uncaught exception.

Errors and exceptions are wonderful tools that help you anticipate the unexpected. They help you catch problems and fail gracefully. Errors and exceptions, however, are confusingly similar. They both announce when something is wrong, they both provide an error message, and they both have an error type. Errors, however, are older than exceptions. They are a procedural device that halts script execution and, if possible, delegates error handling to a global error handler function. Some errors are unrecoverable. Today we largely rely on exceptions instead of errors, but we must still maintain a defensive posture; many older PHP functions (e.g., `fopen()`) still trigger errors when things go wrong.

## Note

It's possible to circumvent PHP errors with the `@` prefix in front of a PHP function that might trigger an error (e.g., `@fopen()`). *This is an antipattern.* I recommend you change your code to avoid these situations.

Exceptions are an object-oriented evolution of PHP's error handling system. They are instantiated, thrown, and caught. Exceptions are a more flexible device that anticipates and handles problems *in situ* without halting script execution. Exceptions are also an offensive *and* defensive device. We must anticipate exceptions thrown by third-party vendor code with `try {} catch {}` blocks. We can also act offensively by throwing an exception; this delegates exception handling to other developers when we don't know how to handle a given situation on our own.

# Exceptions

An exception is an object of class `Exception` that is *thrown* when you encounter an irreparable situation from which you cannot recover (e.g., a remote API is unresponsive, a database query fails, or a precondition is not satisfied). I call these *exceptional situations*. Exceptions are used offensively to delegate responsibility when a problem occurs, and they are used defensively to anticipate and mitigate potential problems.

You instantiate an `Exception` object with the `new` keyword just like any other PHP object. An `Exception` object has two primary properties: a message and a numeric code. The message describes what went wrong. The numeric code is optional and can be used to provide context for a given exception. You provide the message and optional numeric code when you instantiate an `Exception` object like this:

```
<?php  
$exception = new Exception('Danger, Will Robinson!', 100);
```

You can inspect an `Exception` object with its `getCode()` and `getMessage()` public instance methods like this:

```
<?php  
$code = $exception->getCode(); // 100  
$message = $exception->getMessage(); // 'Danger...'
```

## Throw exceptions

You can assign an exception to a variable upon instantiation, but exceptions are meant to be *thrown*. If you write code for other developers, you must act offensively in exceptional situations, meaning you throw exceptions when your code encounters exceptional situations or cannot otherwise operate under current conditions. PHP component and framework authors, in particular, cannot presume how to handle exceptional situations; instead, they throw an exception and delegate responsibility to the developer using their code.

When an exception is thrown, code execution is immediately halted and subsequent PHP code is not run. To throw an exception, use the `throw` keyword followed by the `Exception` instance:

```
<?php  
throw new Exception('Something went wrong. Time for lunch!');
```

You can only throw an instance of class `Exception` (or a subclass of `Exception`). PHP provides these built-in `Exception` subclasses:

- [Exception](#)
- [ErrorException](#)

The [Standard PHP Library](#) (SPL) supplements PHP's built-in exceptions with these additional `Exception` subclasses:

- [LogicException](#)
  - [BadFunctionCallException](#)
    - [BadMethodCallException](#)
  - [DomainException](#)

- [InvalidArgumentException](#)
- [LengthException](#)
- [OutOfRangeException](#)
- [RuntimeException](#)
  - [OutOfBoundsException](#)
  - [OverflowException](#)
  - [RangeException](#)
  - [UnderflowException](#)
  - [UnexpectedValueException](#)

Each subclass exists for a certain situation and provides context for *why* an exception is thrown. For example, if a PHP component method expects a string argument with at least five characters but is given a string with only two characters, it can throw an `InvalidArgumentException` instance. Because PHP provides an exception *class*, you can easily extend the `Exception` class to create your own custom exception subclasses with their own custom properties and methods. Which exception subclass you use is subjective. Choose or create the exception subclass that best answers *why am I throwing this exception?*, and document your choice.

## Catch exceptions

Thrown exceptions should be *caught* and handled gracefully. You must act defensively when using PHP components and frameworks written by other developers. Good PHP components and frameworks provide documentation that explains when and under what circumstances they throw exceptions. It is your responsibility to anticipate, catch, and handle these exceptions. Uncaught exceptions terminate your PHP application with a fatal error and, worse, can expose sensitive debugging details to your PHP application's users. We've all seen this. It is very important that you catch exceptions and handle them gracefully.

Surround code that might throw an exception with a `try/catch` block to intercept and handle potential exceptions. [Example 5-38](#) demonstrates a failed `PDO` database connection that throws a `PDOException` object. The exception is caught by the `catch` block, and we show a friendly error message instead of an ugly stack trace.

### Example 5-38. Catch thrown exception

```
<?php
try {
    $pdo = new PDO('mysql://host=wrong_host;dbname=wrong_name');
} catch (PDOException $e) {
    // Inspect the exception for logging
    $code = $e->getCode();
    $message = $e->getMessage();

    // Display a nice message to the user
    echo 'Something went wrong. Check back soon, please.';
    exit;
}
```

You can use multiple `catch` blocks to intercept multiple types of exceptions. This is useful if you need to act differently based on the type of exception thrown. You can also use a `finally` block to *always* run a block of code after you catch *any* exception ([Example 5-39](#)).

## Example 5-39. Catch multiple thrown exceptions

```
<?php
try {
    throw new Exception('Not a PDO exception');
    $pdo = new PDO('mysql://host=wrong_host;dbname=wrong_name');
} catch (PDOException $e) {
    // Handle PDO exception
    echo "Caught PDO exception";
} catch (Exception $e) {
    // Handle all other exceptions
    echo "Caught generic exception";
} finally {
    // Always do this
    echo "Always do this";
}
```

In [Example 5-39](#), the first catch block intercepts `PDOException` exceptions. All other exceptions are intercepted by the second catch block. Only one catch block is run for each caught exception. If PHP does not find an applicable catch block, the exception continues to bubble upward until the PHP script ultimately terminates with a fatal error.

# Exception Handlers

You may be thinking *how am I supposed to catch every possible exception?* And that's a good question. PHP lets you register a global *exception handler* to catch otherwise uncaught exceptions. *You should always set a global exception handler.* An exception handler is a final safety net that lets you show an appropriate error message to your PHP application's users if you otherwise fail to catch and handle an exception. For my own PHP applications, I use exception handlers to show debugging information during development and a user-friendly message during production.

An exception handler is anything that is *callable*. I prefer to use an anonymous function, but you can also use a class method. Whatever you choose, it must accept one argument of class `Exception`. You register your exception handler with the `set_exception_handler()` function like this:

```
<?php
set_exception_handler(function (Exception $e) {
    // Handle and log exception
});
```

## Tip

I strongly recommend you log exceptions inside your exception handler. Your logger can alert you when things go wrong, and it saves exception details for later review.

In some situations, you may need to replace an existing exception handler with your own exception handler. PHP etiquette suggests you restore the existing exception handler when your code is finished. You can restore a previous exception handler with the `restore_exception_handler()` function ([Example 5-40](#)).

## Example 5-40. Set global exception handler

```
<?php
// Register your exception handler
set_exception_handler(function (Exception $e) {
    // Handle and log exception
});

// Your code goes here...

// Restore previous exception handler
restore_exception_handler();
```

# Errors

PHP provides error-reporting functions in addition to exceptions. This confuses many PHP developers. PHP can trigger different types of errors, including fatal errors, runtime errors, compile-time errors, startup errors, and (more rarely) user-triggered errors. You'll most often encounter PHP errors caused by syntax mistakes or uncaught exceptions.

The difference between errors and exceptions is subtle. Errors are often triggered when a PHP script cannot fundamentally run as expected for whatever reason (e.g., there is a syntax mistake). It is also possible to trigger your own errors with the `trigger_error()` function and handle them with a custom error handler, but it is better to use exceptions when writing userland code. Unlike errors, PHP exceptions can be thrown and caught at any level of your PHP application. Exceptions provide more contextual information than PHP errors. And you can extend the topmost `Exception` class with your own custom exception subclasses. Exceptions and a good logger like Monolog are a far more versatile solution than PHP errors. However, modern PHP developers must anticipate and handle both PHP errors and PHP exceptions.

You can instruct PHP which errors to report, and which to ignore, with the `error_reporting()` function or the `error_reporting` directive in your `php.ini` file. Both accept named `E_*` constants that determine which errors are reported and which are ignored.

## Note

Learn more about PHP error reporting at <http://php.net/manual/function.error-reporting.php>.

PHP error reporting can be as sensitive or stoic as you tell it to be. In development, I prefer PHP to obnoxiously display and log all error messages. In production, I instruct PHP to log most error messages but not display them. Whatever you do, you should always follow these four rules:

- Always turn on error reporting.
- Display errors during development.
- *Do not* display errors during production.
- Log errors during development and production.

Here are my error-reporting `php.ini` settings for development:

```
; Display errors
display_startup_errors = On
display_errors = On

; Report all errors
error_reporting = -1

; Turn on error logging
log_errors = On
```

Here are my error-reporting `php.ini` settings for production:

```
; DO NOT display errors
display_startup_errors = Off
display_errors = Off

; Report all errors EXCEPT notices
```

```
error_reporting = E_ALL & ~E_NOTICE
```

```
; Turn on error logging  
log_errors = On
```

The main difference is that I display errors in my PHP script output during development. I do not display errors in my PHP script output in production. However, I log errors in both environments. If I have a bug in my production PHP application (and this never happens...cough), I can review my PHP log file for details.

# Error Handlers

Just as you can with exception handlers, you can set a global error handler to intercept and handle PHP errors with your own logic. The error handler lets you fail gracefully by cleaning up loose ends before terminating the PHP script.

An error handler, like an exception handler, is anything that is callable (e.g., a function or class method). It is your responsibility to `die()` or `exit()` inside of your error handler. If you don't manually terminate the PHP script inside your error handler, the PHP script will continue executing from where the error occurred. You register your global error handler with the `set_error_handler()`, and you pass it an argument that is callable:

```
<?php
set_error_handler(function ($errno, $errstr, $errfile, $errline) {
    // Handle error
});
```

Your error-handler callable receives five arguments:

`$errno`

The error level (maps to a PHP `E_*` constant).

`$errstr`

The error message.

`$errfile`

The filename in which the error occurred.

`$errline`

The file line number on which the error occurred.

`$errcontext`

An array that points to the active symbol table when the error occurred. This is optional and is only useful for advanced debugging purposes. I usually ignore this argument.

There's one important caveat that you absolutely must know when using a custom error handler. PHP will send *all* errors to your error handler, even those that are excluded by your current error-reporting setting. It is your responsibility to inspect each error code (the first argument) and act appropriately. You *can* instruct your error handler to only respond to a subset of error types with a second argument to the `set_error_handler()` function; this argument is a bitwise mask of `E_*` constants (e.g., `E_ALL | E_STRICT`).

This is as good a time as any to segue into a common practice that I and many other PHP developers use in our PHP applications. I like to convert PHP errors into `ErrorException` objects. The `ErrorException` class is a subclass of `Exception`, and it comes built into PHP. This lets me convert PHP errors into exceptions and funnel them into my existing exception handling workflow.

## Note

Not all errors can be converted into exceptions! These errors include `E_ERROR`, `E_PARSE`, `E_CORE_ERROR`, `E_CORE_WARNING`, `E_COMPILE_ERROR`, `E_COMPILE_WARNING`, and most of `E_STRICT`.

Converting PHP errors is a bit tricky, and we must be careful to convert only the errors that satisfy the `error_reporting` setting in our `php.ini` file. Here's an example error-handler function that converts PHP errors into `ErrorException` objects:

```
<?php
set_error_handler(function ($errno, $errstr, $errfile, $errline) {
    if (!error_reporting() & $errno) {
        // Error is not specified in the error_reporting
        // setting, so we ignore it.
        return;
    }

    throw new \ErrorException($errstr, $errno, 0, $errfile, $errline);
});
```

This error-handler function converts the appropriate PHP errors into `ErrorException` objects and throws them into our existing exception-handling system. It is considered good etiquette to restore the previous error handler (if any) after your own code is done. You can restore the previous handler with the `restore_error_handler()` function ([Example 5-41](#)).

## Example 5-41. Set global error handler

```
<?php
// Register error handler
set_error_handler(function ($errno, $errstr, $errfile, $errline) {
    if (!error_reporting() & $errno) {
        // Error is not specified in the error_reporting
        // setting, so we ignore it.
        return;
    }

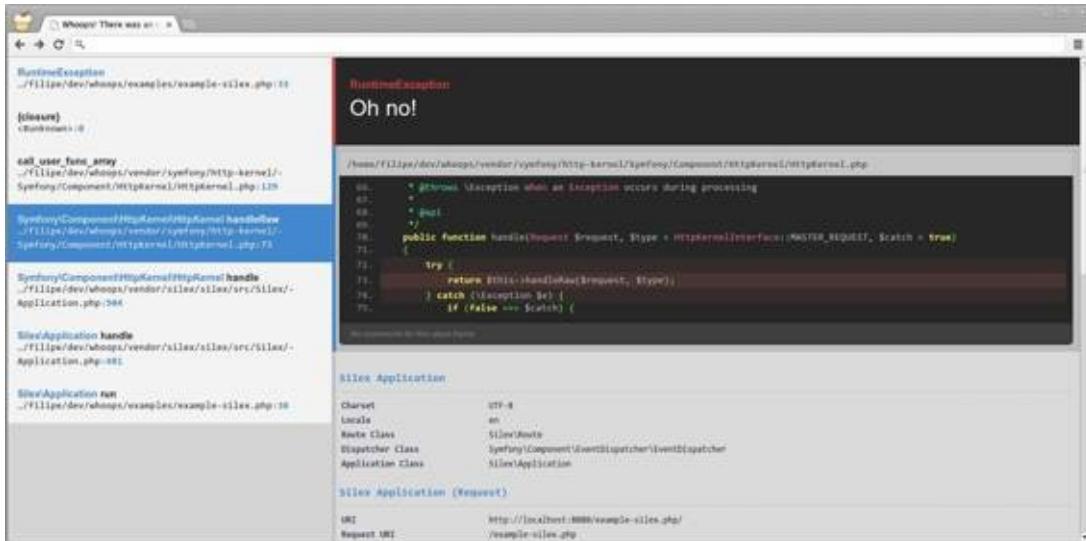
    throw new \ErrorException($errstr, $errno, 0, $errfile, $errline);
});

// Your code goes here...

// Restore previous error handler
restore_error_handler();
```

# Errors and Exceptions During Development

We know we should display errors during development. But PHP's default error messages are ugly and often injected into the normal PHP script output, resulting in a hard-to-read mess. Use [Whoops](#) instead. Whoops is a modern PHP component that provides a well-designed, easy-to-read diagnostics page for PHP errors and exceptions. Whoops, created and maintained by [Filipe Dobreira](#) and [Denis Sokolov](#), looks like [Figure 5-1](#).



**Figure 5-1. Whoops screenshot**

The Whoops diagnostic screen is light years better than the default PHP error and exception output.

Whoops is easy to implement, too. Update your `composer.json` file as shown below, and run either `composer install` or `composer update`:

```
{  
    "require": {  
        "filip/whoops": "~1.0"  
    }  
}
```

Next, register the Whoops error and exception handlers in your PHP application's bootstrap file, as shown in [Example 5-42](#).

## Example 5-42. Register the Whoops handler

```
<?php  
// Use composer autoloader  
require 'path/to/vendor/autoload.php';  
  
// Setup Whoops error and exception handlers  
$whoops = new \Whoops\Run;  
$whoops->pushHandler(new \Whoops\Handler\PrettyPageHandler);  
$whoops->register();
```

That's it. When your script triggers a PHP error or when your application does not catch an exception, you'll see the Whoops diagnostic screen.

[Example 5-42](#) uses the Whoops `PrettyPageHandler` handler, which creates the diagnostic screen shown in [Figure 5-1](#). There are other Whoops handlers, too, including a plain-text handler, a callback handler, a JSON response handler, an XML response handler, and (if your pointy-haired boss likes to say the word *enterprise* a lot) a SOAP response handler. I

use Whoops during development for each application I develop.

# Production

We know we should log errors in production. PHP provides the `error_log()` function to write messages to the filesystem, to syslog, or into an email. But there's a better option, and it's called [Monolog](#). Monolog is a very good PHP component that specializes in one thing — logging. It's easy to integrate into your PHP applications with Composer.

First, require the `monolog/monolog` package in your `composer.json` file:

```
{  
    "require": {  
        "monolog/monolog": "~1.11"  
    }  
}
```

Next, install the component with either `composer install` or `composer update`, and add the code from [Example 5-43](#) to the top of your PHP application's bootstrap file.

## Example 5-43. Use Monolog for development logging

```
<?php  
// Use Composer autoloader  
require 'path/to/vendor/autoload.php';  
  
// Import Monolog namespaces  
use Monolog\Logger;  
use Monolog\Handler\StreamHandler;  
  
// Setup Monolog logger  
$log = new Logger('my-app-name');  
$log->pushHandler(new StreamHandler('path/to/your.log', Logger::WARNING));
```

That's it. You now have a Monolog logger that will write all logged messages of type `Logger::WARNING` or higher to the `path/to/your.log` file.

Monolog is very extensible. You can define multiple handlers that only handle specific log levels. For example, we can push a second Monolog handler that emails an administrator for critical, alert, or emergency errors. We'll need the SwiftMailer PHP component, so let's add that to the `composer.json` file and run `composer update`:

```
{  
    "require": {  
        "monolog/monolog": "~1.11",  
        "swiftmailer/swiftmailer": "~5.3"  
    }  
}
```

Next, we'll modify our code and add a new Monolog handler that accepts a SwiftMailer instance to send email messages ([Example 5-44](#)).

## Example 5-44. Use Monolog for production logging

```
<?php  
// Use Composer autoloader  
require 'vendor/autoload.php';  
  
// Import Monolog namespaces  
use Monolog\Logger;  
use Monolog\Handler\StreamHandler;  
use Monolog\Handler\SwiftMailerHandler;  
  
date_default_timezone_set('America/New_York');  
  
// Setup Monolog and basic handler  
$log = new Logger('my-app-name');  
$log->pushHandler(new StreamHandler('logs/production.log', Logger::WARNING));
```

```
// Add SwiftMailer handler for critical errors
$transport = \Swift_SmtpTransport::newInstance('smtp.example.com', 587)
    ->setUsername('USERNAME')
    ->setPassword('PASSWORD');
$mailer = \Swift_Mailer::newInstance($transport);
$message = \Swift_Message::newInstance()
    ->setSubject('Website error!')
    ->setFrom(array('daemon@example.com' => 'John Doe'))
    ->setTo(array('admin@example.com')));
$log->pushHandler(new SwiftMailerHandler($mailer, $message, Logger::CRITICAL));

// Use logger
$log->critical('The server is on fire!');
```

Now when a critical, alert, or emergency message is logged, Monolog emails the logged message using the SwiftMailer \$mailer and \$message objects. The email body is the logged message text.

## **Part III. Deployment, Testing, and Tuning**

# Chapter 6. Hosting

So you have a PHP application. Congratulations! However, it doesn't do anyone any good unless your users can, you know, *use* it. You need to host your application on a server and make it accessible to its intended audience. Generally speaking, there are four ways to host PHP applications: shared servers, virtual private servers, dedicated servers, and platforms as a service. Each has its unique benefits and is suitable for different types of applications and budgets.

There are also many web hosting companies, and it can be overwhelming if you are brand new to the web hosting landscape. Some hosting companies provide only shared servers. Other companies provide a mix of shared servers, virtual private servers, and dedicated servers. This chapter will focus less on the companies themselves and more on hosting options.

# Shared Server

A shared server is the most affordable hosting option and costs \$1–10/month. *You should avoid shared hosting plans.* This is not a commentary on shared hosting companies' quality of service or customer support. There are many good shared hosting companies. Simply put, shared hosting options are not developer-friendly.

A shared server, as its name implies, means that you share server resources with other people. If you purchase a shared hosting plan, your hosting account lives on the same physical machine as many other customers'. If your particular machine has 2 Gb of memory, your PHP application might receive only a fraction of that memory, depending on how many other customer accounts live on the same machine. If another account on the same machine runs a poorly coded script, it can negatively affect your own application. Some shared hosting companies oversell shared servers, and your PHP application constantly battles for system resources on a crowded machine.

Shared servers are also very difficult to customize. For example, your application may need [Memcached](#) or [Redis](#) for a fast, in-memory cache. You may want to install [Elasticsearch](#) to add search functionality to your application. Unfortunately, shared server software is difficult — if not impossible — to customize. Your applications suffer as a result.

Shared servers rarely provide remote SSH access. Instead, you're often handicapped with (S)FTP access only. This limitation severely restricts your ability to automate PHP application deployment.

If your budget is super-small or your needs extremely modest, a shared server may be sufficient. However, if you're building a business website or a moderately popular PHP application, you're better off using a virtual private server, a dedicated server, or a PaaS.

# Virtual Private Server

A virtual private server (VPS) looks, feels, and acts like a bare-metal server. But it's not a bare-metal server. A VPS is a collection of system resources that are distributed across one or many physical machines. A VPS still has its own filesystem, root user, system processes, and IP address. A VPS is allocated a specific amount of memory, CPU, and bandwidth — and they're all yours.

VPSs provide more system resources than a shared server. A VPS provides root SSH access. And a VPS does not limit what software you can install. Great power, though, comes with great responsibility. VPSs give you root access to a virgin operating system. It is your responsibility to configure and secure the operating system for your PHP application. VPSs are ideal for most PHP applications. They provide sufficient system resources (e.g., CPU, memory, and disk space) that scale up or down on demand. A VPS costs \$10–100/month based on the amount of system resources needed by your PHP application. If your PHP application becomes super-popular (hundreds of thousands of visitors a month) and a VPS becomes too costly, you might consider upgrading to a dedicated server.

## Tip

I almost always prefer VPSs for their balance of cost, features, and flexibility. [Linode](#), my favorite hosting company, provides VPS and dedicated hosting plans. Linode isn't the cheapest option, but my personal experience shows Linode is fast and stable, and it comes with a vast treasure of helpful tutorials.

# Dedicated Server

A dedicated server is a rack-mounted machine that your hosting company installs, runs, and maintains on your behalf. You configure dedicated servers to your exact specifications. Dedicated servers are real machines that must be transported, installed, and monitored. They cannot be set up and configured as quickly as VPSs. That being said, dedicated servers provide the ultimate performance for demanding PHP applications.

Dedicated servers act much like VPSs. You get root SSH access to a virgin operating system, and you must secure and configure the operating system for your PHP application. The benefit of a dedicated server is cost-effectiveness. Eventually a VPS becomes too costly as you consume more system resources. You save money by investing in your own infrastructure.

A dedicated server costs hundreds of dollars per month depending on the server specifications. It can be unmanaged (i.e., you manage the server yourself) or managed (i.e., you pay extra for your hosting company to manage the server).

# PaaS

Platforms as a service (PaaS) are a quick way to launch your PHP application, and — unlike with a virtual private or dedicated server — you don't have to manage a PaaS. All you have to do is log into your PaaS provider's control panel and click a few buttons. Some PaaS providers have a command-line or HTTP API with which you can deploy and manage your hosted PHP applications. Popular PHP PaaS providers include:

- [AppFog](#)
- [AWS Elastic Beanstalk](#)
- [Engine Yard](#)
- [Fortrabbit](#)
- [Google App Engine](#)
- [Heroku](#)
- [Microsoft Azure](#)
- [Pagoda Box](#)
- [Red Hat OpenShift](#)
- [Zend Developer Cloud](#)

PaaS pricing varies by provider but is similar to virtual private servers: \$10–100/month. You pay for the system resources allocated to your PHP application. System resources can be scaled up or down on demand. I recommend PaaS hosting plans for developers who do not want to manage their own servers.

# Choose a Hosting Plan

Choose only what you need when you need it. You can always scale your hosting infrastructure up or down when necessary. For small PHP applications or prototypes, a PaaS provider like Engine Yard or Heroku is the best and quickest solution. If you prefer more control over your server configuration, get a VPS. If your application becomes super-popular and your VPS is buckling beneath the weight of millions of visitors (congratulations, by the way!), get a dedicated server. Whichever hosting option you choose, make sure it provides the latest stable PHP version and extensions required by your PHP application.

# Chapter 7. Provisioning

After you choose a host for your application, it's time to configure and provision the server for your PHP application. I'll be honest — provisioning a server is an art, not a science. How you provision your server depends entirely on your application's needs.

## Note

If you use a PaaS, your server infrastructure is managed by the PaaS provider. All you have to do is follow the provider's instructions to move your PHP application onto their platform, and you're ready to go.

If you don't use a PaaS, you must provision either a VPS or dedicated server to run your PHP application. Provisioning a server is not as hard as it sounds (stop laughing), but it does require familiarity with the command line. If the command line is alien to you, you're better off with a PaaS like Engine Yard or Heroku.

I don't consider myself a system administrator. However, basic system administration is an incredibly valuable skill for application developers that enables more flexible and robust application development. In this chapter, I'll share my system administration knowledge so you can feel comfortable opening a terminal to provision a server for your PHP application. Afterward, I'll suggest a few additional resources for you to continue improving your system administration skills.

## Note

In this chapter, I assume you know how to edit a text file using a command-line editor like [nano](#) or [vim](#) (these are available on most Linux distributions). Otherwise, you'll need an alternative method of accessing and editing files on your server.

# Our Goal

First, we need to acquire a virtual private or dedicated server. Next, we need to install a web server to receive HTTP requests. Finally, we need to set up and manage a group of PHP processes to handle PHP requests; these processes must communicate with our web server.

Several years ago, it was common practice to install the Apache web server and the Apache `mod_php` module. The Apache web server spawns a unique child process to handle *each* HTTP request. The Apache `mod_php` module embeds a unique PHP interpreter inside each spawned child process — even processes that serve only static assets like JavaScript, images, or stylesheets. This is a lot of overhead that wastes system resources. I see fewer and fewer PHP developers use Apache nowadays because there are more efficient solutions.

Today, we use the [nginx](#) web server, which sits in front of (and forwards PHP requests to) a collection of PHP-FPM processes. That's the solution I'll demonstrate in this chapter.

# Server Setup

First, let's set up a virtual private server (VPS). I absolutely adore [Linode](#). It isn't the cheapest VPS provider, but it's one of the most reliable. Head over to Linode's website (or your preferred vendor) and purchase a new VPS. Your vendor will ask you to choose a Linux distribution and a root password for your new server.

## Tip

Many VPS providers, like [Linode](#) and [Digital Ocean](#), bill by the hour. This means you can fire up and play with a VPS at virtually zero cost.

# First Login

The first thing you should do is log in to your new server. Let's do that now. Open a terminal on your local machine and ssh into your server. Be sure you swap in your own machine's IP address:

```
ssh root@123.456.78.90
```

You may be asked to confirm the authenticity of your new server. Type **yes** and press Enter:

```
The authenticity of host '123.456.78.90 (123.456.78.90)' can't be established.  
RSA key fingerprint is 21:eb:37:f3:a5:d3:c0:77:47:c4:15:3d:3c:dc:3c:d1.  
Are you sure you want to continue connecting (yes/no)?
```

Next, you'll be prompted for the root user's password. Type the password and press Enter:

```
root@123.456.78.90's password:
```

You are now logged into your new server!

## Software Updates

The very next thing you should do is update your operating system's software with these commands.

```
# Ubuntu  
apt-get update;  
apt-get upgrade;  
  
# CentOS  
yum update
```

These commands spit out a lot of information as software updates for your operating system are downloaded and applied. This is an important first step because it ensures you have the latest updates and security fixes for your operating system's default software.

## Nonroot User

Your new server is not secure. Here are a few good practices to harden your new server's security.

Create a *nonroot* user. You should log in to your server as this nonroot user in the future. The root user has unlimited power on your server. It is God. It can run any command without question. *You should make it as difficult as possible to access your server as the root user.*

## Ubuntu

Create a new nonroot user named `deploy` with the command in [Example 7-1](#). Enter a user password when prompted, and follow the remaining on-screen instructions.

### Example 7-1. Create nonroot user on Ubuntu

```
adduser deploy
```

Next, assign the `deploy` user to the `sudo` group with this command:

```
usermod -a -G sudo deploy
```

This gives the `deploy` user sudo privileges (i.e., it can perform privileged tasks with password authentication).

## CentOS

Create a new nonroot user named `deploy` with this command:

```
adduser deploy
```

Give the `deploy` user a password with this command. Enter and confirm the new password when prompted:

```
passwd deploy
```

Next, assign the `deploy` user to the `wheel` group with this command:

```
usermod -a -G wheel deploy
```

This gives the `deploy` user sudo privileges (i.e., it can perform privileged tasks with password authentication).

# SSH Key-Pair Authentication

On your local machine, you can log into your new server as the nonroot deploy user like this:

```
ssh deploy@123.456.78.90
```

You'll be prompted for the deploy user's password, and then you'll be logged in to the server. We can make the login process more secure by disabling password authentication. Password authentication is vulnerable to brute-force attacks in which bad guys try to guess your password over and over in quick succession. Instead, we'll use *SSH key-pair authentication* when we ssh into our server.

Key-pair authentication is a complex subject. In basic terms, you create a pair of "keys" on your local machine. One key is private (this stays on your local machine), and one key is public (this goes on the remote server). They are called a *key pair* because messages encrypted with the public key can be decrypted only by the related private key.

When you log in to the remote machine using SSH key-pair authentication, the remote machine creates a random message, encrypts it with your public key, and sends it to your local machine. Your local machine decrypts the message with your private key and returns the decrypted message to the remote server. The remote server then validates the decrypted message and grants you access to the server. This is a dramatic simplification, but you get the point.

If you log in to your remote server from many different computers, you probably do not want to use SSH key-pair authentication. This would require you to generate public/private SSH key pairs for each local computer and copy each key pair's public key to your remote server. In this case, it's probably preferable to continue using password authentication with a secure password. However, if you are only accessing your remote server from a single local computer (as many developers often do), SSH key-pair authentication is the way to go. You can create an SSH key-pair on your local machine with this command:

```
ssh-keygen
```

Follow the subsequent on-screen instructions and enter the requested information when prompted. This command creates two files on your local machine: `~/.ssh/id_rsa.pub` (your public key) and `~/.ssh/id_rsa` (your private key). The private key should stay on your local computer and remain a secret. Your public key, however, must be copied onto your new server. We can copy the public key with the `scp` (secure copy) command:

```
scp ~/.ssh/id_rsa.pub deploy@123.456.78.90:
```

Be sure you include the trailing `:` character! This command uploads your public key to the deploy user's home directory on your remote server. Next, log in to your remote server as the deploy user. After you log in to your remote server, make sure the `~/.ssh` directory exists. If it does not exist, create the `~/.ssh` directory with this command:

```
mkdir ~/.ssh
```

Next, create the `~/.ssh/authorized_keys` file with this command:

```
touch ~/.ssh/authorized_keys
```

This file will contain a list of public keys that are allowed to log into this remote server. Execute this command to append your recently uploaded public key to the `~/.ssh/authorized_keys` file:

```
cat ~/id_rsa.pub >> ~/.ssh/authorized_keys
```

Finally, we need to modify a few directory and file permissions so that only the `deploy` user can access its own `~/.ssh` directory and read its own `~/.ssh/authorized_keys` file. Assign these permissions with these commands:

```
chown -R deploy:deploy ~/.ssh;
chmod 700 ~/.ssh;
chmod 600 ~/.ssh/authorized_keys;
```

We're done! On your local machine, you should now be able to ssh into the remote server without entering a password.

### Note

You can only ssh into your remote server without a password from the local machine that has your private key!

# Disable Passwords and Root Login

Let's make the remote server even more secure. We'll disable password authentication for all users, and we'll prevent the root user from logging in — period. Remember, the root user can do anything, so we want to make it as difficult as possible to access our server as the root user.

Log in to the remote server as the deploy user and open the `/etc/ssh/sshd_config` file in your preferred text editor. This is the SSH server software's configuration file. Find the `PasswordAuthentication` setting and change its value to `no`; uncomment this setting if necessary. Find the `PermitRootLogin` setting and change its value to `no`; uncomment this setting if necessary. Save your changes and restart the SSH server with this command to apply your changes:

```
# Ubuntu
sudo service ssh restart

# CentOS
sudo systemctl restart sshd.service
```

You're done. You've secured your server, and it's time to install additional software to run your PHP application. From this point forward, all instructions should be completed on the remote server as the nonroot deploy user.

## Note

Server security is an ongoing task that should be constantly monitored. I recommend you implement a firewall in addition to my previous instructions. Ubuntu users can use [UFW](#). CentOS users can use [iptables](#).

# PHP-FPM

[PHP-FPM](#) (PHP FastCGI Process Manager) is software that manages a pool of related PHP processes that receive and handle requests from a web server like nginx. The PHP-FPM software creates one master process (usually run by the operating system's root user) that controls how and when HTTP requests are forwarded to one or more child processes. The PHP-FPM master process also controls when child PHP processes are created (to answer additional web application traffic) and destroyed (if they are too old or no longer necessary). Each PHP-FPM pool process lives longer than a single HTTP request, and it can handle 10, 50, 100, 500, or more HTTP requests.

# Install

The simplest way to install PHP-FPM is with your operating system's native package manager, as demonstrated by the following commands.

## Tip

See [Appendix A](#) for a detailed PHP-FPM installation guide.

```
# Ubuntu
sudo apt-get install python-software-properties;
sudo add-apt-repository ppa:ondrej/php5-5.6;
sudo apt-get update;
sudo apt-get install php5-fpm php5-cli php5-curl \
    php5-gd php5-json php5-mcrypt php5-mysqlnd;

# CentOS
sudo rpm -Uvh \
    http://dl.fedoraproject.org/pub/epel/7/x86_64/e/epel-release-7-5.noarch.rpm;
sudo rpm -Uvh \
    http://rpms.famillecollet.com/enterprise/remi-release-7.rpm;
sudo yum -y --enablerepo=epel,remi,remi-php56 install php-fpm php-cli php-gd \
    php-mbstring php-mcrypt php-mysqlnd php-opcache php-pdo php-devel;
```

## Tip

If the EPEL rpm installation fails, open a web browser and navigate to [http://dl.fedoraproject.org/pub/epel/7/x86\\_64/e/](http://dl.fedoraproject.org/pub/epel/7/x86_64/e/). Look for an updated EPEL release version and use that.

# Global Configuration

On Ubuntu, the primary PHP-FPM configuration file is `/etc/php5/fpm/php-fpm.conf`. On CentOS, the primary PHP-FPM configuration file is `/etc/php-fpm.conf`. Open this file in your preferred text editor.

## Note

PHP-FPM configuration files use the INI file format. Learn more about the INI format on [Wikipedia](#).

These are the most important *global* PHP-FPM settings that I recommend you change from their default values. These two settings might be commented out by default; uncomment them if necessary. These settings prompt the master PHP-FPM process to restart if a specific number of its child processes fail within a specific interval of time. These settings are a basic safety net for your PHP-FPM processes that can resolve simple issues. They are not a solution to more fundamental problems caused by bad PHP code.

```
emergency_restart_threshold = 10
```

The maximum number of PHP-FPM child processes that can fail within a given time interval until the master PHP-FPM process gracefully restarts

```
emergency_restart_interval = 1m
```

The length of time that governs the `emergency_restart_threshold` setting

## Note

Read more about PHP-FPM global configuration at  
<http://php.net/manual/en/install.fpm.configuration.php>.

# Pool Configuration

Elsewhere in the PHP-FPM configuration file is a section named `Pool Definitions`. This section contains configuration settings for each PHP-FPM pool. A PHP-FPM pool is a collection of related PHP child processes. One PHP application typically has its own PHP-FPM pool.

On Ubuntu, the `Pool Definitions` section contains this one line:

```
include=/etc/php5/fpm/pool.d/*.conf
```

CentOS includes the pool definition files at the top of the primary PHP-FPM configuration file with this line:

```
include=/etc/php-fpm.d/*.conf
```

This line prompts PHP-FPM to load individual pool definition files located in the `/etc/php5/fpm/pool.d/` directory (for Ubuntu) or the `/etc/php-fpm.d/` directory (for CentOS). Navigate into this directory, and you should see one file named `www.conf`. This is the configuration file for the default PHP-FPM pool named `www`. Open this file in your preferred text editor.

## Note

Each PHP-FPM pool configuration begins with a [ character, the pool name, and a ] character. The default PHP-FPM pool configuration, for example, begins with [www].

Each PHP-FPM pool runs as the operating system user and group that you specify. I prefer to run each PHP-FPM pool as a unique nonroot user to help me identify each PHP application's PHP-FPM processes on the command line with the `top` or `ps aux` commands. This is a good habit, too, because each PHP-FPM pool's processes are inherently sandboxed by the permissions available to their operating system user and group.

We'll configure the default `www` PHP-FPM pool to run as the `deploy` user and group. If you haven't already, open the `www` PHP-FPM pool configuration file in your preferred text editor. Here are the settings I recommend you change from their default values:

```
user = deploy
```

The system user that owns this PHP-FPM pool's child processes. Set this to your PHP application's nonroot operating system user name.

```
group = deploy
```

The system group that owns this PHP-FPM pool's child processes. Set this to your PHP application's nonroot operating system group name.

```
listen = 127.0.0.1:9000
```

The IP address and port number on which this PHP-FPM pool listens for and accepts inbound requests from nginx. The value `127.0.0.1:9000` instructs this specific PHP-FPM pool to listen for incoming connections on local port `9000`. I use port `9000`, but you can use any nonprivileged port number (any port number greater than `1024`) that is not already in use by another system process. We'll revisit this setting when we configure our nginx virtual host.

```
listen.allowed_clients = 127.0.0.1
```

The IP address(es) that can send requests to this PHP-FPM pool. For security reasons, I set this to `127.0.0.1`. This means that only the current machine can forward requests to this PHP-FPM pool. This setting might be commented out by default. Uncomment this setting if necessary.

```
pm.max_children = 51
```

This value sets the total number of PHP-FPM pool processes that can exist at any given time. There is no correct value for this setting. You should test your PHP application, determine how much memory each individual PHP process uses, and set this to the total number of PHP processes that your machine's available memory can accommodate. Most small to medium-sized PHP applications often use between 5 MB and 15 MB of memory for each individual PHP process (your mileage may vary). Assuming we are on a machine with 512 MB of memory available to this PHP-FPM pool, we can set this value to `512MB total / 10MB per process`, or 51 processes.

```
pm.start_servers = 3
```

The number of PHP-FPM pool processes that are available immediately when PHP-FPM starts. Again, there is no correct value for this setting. For most small or medium-sized PHP applications, I recommend a value of 2 or 3. This ensures that your PHP application's initial HTTP requests don't have to wait for PHP-FPM to initialize PHP-FPM pool processes. Two or three processes are already ready and waiting.

```
pm.min_spare_servers = 2
```

The smallest number of PHP-FPM pool processes that exist when your PHP application is idle. This will typically be in the same ballpark as your `pm.start_servers` setting, and it ensures that new HTTP requests don't have to wait for PHP-FPM to initialize new pool processes to handle new requests.

```
pm.max_spare_servers = 4
```

The largest number of PHP-FPM pool processes that exist when your PHP application is idle. This will typically be a bit more than your `pm.start_servers` setting, and it ensures that new HTTP requests don't have to wait for PHP-FPM to initialize new pool processes to handle new requests.

```
pm.max_requests = 1000
```

The maximum number of HTTP requests that each PHP-FPM pool process handles before being recycled. This setting helps us avoid accumulating memory leaks caused by poorly coded PHP extensions or libraries. I recommend a value of `1000`, but you should tweak this based on your own application's needs.

```
slowlog = /path/to/slowlog.log
```

The absolute filesystem path to a log file that records information about HTTP requests that take longer than  $\{n\}$  number of seconds to process. This is helpful for identifying and debugging bottlenecks in your PHP applications. Bear in mind, this PHP-FPM pool's user or group must have permission to write to this file. The value /path/to/slowlog.log is an example; replace this value with your own file path.

```
request_slowlog_timeout = 5s
```

The length of time after which the current HTTP request's backtrace is dumped to the log file specified by the slowlog setting. The value you choose depends on what you consider to be a slow request. A value of 5s is a reasonable value to start with.

After you edit and save the PHP-FPM configuration file, restart the PHP-FPM master process with this command:

```
# Ubuntu  
sudo service php5-fpm restart
```

```
# CentOS  
sudo systemctl restart php-fpm.service
```

## Note

Read more about PHP-FPM pool configuration at <http://php.net/manual/install.fpm.configuration.php>.

# **nginx**

nginx (pronounced *in gen ex*) is a web server similar to Apache, but it's much simpler to configure and often uses less system memory. I don't have time to dig into nginx in detail, but I do want to show you how to install nginx on your server and forward appropriate requests to your PHP-FPM pool.

# Install

The simplest way to install nginx is with your operating system's native package manager.

## Ubuntu

On Ubuntu, install nginx with a PPA. This is an Ubuntu-specific term for a prepackaged archive maintained by the nginx community:

```
sudo add-apt-repository ppa:nginx/stable;
sudo apt-get update;
sudo apt-get install nginx;
```

## CentOS

On CentOS, install nginx using the same EPEL third-party software repository we added earlier. The default CentOS software repositories might not have the latest nginx version:

```
sudo yum install nginx;
sudo systemctl enable nginx.service;
sudo systemctl start nginx.service;
```

# Virtual Host

Next, we'll configure an nginx *virtual host* for our PHP application. A virtual host is a group of settings that tell nginx our application's domain name, where the PHP application lives on the filesystem, and how to forward HTTP requests to the PHP-FPM pool.

First, we must decide where our application lives on the filesystem. The PHP application files must live in a filesystem directory that is readable and writable by the nonroot `deploy` user. For this example, I'll place application files in the `/home/deploy/apps/example.com/current` directory. We'll also need a directory to store application log files. I'll place log files in the `/home/deploy/apps/logs` directory. Use these commands to create the directories and assign correct permissions:

```
mkdir -p /home/deploy/apps/example.com/current/public;
mkdir -p /home/deploy/apps/logs;
chmod -R +rx /home/deploy;
```

Place your PHP application in the `/home/deploy/apps/example.com/current` directory. The nginx virtual host configuration assumes your PHP application has a `public/` directory; this is the virtual host document root.

Each nginx virtual host has its own configuration file. If you use Ubuntu, create the `/etc/nginx/sites-available/example.conf` configuration file. If you use CentOS, create the `/etc/nginx/conf.d/example.conf` configuration file. Open the `example.conf` configuration file in your preferred text editor.

nginx virtual host settings live inside a `server {}` block. Here is the complete virtual host configuration file:

```
server {
    listen 80;
    server_name example.com;
    index index.php;
    client_max_body_size 50M;
    error_log /home/deploy/apps/logs/example.error.log;
    access_log /home/deploy/apps/logs/example.access.log;
    root /home/deploy/apps/example.com/current/public;

    location / {
        try_files $uri $uri/ /index.php$is_args$args;
    }

    location ~ \.php {
        try_files $uri =404;
        fastcgi_split_path_info ^(.+\.php)(/.+)$;
        include fastcgi_params;
        fastcgi_param SCRIPT_FILENAME $document_root$fastcgi_script_name;
        fastcgi_param SCRIPT_NAME $fastcgi_script_name;
        fastcgi_index index.php;
        fastcgi_pass 127.0.0.1:9000;
    }
}
```

Copy and paste this code into the `example.conf` virtual host configuration file. Make sure you update the `server_name` setting and swap the `error_log`, `access_log`, and `root` paths with appropriate values. Here's a quick explanation of each virtual host setting:

`listen`

The port number on which nginx listens for inbound HTTP requests. In most cases, this is port 80 for HTTP traffic or port 443 for HTTPS traffic.

## `server_name`

The domain name that identifies this virtual host. Change this to your application's domain name, and ensure the domain name points at your server's IP address. nginx sends an HTTP request to this virtual host if the request's `Host` : header matches the virtual host's `server_name` value.

## `index`

The default files served if none is specified in the HTTP request URI.

## `client_max_body_size`

The maximum HTTP request body size accepted by nginx for this virtual host. If the request body size exceeds this value, nginx returns a HTTP 4xx response.

## `error_log`

The filesystem path to this virtual host's error log file.

## `access_log`

The filesystem path to this virtual host's access log file.

## `root`

The document root directory.

There are also two `location` blocks. These tell nginx how to handle HTTP requests that match specific URL patterns. The first `location / {}` block uses a `try_files` directive that looks for real files that match the request URI. If a file is not found, it looks for a directory that matches the request URI. If a directory is not found, it rewrites the HTTP request URI to `/index.php` and appends the query string if available. The rewritten URL, or any request whose URI ends with `.php`, is managed by the `location ~ \.php {}` block.

The `location ~ \.php {}` block forwards HTTP requests to our PHP-FPM pool. Remember how we set up our PHP-FPM pool to listen for requests on port 9000? This block forwards PHP requests to port 9000, and the PHP-FPM pool takes over.

## Note

There are a few extra lines in the `location ~ \.php {}` block. These lines prevent potential [remote code execution attacks](#).

On Ubuntu, we must symlink the virtual host configuration file into the `/etc/nginx/sites-enabled/` directory with this command:

```
sudo ln -s /etc/nginx/sites-available/example.conf \
           /etc/nginx/sites-enabled/example.conf;
```

Finally, restart nginx with this command:

```
# Ubuntu
sudo service nginx restart

# CentOS
sudo systemctl restart nginx.service
```

Your PHP application is up and running! There are many ways to configure nginx. I've included only the most essential nginx settings in this chapter because this is a PHP book, not an nginx book. You can learn more about nginx configuration at any of these helpful

resources:

- <http://nginx.org/>
- <https://github.com/h5bp/server-configs-nginx>
- <https://serversforhackers.com/editions/2014/03/25/nginx/>

# Automate Server Provisioning

Server provisioning is a lengthy process. It's also not a fun process, especially if you manually provision many servers. Fortunately, there are tools available that help automate server provisioning. Some popular server provisioning tools are:

- [Puppet](#)
- [Chef](#)
- [Ansible](#)
- [SaltStack](#)

Each tool is different, but they all accomplish the same goal — they automatically provision new servers based on your exact specifications. If you are responsible for multiple servers, I strongly encourage you to explore provisioning tools, because they save a ton of time.

# Delegate Server Provisioning

There are online services, too, that perform server provisioning on your behalf. An example service is [Forge](#) by Taylor Otwell. I was a Forge beta tester, and it really is a helpful service. Forge can provision multiple servers on Linode, Digital Ocean, and other popular VPS providers.

Each server provisioned by Forge is automatically secured using the same security practices I demonstrated earlier. Forge automatically installs an nginx and PHP-FPM software stack. Forge also simplifies PHP application deployment, SSL certificate installation, CRON task creation, and other mundane or confusing system administration tasks. I highly recommend Forge if system administration isn't your cup of tea.

# Further Reading

I find system administration fascinating. I don't want to do it as a full-time job, but I enjoy tinkering on the command line. The best system administration learning resource for developers, in my opinion, is [Servers for Hackers](#) by Chris Fidao.

# What's Next

In this chapter we discussed how to provision a server to run PHP applications. Next we'll talk about how to tune your server to eke out maximum performance for your PHP application.

# Chapter 8. Tuning

By this point, your PHP application should be running alongside nginx with its own PHP-FPM process pool. We're not done yet, though. We should *tune* PHP's configuration with settings appropriate for your application and production server. Default PHP installations are like an average suit you find at your local department store; they fit, but they don't fit well. A tuned PHP installation is a custom tailored suit prepared with your exact measurements.

Don't get too excited. PHP tuning is not a universal cure for application performance. Bad code is still bad code. For example, PHP tuning cannot solve poorly written SQL queries or unresponsive API calls. However, PHP tuning is a low-hanging fruit that can improve PHP efficiency and application performance.

# The `php.ini` File

The PHP interpreter is configured and tuned with a file named `php.ini`. This file can live in one of several directories on your operating system. If you run PHP with PHP-FPM, as I demonstrated earlier, you can find the `php.ini` configuration file at `/etc/php5/fpm/php.ini`. Oddly enough, this `php.ini` file does not control the PHP interpreter used when you invoke `php` on the command line. PHP on the command line uses its own `php.ini` file often located at `/etc/php5/cli/php.ini`. If you built PHP from source, the `php.ini` location is likely beneath the `$PREFIX` directory specified when you configured the PHP source files. I'll assume you're running PHP with PHP-FPM as described, but all of these optimizations are applicable to any `php.ini` file.

## Tip

Scan your `php.ini` file for best security practices with the [PHP Iniscan tool](#), written by Chris Cornutt.

The `php.ini` file uses the INI format. You can learn about the INI format on [Wikipedia](#).

# Memory

My first concern when running PHP is how much memory each PHP process consumes. The `memory_limit` setting in the `php.ini` file determines the maximum amount of system memory that can be used by a single PHP process.

The default value is `128M`, and this is probably fine for most small to medium-sized PHP applications. However, if you are running a tiny PHP application, you can save system resources by lowering this value to something like `64M`. If you are running a memory-intensive PHP application (e.g., a Drupal website), you may see improved performance with a higher value like `512M`. The value you choose is dictated by the amount of available system memory. Figuring out how much memory to allocate to PHP is more an art than a science. These are the questions I ask myself to determine my PHP memory limit and the number of PHP-FPM processes I can afford:

What is the total amount of memory I can allocate for PHP?

First, I determine how much system memory I can allocate for PHP. For example, I may be working with a Linode virtual machine with 2 GB of total memory. However, other processes (e.g., nginx, MySQL, or memcache) might run on the same machine and consume memory of their own. I think I can safely set aside 512 MB of memory for PHP.

How much memory, on average, is consumed by a single PHP process?

Next, I determine how much memory, on average, is consumed by a single PHP process. This requires me to monitor process memory usage. If you live in the command line, then you can run `top` to see realtime stats for running processes. You can also invoke the `memory_get_peak_usage()` PHP function at the tail end of a PHP script to output the maximum amount of memory consumed by the current script. Either way, run the same PHP script several times (to warm caches) and take the average memory consumption. I often find PHP processes consume between 5–20 MB of memory (your mileage may vary). If you are working with file uploads, image data, or a memory-intensive application, this value will obviously be higher.

How many PHP-FPM processes can I afford?

I have 512 MB of total memory allocated for PHP. I determine that each PHP process, on average, consumes about 15 MB of memory. I divide the total memory by the amount of memory consumed by each PHP process, and I determine I can afford 34 PHP-FPM processes. This value is an estimate and should be refined with experimentation.

Do I have enough system resources?

Finally, I ask myself if I believe I have sufficient system resources to run my PHP application and handle the expected web traffic. If yes, awesome. If no, I need to upgrade my server with more memory and return to the first question.

## Note

Use [Apache Bench](#) or [Seige](#) to stress-test your PHP applications under production-like conditions. If your PHP application does not have sufficient resources, it's wise to figure this out *before* you take your application into production.

# Zend OPcache

After I figure out my memory allocation, I configure the PHP Zend OPcache extension. This is an *opcode cache*. What's an opcode cache? Let's first examine how a typical PHP script is processed for every HTTP request. First, nginx forwards an HTTP request to PHP-FPM, and PHP-FPM assigns the request to a child PHP process. The PHP process finds the appropriate PHP scripts, it reads the PHP scripts, it compiles the PHP scripts into an opcode (or bytecode) format, and it executes the compiled PHP opcode to generate an HTTP response. The HTTP response is returned to nginx, and nginx returns the HTTP response to the HTTP client. This is a lot of overhead for every HTTP request.

We can speed this up by *caching* the compiled opcode for each PHP script. Then we can read and execute precompiled opcode from cache instead of finding, reading, and compiling PHP scripts for each HTTP request. The Zend OPcache extension is built into PHP 5.5.0+. Here are my *php.ini* settings to configure and optimize the Zend OPcache extension:

```
opcache.memory_consumption = 64
opcache.interned_strings_buffer = 16
opcache.max_accelerated_files = 4000
opcache.validate_timestamps = 1
opcache.revalidate_freq = 0
opcache.fast_shutdown = 1
```

`opcache.memory_consumption = 64`

The amount of memory (in megabytes) allocated for the opcode cache. This should be large enough to store the compiled opcode for all of your application's PHP scripts. If you have a small PHP application with few scripts, this can be a lower value like 16 MB. If your PHP application is large with many scripts, use a larger value like 64 MB.

`opcache.interned_strings_buffer = 16`

The amount of memory (in megabytes) used to store interned strings. What the heck is an interned string? That was my first question, too. The PHP interpreter, behind the scenes, detects multiple instances of identical strings and stores the string in memory *once* and uses pointers whenever the string is used again. This saves memory. By default, PHP's string interning is isolated in each PHP process. This setting lets all PHP-FPM pool processes store their interned strings in a shared buffer so that interned strings can be referenced across multiple PHP-FPM pool processes. This saves even more memory. The default value is 4 MB, but I prefer to bump this to 16 MB.

`opcache.max_accelerated_files = 4000`

The maximum number of PHP scripts that can be stored in the opcode cache. You can use any number between 200 and 100000. I use 4000. Make sure this number is larger than the number of files in your PHP application.

`opcache.validate_timestamps = 1`

When this setting is enabled, PHP checks PHP scripts for changes on the interval of time specified by the `opcache.revalidate_freq` setting. If this setting is disabled, PHP does not check PHP scripts for changes, and you must clear the opcode cache manually. I recommend you enable this setting during development and disable this setting during production.

```
opcache.revalidate_freq = 0
```

How often (in seconds) PHP checks compiled PHP files for changes. The benefit of a cache is to avoid recompiling PHP scripts on each request. This setting determines how long the opcode cache is considered fresh. After this time interval, PHP checks PHP scripts for changes. If PHP detects a change, PHP recompiles and recaches the script. I use a value of `0` seconds. This value requires PHP to revalidate PHP files on every request *if and only if* you enable the `opcache.validate_timestamps` setting. This means PHP revalidates files on every request during development (a good thing). This setting is moot during production because the `opcache.validate_timestamps` setting is disabled anyway.

```
opcache.fast_shutdown = 1
```

This prompts the opcache to use a faster shutdown sequence by delegating object deconstruction and memory release to the Zend Engine memory manager. Documentation is lacking for this setting. All you need to know is *turn this on*.

# File Uploads

Does your PHP application accept file uploads? If not, turn off file uploads to improve application security. If your application does accept file uploads, it's best to set a maximum upload filesize that your application accepts. It's also best to set a maximum number of uploads that your application accepts at one time. These are the *php.ini* settings I use for my own applications:

```
file_uploads = 1  
upload_max_filesize = 10M  
max_file_uploads = 3
```

By default, PHP allows up to 20 uploads in a single request. Each uploaded file can be up to 2 MB in size. You probably don't need to allow 20 uploads at once; I only allow three uploads in a single request, but change this setting to a value that makes sense for your application.

If my PHP applications accept file uploads, they often need to accept files much larger than 2 MB. I bump the `upload_max_filesize` setting to `10M` or higher based on each application's requirements. Don't set this to something too large, otherwise your web server (e.g., nginx) may complain about the HTTP request having too large a body or timing out.

## Note

If you accept very large file uploads, be sure your web server is configured accordingly. You may need to adjust the `client_max_body_size` setting in your nginx virtual host configuration *in addition to* your *php.ini* file.

# Max Execution Time

The `max_execution_time` setting in your `php.ini` file determines the maximum length of time that a single PHP process can run before terminating. By default, this is set to 30 seconds. You don't want PHP processes running for 30 seconds. We want our applications to be super-fast (measured in milliseconds). I recommend you change this to 5 seconds:

```
max_execution_time = 5
```

## Note

You can override this setting on a per-script basis with the [set\\_time\\_limit\(\)](#) PHP function.

*What if my PHP script needs to run a long time?* you ask. It shouldn't. The longer PHP runs, the longer your web application visitors must wait for a response. If you have long-running tasks (e.g., resizing images or generating reports), offload those tasks to a separate worker process.

## Tip

I use the `exec()` PHP function to invoke the `at` bash command. This lets me fork separate nonblocking processes that do not delay the current PHP process. If you use the `exec()` PHP function, it is your responsibility to escape shell arguments with the [escapeshellarg](#) PHP function.

Assume we need to run a report and generate a PDF file with the results. This task may take 10 minutes to complete. Surely we don't want the PHP request to sit around for 10 minutes. Instead, we create a separate PHP file called `create-report.php` that will chug along for 10 minutes and eventually generate our report. However, our web application will take only milliseconds to spin off a separate background process and return an HTTP response, like this:

```
<?php  
exec('echo "create-report.php" | at now');  
echo 'Report pending...';
```

The standalone `create-report.php` script runs in a separate background process; it can update a database or email the report recipient upon completion. There is absolutely no reason why the primary PHP script should hold up the user experience for long-running tasks.

## Tip

If you find yourself spawning a lot of background processes, you may be better served with a dedicated job queue. [PHP Resque](#) is a great job queue manager based on the [original Resque](#) job queue manager from GitHub.

# Session Handling

PHP's default session handler can slow down larger applications because it stores session data on disk. This creates unnecessary file I/O that takes time. Instead, offload session handling to a faster in-memory data store like [Memcached](#) or [Redis](#). This has the added benefit of future scalability. If your session data is stored on disk, this prevents you from scaling PHP across additional servers. If your session data is, instead, stored on a central Memcached or Redis data store, it can be accessed from any number of distributed PHP-FPM servers.

Install the the [PECL Memcached extension](#) to access a Memcached datastore from PHP. You can now change PHP's default session store to Memcached by adding these lines to your *php.ini* file:

```
session.save_handler = 'memcached'  
session.save_path = '127.0.0.2:11211'
```

# Output Buffering

Networks are more efficient when sending more data in fewer chunks, rather than less data in more chunks. In other words, deliver content to your visitor's web browser in fewer pieces to reduce the total number of HTTP requests.

This is why you enable PHP output buffering. By default, PHP's output buffer is enabled (except on the command line). PHP's output buffer collects up to 4,096 bytes before flushing its contents back to the web server. Here are my recommended *php.ini* settings:

```
output_buffering = 4096  
implicit_flush = false
```

## Tip

If you change the output buffer size, make sure its value is a multiple of 4 (for 32-bit systems) or 8 (for 64-bit systems).

# Realpath Cache

PHP maintains a cache of file paths that are used by your PHP application so it does not have to continually search the include path each time it includes or requires a file. This cache is called the *realpath cache*. If you are running a large PHP application that uses a lot of separate files (Drupal, Composer components, etc.), you can realize better performance by increasing the size of PHP's realpath cache.

The default realpath cache size is 16k. It's not obvious how to figure out the exact size you need, but here's a trick you can use. First, bump the realpath cache size to something obnoxiously large, like 256k. Then output the actual realpath cache size at the tail end of a PHP script with `print_r(realpath_cache_size());`. Change your realpath cache size to this actual value. You can set the realpath cache size in your `php.ini` file:

```
realpath_cache_size = 64k
```

## Up Next

We've got a server firing on all cylinders, and we're ready to deploy our PHP application into production. In the next chapter we'll discuss several strategies to automate PHP application deployment.

# Chapter 9. Deployment

We've got a provisioned server running nginx and PHP-FPM. Now we need to deploy our PHP application to a production server. There are many ways to push code into production. FTP was a popular way to deploy PHP code back when PHP developers first started banging rocks together. FTP still works, but today there are safer and more predictable deployment strategies. This chapter shows you how to use modern tools to automate deployment in a simple, predictable, and reversible way.

# Version Control

I assume you are using version control, right? If you are, good job. If you aren't, stop what you are doing and version control your code. I prefer to version control my code with [Git](#), but other version control software like [Mercurial](#) works, too. I use Git because it's what I know, and it works seamlessly with popular online repositories like [Bitbucket](#) and [GitHub](#).

Version control is an invaluable tool for PHP application developers because it lets us track changes to our codebase. We can tag points in time as a release, we can roll back to a previous state, and we can experiment with new features on separate branches that do not affect our production code. More important, version control helps us automate PHP application deployment.

# **Automate Deployment**

It is important that you automate application deployment so that it becomes a simple, predictable, and reversible process. The last thing you want to worry about is a complicated deployment process. Complicated deployments are scary, and scary things are used less often.

## **Make It Simple**

Instead, make your deployment process a simple one-line command. A simple deployment process is less scary, and that means you're more likely to push code to production.

## **Make It Predictable**

Make your deployment process predictable. A predictable process is even less scary because you know exactly what it is going to do. It should not have unexpected side effects. If it runs into an error, it aborts the deployment process and leaves the existing codebase in place.

## Make It Reversible

Make your deployment process reversible. If you accidentally push bad code into production, it should be a simple one-line command to roll back to the previous stable codebase. This is your safety net. A reversible deployment process should make you excited — not afraid — to push code into production. If you screw up, just roll back to the previous release.

# Capistrano

[Capistrano](#) is software that automates application deployment in a simple, predictable, and reversible way. Capistrano runs on your local machine and talks with remote servers via SSH. Capistrano was originally written to deploy Ruby applications, but it's just as useful for any programming language — including PHP.

# How It Works

You install Capistrano on your local workstation. Capistrano deploys your PHP application to a remote server by issuing SSH commands from your local workstation to the remote server. Capistrano organizes application deployments in their own directories on the remote server. Capistrano maintains five or more application deployment directories in case you must roll back to an earlier release. Capistrano also creates a *current/* directory that is a symlink to the current application deployment's directory. Your production server's Capistrano-managed directory structure might look like [Example 9-1](#).

## Example 9-1. Example directory structure

```
/  
  home/  
    deploy/  
      apps/  
        my_app/  
          current/  
          releases/  
            release1/  
            release2/  
            release3/  
            release4/  
            release5/
```

When you deploy a new application release to production, Capistrano first retrieves the latest version of your application code from its Git repository. Next, Capistrano places the application code in a new release directory. Finally, Capistrano symlinks the *current/* directory to the new release directory. When you ask Capistrano to roll back to a previous release, Capistrano points the *current/* directory symlink to a previous release directory. Capistrano is an elegant and simple deployment solution that makes PHP application deployments simple, predictable, and reversible.

## Install

Install Capistrano on your local machine. Do *not* install Capistrano on your remote servers. You'll need `ruby` and `gem`, too. OS X users already have these. Linux users can install `ruby` and `gem` with their respective package managers. After you install `ruby` and `gem`, install Capistrano with this command:

```
gem install capistrano
```

# Configure

After you install Capistrano, you must initialize your project for Capistrano. Open a terminal, navigate to your project's topmost directory, and run this command:

```
cap install
```

This command creates a file named *Capfile*, a directory named *config/*, and a directory named *lib/*. Your project's topmost directory should now have these files and directories:

```
Capfile
config/
  deploy/
    production.rb
    staging.rb
  deploy.rb
lib/
  capistrano/
    tasks/
```

The *Capfile* file is Capistrano's central configuration file, and it aggregates the configuration files located in the *config/* directory. The *config/* directory contains configuration files for each remote server environment (e.g., testing, staging, or production).

## Note

Capsitrano configuration files are written in the Ruby language. However, they are still easy to edit and understand.

By default, Capistrano assumes you have multiple environments for your application. For example, you might have separate staging and production environments. Capistrano provides a separate configuration file for each environment in the *config/deploy/* directory. Capistrano also provides the *config/deploy.rb* configuration file, which contains settings common to all environments.

In each environment, Capistrano has the notion of server *roles*. For example, your production environment may have a front-facing web server (the *web* role), an application server (the *app* role), and a database server (the *db* role). Only the largest applications necessitate this architecture. Smaller PHP applications generally use only one machine that runs the web server (nginx), application server (PHP-FPM), and database server (MariaDB).

For this demonstration, I'm only going to use Capistrano's *web* role and ignore its *app* and *db* roles. Capistrano's roles let you organize tasks to be executed only on servers that belong to a given role. This isn't something we're going to worry about here. However, I am going to respect Capistrano's notion of server environments. This demonstration will use the *production* environment, but the following steps are equally applicable to other environments (e.g., *staging* or *testing*).

## The config/deploy.rb file

Let's look at the *config/deploy.rb* file. This configuration file contains settings common to all environments (e.g., *staging* and *production*). Most of our Capistrano configuration settings go in this file. Open the *config/deploy.rb* file in your preferred text editor and

update these settings:

:application

This is the name of your PHP application. It should contain only letters, numbers, and underscores.

:repo\_url

This is your Git repository URL. This URL must point to a Git repository, and the repository must be accessible from your remote server.

:deploy\_to

This is the absolute directory path on your remote server in which your PHP application is deployed. This would be `/home/deploy/apps/my_app` as shown in [Example 9-1](#).

:keep\_releases

This is the number of old releases that should be retained in case you want to roll back your application to an earlier version.

## The config/deploy/production.rb file

This file contains settings only for your production environment. This file defines the production environment roles, and it lists the servers that belong to each role. We're only using the web role, and we have only one server that belongs to this role. Let's use the server we provisioned in [Chapter 7](#). Update the entire `config/deploy/production.rb` file with this content. Make sure you replace the example IP address:

```
role :web, %w{deploy@123.456.78.90}
```

## Authenticate

Before we deploy our application with Capistrano, we must establish authentication between our local computer and our remote servers, and between our remote servers and the Git repository. We already discussed how to set up SSH key-pair authentication between our local computer and remote server. You should also establish SSH key-pair authentication between your remote servers and the Git repository.

Use the same instructions we discussed earlier to generate an SSH public and private keypair on each remote server. The Git repository should have access to each remote server's public key; both GitHub and Bitbucket let you add multiple public SSH keys to your user account. Ultimately, you must be able to clone the Git repository to your remote servers without a password.

# Prepare the Remote Server

We're almost ready to deploy our application. First, we need to prepare our remote server. Log in to your remote server with SSH and create the directory in which we'll deploy our PHP application. This directory must be readable and writable by the `deploy` user. I like to create a directory for my applications in the `deploy` user's home directory, like this:

```
/  
home/  
  deploy/  
    apps/  
      my_app/
```

## Virtual host

Capistrano symlinks the `current/` directory to the current application release directory. Update your web server's virtual host document root directory so that it points to Capistrano's `current/` directory. Given this filesystem diagram, your virtual host document root might become `/home/deploy/apps/my_app/current/public/`; this assumes your PHP application contains a `public/` directory that serves as the document root. Restart your web server to load your virtual host configuration changes.

## Software dependencies

Your remote server doesn't need Capistrano, but it does need Git. It also needs any software required to run your PHP application. You can install Git with these commands:

```
# Ubuntu  
sudo apt-get install git;  
  
# CentOS  
sudo yum install git;
```

# Capistrano Hooks

Capistrano allows us to run our own commands at specific moments (or *hooks*) during application deployment. Many PHP developers manage application dependencies with Composer. We can install Composer dependencies during each Capistrano deployment with a Capistrano hook. Open the *config/deploy.rb* file in your preferred text editor and append this Ruby code:

```
namespace :deploy do
  desc "Build"
  after :updated, :build do
    on roles(:web) do
      within release_path do
        execute :composer, "install --no-dev --quiet"
      end
    end
  end
end
```

## Tip

If your project uses the Composer dependency manager, make sure Composer is installed on your remote servers.

Our application's dependencies are now installed automatically after each production deployment. You can read more about Capistrano hooks on the [Capistrano website](#).

## Deploy Your Application

Now's the fun part! Make sure you've committed and pushed your most recent application code to your Git repository. Then open a terminal on your local computer and navigate to your application's topmost directory. If you've done everything correctly, you can deploy your PHP application with this one-line command:

```
cap production deploy
```

## **Roll Back Your Application**

In the off chance you deploy bad code to your production environment, you can roll back to a previous release with this one-line command:

```
cap production deploy:rollback
```

# Further Reading

I've only scratched the surface. Capistrano has many more features that further streamline your deployment workflow. Capistrano is my favorite deployment tool, but there are many other tools available, including:

- [Deployer](#)
- [Magallanes](#)
- [Rocketeer](#)

# What's Next

We've provisioned a server, and we've automated our PHP application deployments with Capistrano. Next we'll discuss how to ensure our PHP applications run as expected. To do this, we'll use *testing* and *profiling*.

# Chapter 10. Testing

Testing is an important part of PHP application development, but it is often neglected. I think many PHP developers don't test because they consider testing an unnecessary burden that requires too much time for too few benefits. Other developers may not know *how* to test, because there are a large number of testing tools and an overwhelming learning curve.

In this chapter I hope to dispel these misunderstandings. I want you to feel comfortable and excited about testing your PHP code. I want you to consider testing an integral part of your workflow that happens at the beginning, middle, and end of the application development process.

# Why Do We Test?

We write tests to ensure that our PHP applications work, and continue to work, according to our expectations. It's as simple as that. How often have you been afraid to deploy an application into production? Before I started testing my code, I was terrified to push a release into production. Would my code work? Would it break? All I could do was cross my fingers and hope for the best. This is no way to code. It's scary and stressful, and it usually ends in frustration. Tests, however, mitigate uncertainty, and they let us write and deploy code with confidence.

Your pointy-haired boss may argue that there isn't enough time to write tests. After all, time is money. This is shortsighted. Installing a testing infrastructure and writing tests takes time, but this is a wise investment that pays dividends into the future. Tests help us write code that works well the first time. Tests let us continuously iterate without breaking old code. We may move forward at a slower pace than if we didn't use tests, but we won't waste countless development hours in the future troubleshooting and refactoring bugs that were overlooked. In the long term, tests save money, prevent downtime, and inspire confidence.

## When Do We Test?

I see many PHP developers write tests as an afterthought. These developers know testing is important, but they consider tests as something they *must* do instead of something they want to do. These developers often push testing to the very end of the application development process. They bang out a few passing tests to satisfy their management team and call it a day. This is wrong. Tests should be a foreground concern before development, during development, and after development.

## **Before**

Install and configure your testing tools before you develop your application. It doesn't matter which testing tools you choose. Install them as if they are a vital application dependency. This makes it physically and mentally easier to test your application during development. This is also a good time to meet with your project manager to define higher-level application behavior.

## **During**

Write and run tests as you build each piece of your application. Did you just add a new PHP class? Test it now, because you probably won't test it later. Testing while you develop helps you build confident and stable code, and it also helps you quickly find and refactor new code that breaks existing functionality.

## After

You probably won't anticipate and test all of your application's behaviors during development. If you find a bug after your launch your application, write a new test to ensure that your bug fix works correctly. Tests are not a once-and-done thing. Tests are continuously modified and improved, just like the application itself. If you update your application's code, be sure you also update the affected tests.

# What Do We Test?

We test the smallest pieces of our application. A PHP application, on a microcosmic scale, has PHP classes, methods, and functions. We should test each public class, method, and function to ensure it behaves as we expect in isolation. If we know each piece works well on its own, we can be confident it also works well when integrated into the whole application. These tests are called *unit tests*.

Unfortunately, testing each individual piece does not guarantee it works correctly with the whole application. This is why we also test our application at a macrocosmic scale with automated testing tools that verify our application's higher-level behaviors. These tests are called *functional tests*.

# How Do We Test?

We know why, when, and what to test. More important, let's chat about *how* we test code. There are several popular ways PHP developers approach testing. Some developers prefer unit tests. Some developers prefer test-driven development (TDD). And other developers prefer behavior-driven development (BDD). *These are not mutually exclusive.*

## Unit Tests

The most popular approach to PHP application testing is unit testing. As I described previously, unit tests certify individual classes, methods, and functions in isolation from the larger application. The de facto standard PHP unit testing framework is [PHPUnit](#), written by [Sebastian Bergmann](#). Sebastian's PHPUnit framework adheres to the xUnit test architecture.

There are alternative PHP unit testing frameworks, like PHPSpec, available for you to use, too. However, most popular PHP frameworks provide PHPUnit tests. It's vital that you know how to read, write, and run PHPUnit tests if you intend to contribute to or release PHP components. I'll show you how to install, write, and run PHP unit tests at the end of this chapter.

## Test-Driven Development (TDD)

Test-driven development means you write tests *before* you write application code. These tests purposefully fail and describe how your application *should* behave. As you build application functionality, your tests will eventually run successfully. TDD helps you build with a purpose; you know ahead of time what you will build and how it should work.

This does not mean that you must write all of your application tests before you write any code. Instead, write a few tests and then build the related functionality. Write tests and build. Write tests and build. TDD is iterative. Move forward in small sprints until your application is complete.

# Behavior-Driven Development (BDD)

Behavior-driven development means that you write stories that describe how your application behaves. There are two types of BDD: SpecBDD and StoryBDD.

SpecBDD is a type of unit test that uses a fluid and human-friendly language to describe your application's implementation. SpecBDD accomplishes the same goal as alternative unit testing tools like PHPUnit. Unlike PHPUnit's xUnit architecture, SpecBDD tests use *human-readable stories* to describe behavior. For example, a PHPUnit test might be named `testRenderTemplate()`. An equivalent SpecBDD test might be named `itRendersTheTemplate()`. The same SpecBDD test might use helper methods named `$this->shouldReturn()`, `$this->shouldBe()`, and `$this->shouldThrow()`. SpecBDD tests use a language that is much easier to read and understand than alternative xUnit tools. The most popular SpecBDD testing tool is [PHPSpec](#).

StoryBDD tools use the same human-friendly stories as SpecBDD tests. StoryBDD tools, however, are more concerned with higher-level behavior than with lower-level implementation. For example, a StoryBDD test confirms that your code creates and emails a PDF report. A SpecBDD test, on the other hand, confirms that a specific PDF generator class method correctly renders a PDF file for a given set of input parameters. The difference is scope. StoryBDD resembles something a project manager would write (e.g., “this should generate and email me a report”). A SpecBDD test resembles something a developer would write (e.g., “this class method should receive an array of data and write it to this PDF file”). StoryBDD and SpecBDD testing tools are not mutually exclusive. They are often used together to build a more comprehensive set of tests. You'll often sit with your project manager to write generic StoryBDD tests that define your application's generic behavior, and then you'll write SpecBDD tests when you design and build your application's implementation. The most popular StoryBDD testing tool is [Behat](#).

## Tip

Write StoryBDD tests that describe your business logic and not a specific implementation. A good StoryBDD test confirms “a shopping cart total increases when I add a product to the cart.” A bad StoryBDD test confirms “a shopping cart total increases when I send an HTTP PUT request to the `/cart` URL with the body `product_id=1&quantity=2`.” The first test is generic and describes only the high-level business logic. The second test is too specific and describes a particular implementation.

# PHPUnit

Let's talk about how to install, write, and run PHPUnit tests. It takes a bit of work to get the infrastructure in place, but it's dead simple to write and run your PHPUnit tests afterward. Before we dig too deep into PHPUnit, let's quickly review some vocabulary. Your PHPUnit tests are grouped into *test cases*, and your test cases are grouped into *test suites*. PHPUnit runs your test suites with a *test runner*.

A test case is a single PHP class that extends the `PHPUnit_Framework_TestCase` class. Each test case contains public methods whose names begin with `test`; these methods are individual tests that assert specific scenarios to be true. Each assertion can pass or fail. You want all assertions to pass.

## Tip

A test case class name must end with `Test`, and its filename must end with `Test.php`. A hypothetical test case class name is `FooTest`, and that class lives in a file named `FooTest.php`.

A test suite is a collection of related test cases. If you are working on a single PHP component, oftentimes you'll only ever have a single test suite. If you are testing a larger PHP application with many different subsystems or components, you may find it best to organize tests into multiple test suites.

A test runner is exactly what it sounds like. It is a way for PHPUnit to run your test suites and output the result. The default PHPUnit test runner is the *command-line runner* that is invoked with the `phpunit` command in your terminal application.

# Directory Structure

Here's how I prefer to organize my PHP projects. The topmost project directory has a *src/* directory where I keep my source code. It also has a *tests/* directory where I keep my tests. Here's an example directory structure:

```
src/
  tests/
    bootstrap.php
  composer.json
  phpunit.xml
  .travis.yml
```

src/

This directory contains my PHP project's source code (i.e., PHP classes).

tests/

This directory contains my PHP project's PHPUnit tests. This directory contains a *bootstrap.php* file that is included by PHPUnit before the unit tests are run.

composer.json

This file lists my PHP project's dependencies managed by Composer, including the PHPUnit test framework.

phpunit.xml

This file provides configuration details for the PHPUnit test runner.

.travis.yml

This file provides configuration details for the Travis CI continuous testing web service.

## Note

Look at your favorite PHP component or framework's source code on GitHub and you'll see it uses a similar organization.

## Install PHPUnit

First we need to install PHPUnit and the Xdebug profiler. PHPUnit runs our tests. The Xdebug profiler generates helpful code coverage information. Composer is the easiest way to install the PHPUnit test framework. Open your terminal application, navigate to your project's topmost directory, and run this command:

```
composer require --dev phpunit/phpunit
```

This command downloads the PHPUnit test framework into your project's *vendor/* directory, and it updates your project's *composer.json* file so that the *phpunit/phpunit* package is listed as a project dependency. The *phpunit* binary is installed in your project's *vendor/bin/* directory. You can add this directory to your environment path, or you can reference *vendor/bin/phpunit* whenever you invoke the PHPUnit command line test runner. The PHPUnit framework classes are autoloaded into your PHP application with your project's other Composer-managed dependencies.

# Install Xdebug

The Xdebug PHP extension is a bit trickier to install. If you installed PHP with your package manager, you can install Xdebug the same way ([Example 10-1](#)).

## Example 10-1. How to install Xdebug

```
# Ubuntu  
sudo apt-get install php5-xdebug  
  
# CentOS  
sudo yum -y --enablerepo=epel,remi,remi-php56 install php-xdebug
```

If you installed PHP from source, you'll need to install the Xdebug extension with the `pecl` command:

```
pecl install xdebug
```

Next, update your `php.ini` configuration file with the path to the compiled Xdebug extension.

### Tip

You can find your PHP extensions directory with the `php-config --extension-dir` or `php -i | grep extension_dir` commands.

Append this line to your `php.ini` file using your own PHP extension path:

```
zend_extension="/PATH/TO/xdebug.so"
```

Restart PHP and you're good to go. We'll discuss the Xdebug profiler in [Chapter 11](#).

# Configure PHPUnit

Now let's configure PHPUnit in our project's *phpunit.xml* file.

```
<?xml version="1.0" encoding="UTF-8"?>
<phpunit bootstrap="tests/bootstrap.php">
    <testsuites>
        <testsuite name="whovian">
            <directory suffix="Test.php">tests</directory>
        </testsuite>
    </testsuites>

    <filter>
        <whitelist>
            <directory>src</directory>
        </whitelist>
    </filter>
</phpunit>
```

PHPUnit test runner settings are attributes on the `<phpunit>` XML root element. The most important setting, in my opinion, is the `bootstrap` setting; it specifies the path (relative to the *phpunit.xml* file) to a PHP file that is included before the PHPUnit test runner executes our tests. We'll autoload our application's Composer dependencies in the *bootstrap.php* file so they are available to our PHPUnit tests. The *bootstrap.php* file also specifies the path to our test suite (i.e., a directory that contains related test cases); PHPUnit runs all PHP files in this directory whose file names end with *Test.php*. Finally, this configuration file lists the directories included in our code coverage analysis with the `<filter>` element. In the previous example XML, the `<whitelist>` element tells PHPUnit to generate code coverage only for code in the *src/* directory.

The gist of this configuration file is to specify our PHPUnit settings in one location. This makes our lives easier locally because we don't have to specify these settings each time we use the `phpunit` command-line runner. This configuration file also lets us apply the same PHPUnit settings on remote continuous testing servers like Travis CI. After you update the *phpunit.xml* configuration file, update the *tests/bootstrap.php* file with this code:

```
<?php
// Enable Composer autoloader
require dirname(__DIR__) . '/vendor/autoload.php';
```

## Tip

Make sure you install your Composer dependencies before running PHPUnit tests.

# The Whovian Class

Before we write unit tests, we need something to test. Here's a hypothetical PHP class named `Whovian` that has a pretty strong opinion about a particular BBC television show. Place this class definition into the `src/Whovian.php` file:

```
<?php
class Whovian
{
    /**
     * @var string
     */
    protected $favoriteDoctor;

    /**
     * Constructor
     * @param string $favoriteDoctor
     */
    public function __construct($favoriteDoctor)
    {
        $this->favoriteDoctor = (string)$favoriteDoctor;
    }

    /**
     * Say
     * @return string
     */
    public function say()
    {
        return 'The best doctor is ' . $this->favoriteDoctor;
    }

    /**
     * Respond to
     * @param string $input
     * @return string
     * @throws \Exception
     */
    public function respondTo($input)
    {
        $input = strtolower($input);
        $myDoctor = strtolower($this->favoriteDoctor);

        if (strpos($input, $myDoctor) === false) {
            throw new Exception(
                sprintf(
                    'No way! %s is the best doctor ever!',
                    $this->favoriteDoctor
                )
            );
        }

        return 'I agree!';
    }
}
```

The `Whovian` class constructor sets the instance's favorite doctor. The `say()` method returns a string with the instance's favorite doctor. And its `respondTo()` method receives a statement from another `Whovian` instance and responds accordingly.

# The WhovianTest Test Case

The unit tests for our `Whovian` class live in the `test/WhovianTest.php` file. We call a group of related tests a *test suite*. In our example, all tests beneath the `test/` directory belong to the same test suite. Each class file beneath the `test/` directory is called a *test case*, and its class methods that begin with `test` (e.g., `testThis` or `testThat`) are individual tests. Each individual test uses assertions to verify a given condition. An assertion can pass or fail.

## Note

Find a list of PHPUnit assertions on the [PHPUnit website](#). Some assertions are undocumented; you can find all available assertions in the source code on [GitHub](#).

Each PHPUnit test case is a class that extends the `PHPUnit_Framework_TestCase` class. Let's declare a test case named `WhovianTest` in the `test/WhovianTest.php` file:

```
<?php
require dirname(__DIR__) . '/src/Whovian.php';

class WhovianTest extends PHPUnit_Framework_TestCase
{
    // Individual tests go here
}
```

Remember, unit tests verify a public interface's expected behavior. We'll test the three public methods in the `Whovian` class. We'll write a unit test to ensure that the `__construct()` method argument becomes the instance's preferred doctor. Next, we'll write a unit test to ensure that the `say()` method's return value mentions the instance's preferred doctor. Finally, we'll write two tests for the `respondTo()` method. One test ensures that the method's return value is the string "I agree!" if the input matches its preferred doctor. The second test that ensures the method throws an exception if the input does not match its preferred doctor.

## Test 1: `__construct()`

Our first test confirms that the constructor sets the `Whovian` instance's favorite doctor:

```
public function testSetsDoctorWithConstructor()
{
    $whovian = new Whovian('Peter Capaldi');
    $this->assertAttributeEquals('Peter Capaldi', 'favoriteDoctor', $whovian);
}
```

This test instantiates a new `Whovian` instance with one string argument: "Peter Capaldi". We use the PHPUnit assertion method `assertAttributeEquals()` to assert the `favoriteDoctor` property on the `$whovian` instance equals the string "Peter Capaldi".

## Note

The PHPUnit assertion `assertAttributeEquals()` receives three arguments. The first argument is the expected value; the second argument is the property name; and the final argument is the object to inspect. What's neat is that the `assertAttributeEquals()` method can inspect and verify protected properties using PHP's reflection capabilities.

Why do we inspect the favorite doctor value with the `assertAttributeEquals()` assertion instead of a getter method (e.g., `getFavoriteDoctor()`)? When we write a test, we test *only one specific method in isolation*. Ideally, our test does not rely on other methods. In

this particular example, we test the `__construct()` method and verify that it assigns its argument value to the object's `$favoriteDoctor` property. The `assertAttributeEquals()` assertion lets us inspect the object's internal state without relying on a separate, untested getter method.

## Test 2: say()

Our next test confirms that the `Whovian` instance's `say()` method returns a string value that contains its favorite doctor's name:

```
public function testSaysDoctorName()
{
    $whovian = new Whovian('David Tennant');
    $this->assertEquals('The best doctor is David Tennant', $whovian->say());
}
```

We use the PHPUnit assertion `assertEquals()` to compare two values. The assertion's first argument is the expected value. Its second argument is the value to inspect.

## Test 3: respondTo() in agreement

Now let's test how a `Whovian` instance responds in agreement with another `Whovian`:

```
public function testRespondToInAgreement()
{
    $whovian = new Whovian('David Tennant');

    $opinion = 'David Tennant is the best doctor, period';
    $this->assertEquals('I agree!', $whovian->respondTo($opinion));
}
```

This test is successful because the `Whovian` instance's `respondTo()` method receives a string argument that includes the name of its favorite doctor.

## Test 4: respondTo() in disagreement

But what if a `Whovian` *disagrees*? Get out of the area as quickly as possible, because s#!t is going to hit the fan. Well, actually, it'll just throw an exception. Let's test that:

```
/**
 * @expectedException Exception
 */
public function testRespondToInDisagreement()
{
    $whovian = new Whovian('David Tennant');

    $opinion = 'No way, Matt Smith was awesome!';
    $whovian->respondTo($opinion);
}
```

If this test throws an exception, the test passes. Otherwise, the test fails. We can test this condition with the `@expectedException` annotation.

### Note

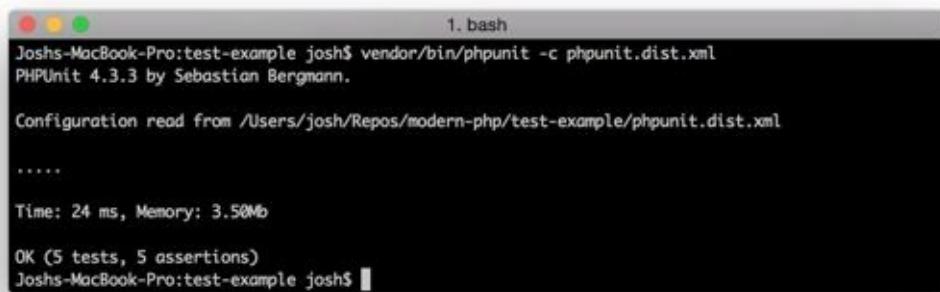
PHPUnit provides several annotations that can control a given test. Read more about PHPUnit annotations in the [PHPUnit documentation](#).

## Run Tests

After you write each test, you should run your test suite to ensure that it passes. This is really simple to do. Open your terminal application and navigate to your project's topmost directory (the same directory as your *phpunit.xml* configuration file). We'll use the PHPUnit binary installed with Composer. Use this command to start the PHPUnit test runner:

```
vendor/bin/phpunit -c phpunit.xml
```

The *-c* option specifies the path to the PHPUnit configuration file. The terminal shows the results from the PHPUnit command-line test runner, and they look like [Figure 10-1](#).



The screenshot shows a terminal window titled "1. bash". The command entered is "vendor/bin/phpunit -c phpunit.dist.xml". The output shows the configuration file being read, followed by execution details: "Time: 24 ms, Memory: 3.50Mb", and finally "OK (5 tests, 5 assertions)". The terminal prompt "josh\$" is visible at the bottom.

```
Joshs-MacBook-Pro:test-example josh$ vendor/bin/phpunit -c phpunit.dist.xml
PHPUnit 4.3.3 by Sebastian Bergmann.

Configuration read from /Users/josh/Repos/modern-php/test-example/phpunit.dist.xml

.....
Time: 24 ms, Memory: 3.50Mb
OK (5 tests, 5 assertions)
Joshs-MacBook-Pro:test-example josh$
```

**Figure 10-1. PHPUnit test results**

These results tell us:

1. PHPUnit read our configuration file.
2. PHPUnit took 24 ms to complete.
3. PHPUnit used 3.5 MB of memory.
4. PHPUnit successfully ran five tests and five assertions.

# Code Coverage

We know our PHPUnit tests pass. However, are we sure we tested as much of our code as possible? Perhaps we forgot to test something. We can see exactly which code is tested (and untested) with PHPUnit's code coverage report ([Figure 10-2](#)). We already specify the path(s) to our source code files in the PHPUnit configuration file. All PHP files in the whitelisted directories are included in PHPUnit's code coverage report. We can generate code coverage each time we run the PHPUnit test runner:

```
vendor/bin/phpunit -c phpunit.xml --coverage-html coverage
```

This is the same command we used earlier, except we append the new `--coverage-html` option whose value is the path to a the code coverage report directory. After you run this command, open the newly generated `coverage/index.html` file in a web browser to see the code coverage results. Ideally, you want to see 100% coverage across the board. However, 100% coverage is *not realistic* and definitely should not be a requirement. How much coverage is good is subjective and varies from project to project.



**Figure 10-2. PHPUnit code coverage report**

## Tip

Use PHPUnit's code coverage report as a *guideline* to improve your code. Don't use code coverage percentages as requirements.

# Continuous Testing with Travis CI

Sometimes even the best PHP developers forget to write tests. This is why it is important to automate your tests. The best tests are like a good backup strategy — out of sight and out of mind. *Tests should run automatically.* My favorite continuous testing service is [Travis CI](#) because it has native hooks into GitHub repositories. I can run my application tests within Travis CI every time I push code to GitHub. Travis CI runs my tests against multiple PHP versions, too.

# Setup

If you have not used Travis CI before, go to <https://travis-ci.org> (for public repositories) or <https://travis-ci.com> (for private repositories). Log in with your GitHub account. Follow the on-screen instructions to choose which repository to test with Travis CI.

Next, create the `.travis.yml` Travis CI configuration file in your application's topmost directory. Don't forget the leading `.` character! Save, commit, and push the Travis CI configuration file to your GitHub repository. Here's an example Travis CI configuration:

```
language: php
php:
  - 5.4
  - 5.5
  - 5.6
  - hhvm
install:
  - composer install --no-dev --quiet
script: phpunit -c phpunit.xml --coverage-text
```

The Travis CI configuration is written in YAML format and includes these settings:

## language

This is the language used for our application. We set this to `php`. This value is case-sensitive!

## php

Travis CI runs our application tests against these PHP versions. It is important that you test against all PHP versions supported by your application.

## install

This is a bash command executed by Travis CI before it runs application tests. This is where you instruct Travis CI to install your project's Composer dependencies. It is important that you use the `--no-dev` option to avoid installing unnecessary development dependencies.

## script

This is the bash command executed by Travis CI to run application tests. By default, this is `phpunit`. You can override Travis CI's default command with this setting. In this example, we tell Travis CI to use our custom PHPUnit configuration file and generate plain text coverage results.

## Run

Travis CI automatically runs your application tests every time you push new commits to your GitHub repository and emails you the test results. How cool is that? There are, of course, many more Travis CI settings to further customize the Travis CI testing environment (e.g., install custom PHP extensions, use custom `ini` settings, and so on). Read more about Travis CI configuration for PHP at [Travis CI](#).

# Further Reading

Here are a few links to help you learn more about PHP application testing:

- <https://phpunit.de/>
- <http://www.phpspec.net/docs/introduction.html>
- <http://behat.org/>
- <https://leanpub.com/grumpy-phpunit>
- <https://leanpub.com/grumpy-testing>
- <http://www.littlehart.net/atthekeyboard/>

# What's Next

In this chapter we learned why, when, and how to write tests. Testing our applications builds confidence and creates more predictable code. However, tests do not let us analyze application *performance*. This is why we must also *profile* our applications. That's what I want to talk about next.

# Chapter 11. Profiling

*Profiling* is how we analyze application performance. It is a great way to debug performance issues and pinpoint bottlenecks in your application code. In other words, if your application is slow, use a profiler to figure out why. Profilers let us traverse the entire PHP call stack, and they tell us which functions or methods are called, in what order, how many times, with what arguments, and for how long. We can also see how much memory and CPU are used throughout the application request lifecycle.

# When to Use a Profiler

You don't need to profile your PHP applications immediately. You only profile PHP applications if there is a performance issue that is otherwise hard to diagnose. How do you know if you have a performance issue? Some issues are obvious (e.g., a database query takes too long). Other issues may not be as obvious.

You can detect performance issues with benchmarking tools like [Apache Bench](#) and [Siege](#). A benchmarking tool allows you to test your application performance *externally*, much as an application user would with a web browser. Benchmarking tools let you set the number of concurrent users and total number of requests that hit a specific application URL. When the benchmarking tool finishes, it tells you the number of requests per second that your application sustained (among other statistics). If you find a particular URL sustains only a small number of requests per second, you may have a performance issue. If the performance issue is not immediately obvious, you use a profiler.

# Types of Profilers

There are two types of profilers. There are those that should run only during development, and there are those that can run during production.

[Xdebug](#) is a popular PHP profiling tool written by Derick Rethans, but it should only be used as a profiler during development because it consumes a lot of system resources to analyze your application. Xdebug profiler results are not human-readable, so you'll need an application to parse and display the results. [KCacheGrind](#) and [WinCacheGrind](#) are good applications for visualizing Xdebug profiler results.

[XHProf](#) is a popular PHP profiler written by Facebook. It is intended to be run during development *and* production. XHProf's profiler results are also not human-readable, but Facebook provides a companion web application called XHGUI to visualize and compare profiler results. I'll talk more about XHGUI later in this chapter.

## Note

Both Xdebug and XHProf are PHP extensions, and you can install them with your operating system's package manager. They can also be installed with pecl.

## Xdebug

Xdebug is one of the most popular PHP profilers, and it makes it easy to analyze your application's call stack to find bottlenecks and performance issues. Refer to [Example 10-1](#) in [Chapter 10](#) for Xdebug installation instructions.

# Configure

Xdebug configuration lives in your *php.ini* file. Here are the Xdebug profiler configuration settings I recommend. Make sure you specify your own profiler output directory. Restart your PHP process after saving these settings:

```
xdebug.profiler_enable = 0  
xdebug.profiler_enable_trigger = 1  
xdebug.profiler_output_dir = /path/to/profiler/results  
  
xdebug.profiler_enable = 0
```

This instructs Xdebug to not run automatically. We don't want Xdebug to run automatically on each request, because that would drastically decrease performance and impede development.

```
xdebug.profiler_enable_trigger = 1
```

This instructs Xdebug to run on-demand. We can activate Xdebug profiling per-request by adding the XDEBUG\_PROFILE=1 query parameter to any of our PHP application's URLs. When Xdebug detects this query parameter, it profiles the current request and generates a report in the output directory specified by the `xdebug.profiler_output_dir` setting.

```
xdebug.profiler_output_dir = /path/to/profiler/results
```

This is the directory path that contains generated profiler results. Profiler reports can be massive (e.g., 500 MB or larger) for complex PHP applications. Make sure you change this value to the correct filesystem path for your application.

## Tip

I recommend you keep profiler results beneath your PHP application's topmost directory. This makes it easy to find and review profiler results while developing your application.

## Trigger

The Xdebug profiler does not run automatically because the `xdebug.profiler_enable` setting is `0`. We trigger the Xdebug profiler for a single request by adding the `XDEBUG_PROFILE=1` query parameter to any PHP application URL. An example HTTP request URL might be `/users/show/1?XDEBUG_PROFILE=1`. When Xdebug detects the `XDEBUG_PROFILE` query parameter, it activates and runs the profiler for the current request. The profiler results are dumped into the directory specified by the `xdebug.profiler_output_dir` setting.

## Analyze

The Xdebug profiler generates results in the CacheGrind format. You'll need a CacheGrind-compatible application to review the profiler results. Some good applications for reviewing CacheGrind files are:

- [WinCacheGrind](#) for Windows
- [KCacheGrind](#) for Linux
- [WebGrind](#) for web browsers

Mac OS X users can install KCacheGrind with Homebrew using this command:

```
brew install qcachegrind
```

### Tip

[Homebrew](#) is a package manager for OS X. We discuss Homebrew in [Appendix A](#).

## XHProf

XHProf is a newer PHP application profiler. It is created by Facebook and is intended to be run during both development and production. It does not collect as much information as Xdebug's profiler, but it consumes fewer system resources, making it suitable for production environments.

# Install

The easiest way to install XHProf is with your operating system's package manager (assuming you installed PHP the same way):

```
# Ubuntu
sudo apt-get install build-essential;
sudo pecl install mongo;
sudo pecl install xhprof-beta;

# CentOS
sudo yum groupinstall 'Development Tools';
sudo pecl install mongo;
sudo pecl install xhprof-beta;
```

Append these lines to your *php.ini* file, and restart your PHP process to load the new extensions:

```
extension=xhprof.so
extension=mongo.so
```

## XHGUI

XHProf is most useful when paired with XHGUI, Facebook's companion web application used to review and compare XHProf profiler output. XHGUI is a PHP web application and requires:

- Composer
- Git
- MongoDB
- PHP 5.3+
- PHP mongo extension

I assume these system requirements are installed. I also assume the XHGUI web application lives in the `/var/sites/xhgui/` directory. This directory path is probably different on your server, so keep that in mind:

```
cd /var/sites;
git clone https://github.com/perf-tools/xhgui.git;
cd xhgui;
php install.php;
```

The XHGUI web application has a `webroot/` directory. Update your web server virtual host's document root to this directory.

# Configure

Open XHGUI's *config/config.default.php* file in a text editor. By default, XHProf collects data for only 1% of all HTTP requests. This is fine for production, but you may want to collect data more frequently during development. You can increase XHProf's data collection by editing these lines in the *config/config.default.php* file:

```
'profiler.enable' => function() {
    return rand(0, 100) === 42;
},
```

Change these lines to:

```
'profiler.enable' => function() {
    return true; // <-- Run on every request
},
```

## Tip

XHProf assumes your PHP application runs on a single server. It also assumes your MongoDB database does not require authentication. If your MongoDB server does require authentication, update the Mongo database connection in the *config/config.default.php* file.

## Trigger

You must include the XHGUI web application's *external/header.php* file at the very beginning of your PHP application. It's easiest to use PHP's `auto_prepend_file` INI configuration setting. You can set this in the *php.ini* configuration file:

```
auto_prepend_file = /var/sites/xhgui/external/header.php
```

Or you can set this in your nginx virtual host configuration:

```
fastcgi_param PHP_VALUE "auto_prepend_file=/var/sites/xhgui/external/header.php";
```

Or you can set this in your Apache virtual host configuration:

```
php_admin_value auto_prepend_file "/var/sites/xhgui/external/header.php"
```

Restart PHP, and XHProf will begin collecting and saving information into its MongoDB database. You can review and compare XHProf runs at the XHGUI virtual host's URL.

# New Relic Profiler

Another popular PHP profiler is [New Relic](#). This is actually a web service that uses a custom operating system daemon and PHP extension to hook into your PHP application and report data back to the web service. Unlike Xdebug and XHProf, New Relic's PHP profiler is not free. That being said, I adore New Relic and recommend it if your budget allows. Like XHProf, New Relic's PHP profiler is meant to be run during production, and it gives you a near real-time view of your application's performance with a really nice online dashboard. Learn more on [New Relic's website](#).

# Blackfire Profiler

As I am writing this book, Symfony is currently testing a new PHP profiler called [Blackfire](#). It provides unique visualization tools to help discover application bottlenecks. I hear it's looking like a really good alternative to Xdebug and XHProf. Keep an eye on this one.

# Further Reading

I hope I've introduced you to PHP profiling in this chapter so that you feel comfortable finding, installing, and using a PHP profiler most appropriate for your application. Here are a few links to help you learn more about PHP profiling:

- <http://www.sitepoint.com/the-need-for-speed-profiling-with-xhprof-and-xhgui/>
- <https://blog.engineyard.com/2014/profiling-with-xhprof-xhgui-part-1>
- <https://blog.engineyard.com/2014/profiling-with-xhprof-xhgui-part-2>
- <https://blog.engineyard.com/2014/profiling-with-xhprof-xhgui-part-3>

# What's Next

At this point we've talked a lot about modern PHP, including new features, good practices, provisioning, tuning, deployment, testing, and profiling. I hope you have filled your brain with tons of fun ideas to implement in your next PHP applications.

Now I want to take a few minutes to chat about the future of PHP. A lot is happening in the PHP ecosystem. The future of PHP is unfolding as we speak thanks to forward-looking projects like [PHP 7](#), [HHVM](#), [Hack](#), and the [PHP-FIG](#). Let's explore HHVM and Hack, specifically, and figure out what they mean for PHP's future.

# Chapter 12. HHVM and Hack

Think what you will about the Facebook application, but I have nothing but praise for the brilliant folks working at Facebook. [Facebook Open Source](#) has developed several important projects in the last few years, two of which have had significant impact in the PHP community.

The first initiative is [HHVM](#), or the *Hip Hop Virtual Machine*. This alternative PHP engine was released in October 2013. Its just-in-time (JIT) compiler provides performance many times better than PHP-FPM. In fact, WP Engine recently migrated to HHVM and realized [3.9x faster](#) custom Wordpress installations. MediaWiki also transitioned to HHVM, and it has [realized drastic improvements](#) in both response times and throughput.

The second initiative is [Hack](#), a new server-side language that is a modification of the PHP language. Hack is mostly backward-compatible with PHP code, although it extends the PHP language with strict typing, new data structures, and a real-time type checking server. That being said, Hack's own developers prefer to call Hack a *dialect* of PHP and not a new language.

# HHVM

Since 1994, if you said *PHP interpreter* you meant the [Zend Engine](#). The Zend Engine was PHP. It was the one and only PHP interpreter. Then Mark Zuckerberg came along and created this little thing called Thefacebook on February 4, 2004. Mr. Zuckerberg and his growing company wrote the Facebook application predominantly with PHP because the language is easy to learn and simple to deploy. The PHP language lets Facebook quickly onboard new developers to grow, innovate, and iterate its platform.

Fast forward, and Facebook is a veritable empire. Its infrastructure is massive. Facebook is so huge that the traditional Zend Engine became a bottleneck for its developers. The Facebook team had a hugely growing user base (by 2007, its user base surpassed 1 in 10 people on the planet), and it had to figure out a way to improve performance without simply building more data centers and buying more servers.

## PHP at Facebook

The PHP language is traditionally interpreted, not compiled. This means that your PHP code remains PHP code until it is sent through an interpreter when executed on the command line or requested by a web server. The PHP script is read by the PHP interpreter and converted into a set of existing [Zend Opcodes](#) (machine-code instructions), and the Zend Opcodes are executed with the Zend Engine. Unfortunately, interpreted languages execute more slowly than compiled languages because they must be converted to machine code during every execution. This taxes system resources. Facebook realized this performance bottleneck and, in 2010, began working on a PHP-to-C++ compiler called HPHPc.

The HPHPc compiler converts PHP code into C++ code. It then compiles the C++ code into an executable that is deployed to production servers. HPHPc was largely successful; it improved Facebook's performance and reduced the strain on its servers. However, HPHPc's potential performance approached a ceiling, it was not 100% compatible with the complete PHP language, and it required a time-consuming compile process that created a lengthy feedback loop for developers. Facebook needed a hybrid solution that delivered superior performance but also allowed for faster development without expensive compile time.

Facebook began working on the next iteration of HPHPc, called HHVM. HHVM converts and caches PHP code into an intermediary bytecode format, and it uses a JIT compiler to translate and optimize its bytecode cache into x86\_64 machine code. HHVM's JIT compiler enables many low-level performance optimizations that are simply not possible by compiling PHP directly to C++ with HPHPc. HHVM also enables a fast feedback loop for developers because it compiles bytecode into machine code only when PHP scripts are requested by a web server — just in time, you might say — much like a traditional interpreted language. What's more amazing is that HHVM's performance [eclipsed HPHPc's performance](#) in November 2012, and it continues to improve ([Figure 12-1](#)).

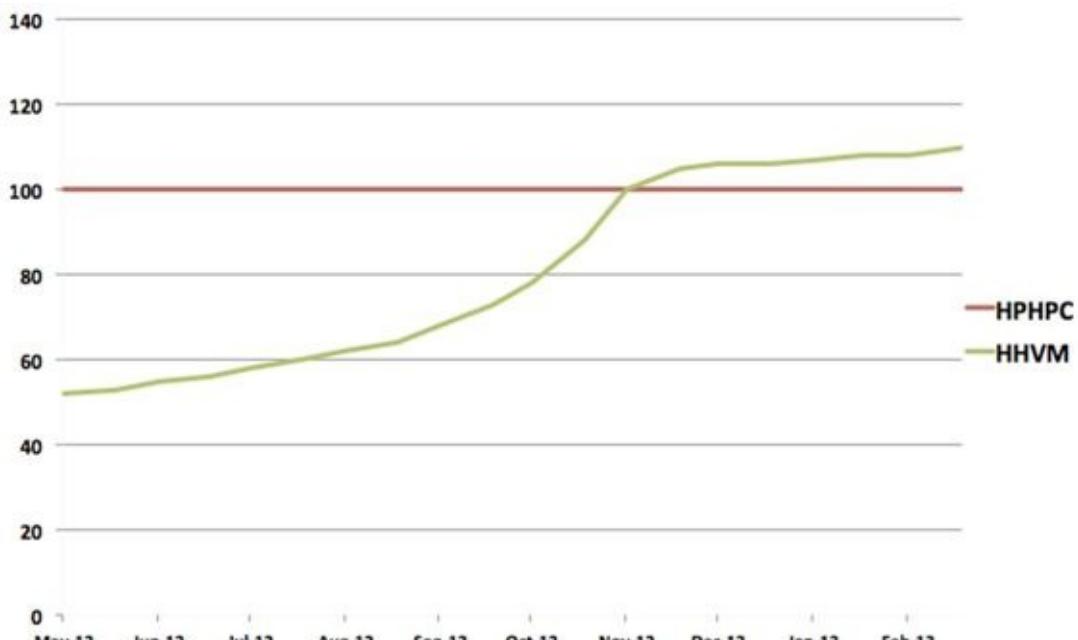


Figure 12-1. [HHVM vs. HPHPc Performance](#)

HPHPc was deprecated soon after HHVM's performance exceeded its own, and HHVM is currently Facebook's preferred PHP interpreter.

## Tip

Don't let HHVM intimidate you! Its implementation may be complex, but at the end of the day HHVM is just a replacement for the more familiar `php` and `php-fpm` binaries:

- You execute PHP scripts with the `hhvm` binary on the command line, just like the `php` binary.
- You use the `hhvm` binary to create a FastCGI server, just like the `php-fpm` binary.
- HHVM uses a `php.ini` configuration file, just like the traditional Zend Engine. It even uses the same INI directives.
- HHVM has native support for many common PHP extensions.

## HHVM and Zend Engine Parity

Facebook's original HPHPc compiler was not compatible with the complete PHP language (i.e., the Zend Engine). Complete parity is an aspiration for Facebook because it lets HHVM become a drop-in replacement for the Zend Engine.

Facebook tested HHVM against the most popular PHP frameworks to ensure compatibility with real-world PHP 5 code. Facebook is close to 100% compatibility. However, Facebook has shifted its focus to user-reported issues on the [HHVM issue tracker](#) to tackle remaining edge-case issues. HHVM is not yet 100% compatible with the traditional Zend Engine, but it's getting closer every day. Facebook, Baidu, and Wikipedia already use HHVM in production. HHVM can also run Wordpress, Drupal, and many popular PHP frameworks.

# Is HHVM Right for Me?

HHVM isn't the right choice for everyone. There are far easier ways to improve application performance. Reducing HTTP requests and optimizing database queries are low-hanging fruit that noticeably improve application performance and response time. If you have not made these optimizations, do them first before you consider HHVM. Facebook's HHVM is for developers who have already made these optimizations and *still* need faster applications. If you believe you need HHVM, here are some resources to help you make the best decision:

## [Extensions](#)

View a list of PHP extensions compatible with HHVM.

## [Framework Parity](#)

Track HHVM parity with the most popular PHP frameworks.

## [Issue Tracker](#)

Track open HHVM issues.

## [FAQs](#)

Read HHVM frequently asked questions.

## [Blog](#)

Follow the latest HHVM news.

# Install

HHVM is easy to install on the most popular Linux distributions. It was originally developed for Ubuntu (my preferred Linux distribution), so I use Ubuntu in the following examples.

## Note

Facebook provides prebuilt packages for other Linux distributions, including Debian and Fedora. You can build HHVM from source on even more Linux distributions.

Per [Facebook's instructions](#), you can install HHVM on the latest version of Ubuntu with the Aptitude package manager like this:

```
wget -O - \
  http://dl.hhvm.com/conf/hhvm.gpg.key | 
  sudo apt-key add -;
echo deb \
  http://dl.hhvm.com/ubuntu trusty main | sudo tee /etc/apt/sources.list.d/hhvm.list;
sudo apt-get update;
sudo apt-get install hhvm;
```

If you're feeling lucky, swap the last line with this one to install the latest nightly build:

```
sudo apt-get install hhvm-nightly;
```

The preceding code adds HHVM's GNU Privacy Guard (GPG) public key for package verification. It adds the HHVM package repository to our local list of repositories. Finally, it installs HHVM with Aptitude like any other software package. The HHVM binary is installed at `/usr/bin/hhvm`.

# Configure

HHVM uses a *php.ini* configuration file just as the Zend Engine does. This file exists at */etc/hhvm/php.ini* by default, and it contains many of the same INI settings used by the Zend Engine. You can find a complete list of HHVM *php.ini* directives at <http://docs.hhvm.com/manual/ini.list.php>.

If you run HHVM as a FastCGI server, add server-related INI directives into the */etc/hhvm/server.ini* file. You can find a complete list of HHVM server directives at <https://github.com/facebook/hhvm/wiki/INI-Settings>. The HHVM wiki page is weak on details, so you may want to peruse these HHVM support communities, too:

- [StackOverflow](#)
- [IRC Channel](#)
- [Facebook Page](#)

The default */etc/hhvm/server.ini* file should be sufficient to get you started. It looks like this:

```
; php options  
  
pid = /var/run/hhvm.pid  
  
; hhvm specific  
  
hhvm.server.port = 9000  
hhvm.server.type = fastcgi  
hhvm.server.default_document = index.php  
hhvm.log.use_log_file = true  
hhvm.log.file = /var/log/hhvm/error.log  
hhvm.repo.central.path = /var/run/hhvm/hhvm.hhbc
```

The most notable settings are `hhvm.server.port = 9000` and `hhvm.server.type = fastcgi`; they tell HHVM to run as a FastCGI server on local port 9000.

When you execute the `hhvm` binary, you specify the path to your configuration files with the `-c` option. If you use `hhvm` to execute command-line scripts, you only need the */etc/hhvm/php.ini* configuration file:

```
hhvm -c /etc/hhvm/php.ini my-script.php
```

If you use the `hhvm` binary to start a FastCGI server, you need both the */etc/hhvm/php.ini* and */etc/hhvm/server.ini* files:

```
hhvm -m server -c /etc/hhvm/php.ini -c /etc/hhvm/server.ini
```

## Extensions

HHVM cannot use PHP extensions that are compiled for the Zend Engine unless the extensions use Facebook's [Zend Extension Source Compatibility Layer](#). Fortunately, most of the PHP extensions we take for granted are supported by HHVM out of the box. Other third-party PHP extensions (e.g., the GeoIP extension) can be compiled separately and loaded into HHVM as a dynamic extension. You can find a list of PHP extensions compatible with HHVM on [GitHub](#).

# Monitor HHVM with Supervisord

HHVM is just fine for your production server, but it's not infallible. I recommend you keep tabs on HHVM's master process with [Supervisord](#), a process monitor that starts the HHVM process on boot and automatically restarts the HHVM process if HHVM fails.

## Tip

If you are unfamiliar with Supervisord, [Chris Fidao](#) has an excellent [tutorial](#).

Install Supervisord with this command if you haven't already:

```
sudo apt-get install supervisor
```

Next, make sure the */etc/supervisor/supervisord.conf* configuration file has these two lines:

```
[include]
files = /etc/supervisor/conf.d/*.conf
```

These two lines let us create a configuration file in the */etc/supervisor/conf.d/* directory for each supervised application. Next, create the */etc/supervisor/conf.d/hhvm.conf* file with this content:

```
[program:hhvm]
command=/usr/bin/hhvm -m server -c /etc/hhvm/php.ini -c /etc/hhvm/server.ini
directory=/home/deploy
autostart=true
autorestart=true
startretries=3
stderr_logfile=/home/deploy/logs/hhvm.err.log
stdout_logfile=/home/deploy/logs/hhvm.out.log
user=deploy
```

The most important settings are:

### command

Supervisord runs this command to kick off the HHVM process. We use the *-m* option to run HHVM in server mode. We also use the *-c* option to provide the path to HHVM's *php.ini* and *server.ini* configuration files.

### autostart

This causes the HHVM process to start when the Supervisord process starts (e.g., on system boot).

### autorestart

This prompts Supervisord to restart the HHVM process if it fails.

### startretries

This is the number of times Supervisord should try to start the HHVM process before Supervisord considers this process a failure.

### user

This is the user that owns the HHVM process. I recommend you use an unprivileged user for security purposes. In this example, I use the same unprivileged deploy user we created in [Example 7-1](#).

## Warning

Make sure you manually create the `/home/deploy/logs` directory, because Supervisord does not create it for you.

After you finish editing the Supervisord configuration files, run these two commands to reload and apply your changes:

```
sudo supervisorctl reread;
sudo supervisorctl update;
```

You can review all processes managed by Supervisord with this command:

```
sudo supervisorctl
```

You can start, stop, or restart a single Supervisord program as shown in the example below. In this example, `hhvm` is the program name specified at the top of the `/etc/supervisor/conf.d/hhvm.conf` file:

```
sudo supervisorctl start hhvm;
sudo supervisorctl stop hhvm;
sudo supervisorctl restart hhvm;
```

So far we've installed HHVM, and we monitor the HHVM process with Supervisord. We still need a web server to proxy requests to HHVM. Remember, HHVM runs a FastCGI server exactly as we do in [Chapter 7](#) with PHP-FPM. We'll use the HHVM FastCGI server to handle PHP requests sent from nginx.

# HHVM, FastCGI, and Nginx

HHVM communicates with a web server (e.g., nginx) with the FastCGI protocol. We need to create an nginx virtual host that proxies PHP requests to the HHVM FastCGI server. Here's an example nginx virtual host definition that does that:

```
server {
    listen 80;
    server_name example.com;
    index index.php;
    client_max_body_size 50M;
    error_log /home/deploy/apps/logs/example.error.log;
    access_log /home/deploy/apps/logs/example.access.log;
    root /home/deploy/apps/example.com/current/public;

    location / {
        try_files $uri $uri/ /index.php$is_args$args;
    }

    location ~ \.php {
        include fastcgi_params;
        fastcgi_index index.php;
        fastcgi_param SCRIPT_FILENAME $document_root$fastcgi_script_name;
        fastcgi_pass 127.0.0.1:9000;
    }
}
```

## Tip

From this point forward, I assume nginx is installed and running on your server. Refer to [Chapter 7](#) for nginx installation instructions.

Assuming you followed the nginx installation instructions in [Chapter 7](#), create a file at `/home/deploy/apps/example.com/current/public/index.php` with this content:

```
<?php
phpinfo();
```

Make sure the `example.com` domain points to your server's IP address and visit <http://example.com/index.php> in a web browser. You should see the word "HipHop" appear in your browser window.

## Tip

You can force your computer to point any domain name to any IP address by updating your local `/etc/hosts` file. For example, this line points the domain name `example.com` to IP address `192.168.33.10`:

```
192.168.33.10 example.com
```

Congratulations! You've installed HHVM as a FastCGI server that can run your PHP application. But a FastCGI server isn't cool. You know what's cool? Hack. HHVM can run that, too.

# The Hack Language

[Hack](#) is a server-side language that is similar to and seamless with PHP. Hack's developers even call Hack a dialect of PHP. Why did Facebook create something so similar to PHP? Facebook created the Hack language for several reasons. The Hack language adds new time-saving data structures and interfaces that are unavailable in PHP. More important, Hack introduces *static typing* to help us write more predictable and stable code. Static typing surfaces errors earlier in the development process using a near-realtime type checking server.

Are new data structures, interfaces, and static typing worth the time required to learn a new(ish) language and toolchain? Maybe. You have to remember that Facebook *is Facebook*. It has thousands of developers all working on a gargantuan codebase. If Facebook can optimize even the smallest part of its development process, it reaps a large reward in both developer efficiency and a more stable, well-performing codebase.

I do not recommend you drop what you're doing and immediately port your existing applications from PHP to Hack. However, if you are starting a new project and have time to install and learn Hack, then — by all means — go wild. You'll certainly benefit from Hack's data structures and static typing.

## Convert PHP to Hack

To convert code from PHP to Hack, change <?php to <?hh. That's it. This is PHP code:

```
<?php  
echo "I'm PHP";
```

And this is equivalent Hack code:

```
<?hh  
echo "I'm Hack";
```

Facebook makes it super-easy to go from PHP to Hack because it understands that converting a large, existing codebase is not a quick task. Start your codebase migration by only changing <?php to <?hh. Next, introduce a few static types. Later on, explore some Hack data structures. The transition to Hack is gradual and painless, and it happens on your schedule; this is by design.

# What is a Type?

Before we compare dynamic and static typing, it's probably helpful to define *type*. Most PHP programmers think a type is the form of data assigned to a variable. For example, the expression `$foo = "bar"` implies the `$foo` variable's value is a string. The expression `$bar = 14` implies the `$bar` variable's value is an integer. These examples demonstrate types, yes, but they betray the full definition of a type.

A *type* is a nebulous label that we assign to properties of an application to prove that certain behaviors exist and, to our own expectations, are fundamentally correct. I'm paraphrasing Chris Smith's excellent [explanation of programming types](#).

We can expand our definition of a type to a syntactical annotation that clarifies the identity of program variables, arguments, or return values. Type annotations (or *hints*) are used in both PHP and Hack. You've probably seen code like this:

```
<?php
class WidgetContainer
{
    protected $widgets;

    public function __construct($widgets = array())
    {
        $this->widgets = array_values($widgets);
    }

    public function addWidget(Widget $widget)
    {
        $this->widgets[] = $widget;

        return $this;
    }

    public function getWidget($index)
    {
        if (isset($this->widgets[$index]) === false) {
            throw new OutOfRangeException();
        }

        return $this->widgets[$index];
    }
}
```

This is an arbitrary example, but it uses syntax hints to enforce specific application properties. For example, in the `addWidget()` method signature we use a `Widget` hint before the `$widget` argument to tell PHP we expect the method argument to be an instance of class `Widget`. The PHP interpreter enforces this expectation. If an argument is provided that is not an instance of class `Widget`, the code fails. In this example, the type is our annotated expectation that the `addWidget()` method accepts arguments only of class `Widget`.

Our earlier naive examples (e.g., `$foo = "bar"`) and this `WidgetContainer` example both demonstrate types. The first example demonstrates a type that proves a variable is a string, even though we don't explicitly annotate the expectation. The PHP interpreter is smart enough to *infer* the string type in this example based on the code syntax. The second example creates a type with an annotation that explicitly defines the expected behavior of the `addWidget()` method, and the PHP interpreter enforces this behavior based on our explicit hint rather than making an inference.

## Tip

Types are more than inferred identities and annotations. However, these are the two manifestations you'll see and use most often when writing PHP and Hack code. You can learn more about programming types in Benjamin C. Pierce's book "["Types and Programming Languages."](#)"

If you thought that PHP type hints *are* static types, you're probably scratching your head right about now because I just burst your bubble. Both static and dynamic typing help us write code that behaves correctly according to our expectations, and both employ their own type systems. The main differences between static and dynamic typing are *when program types are checked* and *how a program is tested for correctness*.

## Static Typing

The correct behavior of a statically typed program is *implied by the code*, via inferences, annotations, or other language-specific types. If a statically typed program compiles successfully, we can be confident the program is proven to behave as written. The program's types become our tests, and they ensure that the program satisfies our basic expectations.

Did you notice I used the word *compiles*? Statically typed languages are often compiled. Type checking and error reporting are delegated to the language compiler. This is nice, because the compiler surfaces type-related program errors at compile time before the application is deployed into production. Unfortunately, compiled languages imply a lengthy feedback loop. A program must be compiled to reveal errors, and complicated programs take a long time to compile. This decelerates development.

The upside to statically typed programs is that they are usually more stable because their behavior is proven by the compiler's type checker. However, we should still write separate tests to verify that the program behavior is *correct*. If a program compiles, that only means the program does what the code says it should do. That does not mean the program does what we intend it to do. That being said, static typing saves us from writing type-related unit tests as we do for dynamically typed programs.

## Dynamic Typing

Unlike static typing, dynamic typing cannot enforce code behavior at compile time, because the program types are not checked until runtime. Dynamically typed programs are often interpreted, too. PHP is a dynamically typed and interpreted language. This means that *every time* you execute a PHP script — either directly on the command line or indirectly via a web server — the PHP code is read by an interpreter, converted into a set of preexisting opcodes codes, and executed.

So how do you find errors if PHP is not compiled? Errors are surfaced during runtime. This is both a blessing and a curse. It's good because we can iterate quickly. We write code and run it. Feedback is near-instantaneous. Unfortunately, we lose the inherent accuracy and tests provided by static type checking. Separate unit tests become far more important to ensure both proper types and intended behavior. Our tests must cover all possible behaviors. This works for the behavior we anticipate, but it fails miserably for the behavior we do not anticipate. Unanticipated behaviors gnash their teeth during runtime as PHP errors, and we must handle them gracefully with friendly messages and appropriate logging.

## Hack Goes Both Ways

Static typing is Hack's biggest selling point. Even more interesting is that Hack does static *and* dynamic typing. Remember, Hack is mostly backward-compatible with regular PHP. This means Hack supports all of PHP's dynamic typing features that you expect. This is possible because Hack is run with HHVM's JIT compiler. The Hack code is type checked as it is written with a standalone type checker. The Hack code is read, optimized, and cached into an intermediary bytecode by HHVM. A Hack file is only converted into x86\_64 machine code and executed on demand. It's really the best of both worlds. We get the accuracy and safety of static typing with Hack's type checker (more on this next) and the flexibility and quick iteration of dynamic typing thanks to HHVM's JIT compiler.

### Note

There are a few PHP features *not* supported by Hack. They are listed at <http://docs.hhvm.com/manual/hack.unsupported.php>. These features are supported by HHVM when executing normal PHP code.

# Hack Type Checking

Hack comes with a standalone type-checking server that runs in the background and type-checks your code *in realtime*. This is huge. This is also the main reason why Facebook created the Hack language. Hack's instantaneous type checking provides the accuracy and safety of static typing without the lengthy feedback loop. If you are using Hack without its type checker, you're holding it wrong.

Here's how to set up Hack's type checker for your application. First, I assume HHVM is installed and running. If not, refer to the HHVM section for installation instructions. Next, create an empty file named `.hhconfig` in your project's topmost directory. This tells the Hack type checker which directory to analyze. The type checker watches files beneath this directory and type-checks the appropriate files whenever it detects filesystem changes. Start the Hack type checker by executing the `hh_client` command in or beneath your project's topmost directory.

Hack's type checker does have a few limitations. Per Hack's [online documentation](#):

The type checker assumes that there is a global autoloader that can load any class on demand. This means that it insists that all class and function names are unique, and has no notion of checking imports or anything of that nature. Furthermore, it does not support conditional definitions of functions or classes — it must be able to statically know what is and what is not defined. It is of course perfectly possible to have a project that meets these requirements without a global autoloader, and the type checker will work fine on such a project, but a project using an autoloader was the intended use case.

Mixing HTML and Hack code are not supported by the type checker. Following and statically analyzing these complicated mode switches is unsupported, particularly since much modern code doesn't make use of this functionality. Hack code can output markup to the browser in a simple way via echo, or using a templating engine or XHP for more complex scenarios.

# Hack Modes

Hack code can be written in three modes: `strict`, `partial`, or `decl`. If you are starting a project with Hack, I recommend you use `strict` mode. If you are migrating existing PHP code to Hack, or if your project uses both PHP and Hack code, you may want to use `partial` mode. The `decl` mode lets you integrate legacy, untyped PHP code into an otherwise `strict` Hack codebase. You declare the mode at the very top of the file, after and adjacent to the opening Hack or PHP tag (see the following examples). Mode names are case-sensitive:

```
<?hh // strict
```

Strict mode requires all code to be appropriately annotated. The Hack type checker will catch all possible type-related errors. This mode also prevents your Hack code from using non-Hack code (e.g., legacy PHP code). Be sure you read up on Hack type annotations before you commit to `strict` mode. Among other requirements, all Hack arrays *must* be typed; you cannot use an untyped array in Hack. You must also annotate return types for functions and methods.

```
<?hh // partial
```

Partial mode (the default) allows Hack code to use PHP code that has not been converted to Hack. Partial mode also does not require you to annotate *all* of a function or method's arguments. You can annotate a subset of the arguments without angering the Hack type checker. If you are just getting started with Hack, or if you are converting an existing PHP codebase, this is probably the best mode for you.

```
<?php // decl
```

`decl` mode lets `strict` Hack code call untyped code. This is often the case when newer Hack code depends on a legacy, untyped PHP class. In this scenario, the legacy PHP code should declare itself in `decl` mode before the newer Hack code can use it.

# Hack Syntax

Hack supports type annotations for class properties, method arguments, and return types. These annotations are checked with Hack's standalone type checker in accordance with each file's mode.

## Tip

Read a [complete list](#) of available type annotations.

Let's revisit our earlier `WidgetContainer` example and introduce type annotations. The updated Hack code looks like this:

```
01. <?hh // strict
02. class WidgetContainer
03. {
04.     protected Vector<Widget> $widgets;
05.
06.     public function __construct(array<Widget> $widgets = array())
07.     {
08.         foreach ($widgets as $widget) {
09.             $this->addWidget($widget);
10.         }
11.     }
12.
13.     public function addWidget(Widget $widget) : this
14.     {
15.         $this->widgets[] = $widget;
16.
17.         return this;
18.     }
19.
20.     public function getWidget(int $index) : Widget
21.     {
22.         if ($this->widgets->containsKey($index) === false) {
23.             throw new OutOfRangeException();
24.         }
25.
26.         return $this->widgets[$index];
27.     }
28. }
```

## Property annotations

On line 4, we declare the `$widgets` class property with the `Vector<Widget>` annotation. This annotation tells us two things:

- This property is a [Vector](#) (similar to a numerically indexed array).
- This property must contain only `Widget` instances.

## Argument annotations

This is probably familiar to those of you who already use PHP type hints. On line 6, we annotate the `__construct()` method's argument with the `array<Widget>` annotation. This annotation tells us two things:

- The argument must be an array.
- The argument must contain only `Widget` instances.

Unlike the property annotation on line 4, this argument can be either a numeric or an associative array. We iterate the array argument's values and add them to the `Vector` data structure. If you did want the argument to be either a numeric or an associative array, you

could use the `array<int, Widget>` or `array<string, Widget>` annotations respectively.

## Return-type annotations

On lines 13 and 20, we annotate the methods' return types. The `addWidget()` method returns itself (more on this soon). The `getWidget()` method returns a `Widget` instance. Return-type annotations are declared *after* the method signature's closing parenthesis and *before* the method body's opening bracket.

### Warning

The exception to this rule is the `__construct()` method. One might think the constructor's return value is `void`; it's not. You should not annotate the constructor method's return type.

Some developers like to enable *method chaining*. This means that a class method returns itself so that multiple method calls can be chained together like this:

```
$object->methodOne()->methodTwo();
```

Hack lets you annotate this behavior with the `this` return type. We use the `this` annotation with the `addWidget()` method on line 13.

# Hack Data Structures

The Hack language's headline feature is static typing. However, Hack also provides new data structures and interfaces that are not found in PHP. These can potentially save you development time versus implementing similar workarounds in vanilla PHP. Some of Hack's new data structures and interfaces are:

- [Collections](#) (vectors, maps, sets, and pairs)
- [Generics](#)
- [Enums](#)
- [Shapes](#)
- [Tuples](#)

Many of these data structures complement, clarify, or supplement PHP's functionality. For example, Hack's Collection interfaces clarify PHP's array ambiguity. Generics let you create data structures to handle homogenous values of a given type that is inferred only when an instance of the generic class is created; this alleviates the need to manually enforce type checking inside a class with PHP's `instanceof` method. Enums are helpful for creating a set of named constants without resorting to abstract classes. Shapes help you type-check data structures that should have a fixed set of keys. And tuples let you use arrays of an immutable length.

Please don't feel like you need to rush out and implement all of these data structures. I admit, some of them are of limited and niche utility. Some data structures duplicate (and extend) functionality found in other data structures. I suggest you read up on which data structures are available and only use them if and when you need them.

## Tip

I believe the most useful Hack data structures are the various Collection interfaces. These provide more appropriate and predictable behavior than PHP's array data structure. It's best to use a Collection instead of a PHP array.

## HHVM/Hack vs. PHP

If HHVM and Hack are so awesome, why should you use PHP? I'm asked this question a lot. I'm also asked if and when PHP will meet its demise. The answer is not black-and-white. It's more a muddy neutral gray.

HHVM is the first true competitor to the traditional Zend Engine PHP runtime. As of PHP 5.x, HHVM is proven to perform better and be more memory-efficient than the Zend Engine on many real-world benchmarks. I think this caught the PHP core development team by surprise. In fact, HHVM's mere existence is probably responsible for PHP's renewed interest in increased performance and reduced memory usage. The PHP core development team is already working on [PHP 7](#), which is scheduled for release in late 2015. The PHP 7 codebase promises to be competitive with, if not better than, HHVM. Whether that will be true or not is anyone's guess. However, the point is that HHVM creates competition, and competition helps everyone. Both HHVM and the Zend Engine will improve, and PHP developers will reap the benefits. Neither HHVM nor the Zend Engine is going to win or lose. I believe they will coexist and feed off of their competitive energies.

The Hack language, in my opinion, is head-and-shoulders better than PHP. There are several reasons for this. First, the Hack language was built by Facebook to answer specific needs. It is focused. It has purpose. And it is not developed by committee. The PHP language, in contrast, has evolved piecemeal over a longer period of time. PHP answers many different needs, and it is controlled by a committee that is not known for its cordial agreements. As of PHP 5.x, the Hack language is the better option for its strict type checking and support for legacy PHP code. I believe a lot of Hack's best features will eventually find their way into PHP. And vice versa. In fact, the Hack language team has said it intends to maintain future compatibility with the Zend Engine. Again, I believe competition will improve both languages and they'll enjoy a symbiotic relationship.

An example of this symbiosis is the official PHP specification. Until recently, the PHP language *was* the Zend Engine for lack of alternative implementations. The introduction of HHVM prompted several developers at Facebook to [announce a PHP language specification](#). This specification is an amazing development in the PHP community, and it ensures that current and future PHP implementations (Zend Engine, HHVM, and so on) all support the same fundamental language.

### Note

You can read the official PHP implementation on GitHub at <https://github.com/php/php-langspec>.

# Further Reading

We've touched on a lot of HHVM and the Hack language in a very short period of time. There are simply not enough pages to cover everything these two initiatives have to offer. Instead, I'll point you to these helpful resources:

- <http://hhvm.com>
- <http://hacklang.org>
- [@ptarjan](#) on Twitter
- [@SaraMG](#) on Twitter
- [@HipHopVM](#) on Twitter
- [@HackLang](#) on Twitter

# **Chapter 13. Community**

The PHP community is your most valuable resource. It is diverse, vibrant, and global. I encourage you to participate in the PHP community to learn from and share with other PHP developers. There's *always* more to learn, and your PHP community is the best way to continue learning. It's also a great way to meet and help other developers.

## Local PUG

My first advice is to find and join your local PHP User Group (PUG). Many cities have them. You can find your local PUG at <http://php.ug>. Your local PUG is the best opportunity to meet and network with fellow PHP developers in your local community.

If there isn't a nearby PUG, you have several options. You can start your own PUG. Unless you live in the middle of a jungle, I bet there are like-minded nearby PHP developers who would love to join a PUG. Otherwise, you can join [NomadPHP](#) — an online user group with monthly speakers and lightning talks that cover all sorts of PHP features and practices.

# Conferences

There are numerous PHP conferences every year. Conferences are an excellent opportunity to meet and mingle with the greatest minds in the PHP community. You can listen to and talk with PHP speakers and thought leaders. And you can stay up-to-date with emerging features and modern practices. Conferences are also an excuse to take a minivacation. You can find a list of upcoming PHP conferences at <http://php.net/conferences/>.

# Mentoring

If you are a beginner PHP developer and need advice or assistance, you can find a mentor at <http://phpmentoring.org>. Many expert PHP developers donate their time to help new PHP developers become better. If you are already an expert PHP developer, consider signing up as a PHP mentor. There are many beginner PHP developers who don't know how or where to start, and your mentorship will be invaluable.

# **Stay Up-to-Date**

The PHP language changes frequently. Here are a few resources to help you stay up-to-date with newer PHP features and modern practices.

## Websites

- <http://php.net>
- <http://php.net/docs.php>
- <http://www.php-fig.org>
- <http://www.phptherightway.com>

## Mailing Lists

- <http://php.net/mailing-lists.php>

## Twitter

- [@official\\_php](#)
- [@phpc](#)

## Podcasts

- <http://voicesoftheelephant.com>
- <http://looselycoupled.info>
- <http://elephantintheroom.io>
- <http://phptownhall.com>
- <http://devhell.info>
- <http://www.phpclasses.org/blog/category/podcast/>
- <http://threedevsandamaybe.com/>

## **Humor**

- [@phpbard](#)
- [@phpdrama](#)

# **Appendix A. Installing PHP**

# Linux

Linux is my favorite development environment. I own a Macbook Pro with OS X, but my development happens in a Linux virtual machine. PHP is easy to install on Linux with a package manager such as aptitude on Ubuntu Server or yum on CentOS.

For now, we're concerned only with PHP for command-line usage. We discuss how to setup PHP-FPM and the nginx web server in [Chapter 7](#).

# Package Managers

Most Linux distributions provide their own package manager. For example, Ubuntu uses the `aptitude` package manager. CentOS and Red Hat Enterprise Linux (RHEL) use the `yum` package manager. Package managers are the simplest way to find, install, update, and remove software on our Linux operating system.

## Warning

Sometimes Linux package managers install out-of-date software. For example, Ubuntu 14.04 LTS provides PHP 5.5.9; this is already behind the latest release — PHP 5.6.3 (as of December 2014).

Fortunately, we can supplement our Linux package manager's default software sources with third-party repositories that contain more up-to-date, community-maintained software packages. We'll use a custom software repository for both Ubuntu and CentOS to install the most recent PHP version. Before we go any further, make sure you are the system root user or a user with `sudo` power. This is required to install software with a Linux package manager.

# Ubuntu 14.04 LTS

Ubuntu does not provide the latest PHP version in its default software repositories. We'll need to add a community-maintained Personal Package Archive (PPA) instead. The term PPA is unique to Ubuntu, but the concept remains the same: we are using a third-party software repository to expand Ubuntu's default software selection. Ondřej Surý maintains an excellent PPA that provides nightly builds for the latest stable PHP release. This PPA is named `ppa:ondrej/php5-5.6`.

## 1. Add software dependencies

Before we add Ondřej Surý's PPA, we must make sure the `add-apt-repository` binary is available on our operating system. This binary is included in the `python-software-properties` Ubuntu package. Type this command into your terminal application and press Enter. Enter your account password if prompted:

```
sudo apt-get install python-software-properties
```

This command installs the Python Software Properties package that includes the `add-apt-repository` binary. Now we can add the custom PPA.

## 2. Add `ppa:ondrej/php5-5.6` PPA

This PPA expands Ubuntu's available software selection beyond the default Ubuntu software repositories. Type this command into your terminal application and press Enter. Enter your account password if prompted:

```
sudo add-apt-repository ppa:ondrej/php5-5.6
```

This command adds the Ondřej Surý PPA to Ubuntu's list of software sources. It also downloads the PPA's GPG public key and appends it to our local GPG keyring. The GPG public key enables Ubuntu to verify that the packages in the PPA have not been tampered with since they were built and signed by their original author.

Ubuntu caches the list of all available software. When we add new software sources, we need to refresh Ubuntu's cache. Type this command in your terminal application and press Enter. Enter your account password if prompted:

```
sudo apt-get update
```

## 3. Install PHP

We can now use Ubuntu's `aptitude` package manager to install the latest PHP stable release from the Ondřej Surý PPA. Before we do, it is important to know which PHP packages are available and what they do. PHP is distributed in two forms. One form is a CLI package that enables you to use PHP on the command line (we will use this one). There are several other PHP packages that integrate PHP with the Apache or nginx web servers (we discuss these in [Chapter 7](#)). For now, we'll stick with the PHP CLI package.

First, let's install the PHP CLI package. Type this command in your terminal application and press Enter. Enter your account password if prompted:

```
sudo apt-get install php5-cli
```

The Linux package manager also contains packages for individual PHP extensions that can be installed separately. Let's install a few of those now. Type this command in your terminal application and press Enter. Enter your account password if prompted:

```
sudo apt-get install php5-curl php5-gd php5-json php5-mcrypt php5-mysqlnd
```

Verify PHP was installed successfully with this terminal command:

```
php -v
```

This command should output something similar to:

```
PHP 5.5.11-3+deb.sury.org-trusty+1 (cli) (built: Apr 23 2014 12:15:16)
Copyright (c) 1997-2014 The PHP Group
Zend Engine v2.5.0, Copyright (c) 1998-2014 Zend Technologies
    with Zend OPcache v7.0.4-dev, Copyright (c) 1999-2014, by Zend Technologies
```

# CentOS 7

Like Ubuntu, CentOS and RHEL do not provide the latest stable version of PHP in their default software repositories. RHEL is very particular about which software packages are included in its official distribution because it prides itself on superior security and stability; software updates are added slowly for the sake of safety.

We're not a Fortune 500 company, so we can afford to install the latest PHP stable release in our CentOS/RHEL Linux distribution. To do so, we'll use the [EPEL](#) (Extra Packages for Enterprise Linux) repository. The EPEL describes itself as:

...a Fedora Special Interest Group that creates, maintains, and manages a high quality set of additional packages for Enterprise Linux, including, but not limited to, Red Hat Enterprise Linux (RHEL), CentOS, Scientific Linux (SL), and Oracle Enterprise Linux(OEL).

The EPEL repository is unrelated to the official CentOS/RHEL Linux distributions, but it can still supplement the default CentOS/RHEL software repositories. And that's exactly what we're going to do.

## 1. Add the EPEL repository

Let's tell our CentOS/RHEL system to use the EPEL software repository. Type these commands into your terminal application one-by-one, and press Enter after each command. Enter your account password if prompted:

```
sudo rpm -Uvh \
  http://dl.fedoraproject.org/pub/epel/7/x86_64/e/epel-release-7-5.noarch.rpm;
sudo rpm -Uvh \
  http://rpms.famillecollet.com/enterprise/remi-release-7.rpm;
```

These commands add the third-party EPEL and remi software repositories to our CentOS/RHEL system. You should now see *epel.repo* and *remi.repo* files in the */etc/yum.repos.d* directory.

## 2. Install PHP

Now we'll install the latest PHP version from the EPEL and remi repositories. As I mentioned earlier in the Ubuntu PHP installation, PHP is distributed in two forms. One form is a CLI package that enables you to use PHP on the command line. For now, we'll stick with the PHP CLI package.

First, let's install the PHP CLI package. Type this command in your terminal application and press Enter. Enter your account password if prompted.

```
sudo yum -y --enablerepo=epel,remi,remi-php56 install php-cli
```

Next, let's install a few additional PHP extensions. You can search for a complete list of PHP extensions with the `yum` package manager. Type this command into your terminal application and press Enter:

```
yum search php
```

Once you find a list of PHP extensions, install them as I do in this example. Your package names might be different:

```
sudo yum -y --enablerepo=epel,remi,remi-php56 \
           install php-gd php-mbstring php-mcrypt php-mysqlnd php-opcache php-pdo
```

The important takeaway from this command is the `--enablerepo` option. This option tells `yum` to install the specified software packages from the EPEL, remi, and remi-php56 repositories. Without this option, `yum` only references its default software sources.

Verify that PHP was installed successfully. Type this command in your terminal application and press Enter:

```
php -v
```

This command should output something similar to:

```
PHP 5.6.3 (cli) (built: Nov 16 2014 08:32:30)
Copyright (c) 1997-2014 The PHP Group
Zend Engine v2.6.0, Copyright (c) 1998-2014 Zend Technologies
    with Zend OPcache v7.0.4-dev, Copyright (c) 1999-2014, by Zend Technologies
```

# OS X

OS X includes PHP out of the box, but it's probably not the latest version and it may not have the PHP extensions you need. I recommend you ignore the PHP that comes with OS X and use a custom PHP build instead. There are many ways to install PHP on OS X, but I recommend two methods: MAMP and Homebrew.

# MAMP

MAMP is the best way to install PHP on OS X if you cringe at the mere thought of the command-line terminal. MAMP (which stands for Mac, Apache, MySQL, and PHP) provides a traditional web-development software stack that includes an Apache web server, a MySQL database server, and PHP. MAMP is an OS X application with a GUI. Many users prefer the familiar GUI interface because it provides a nice point-and-click interface for installing and configuring the MAMP software ([Figure A-1](#)). MAMP lives in your */Applications* folder, and you double-click its application icon to launch it. It has a simple OS X package (.pkg) installer that makes it dead simple to install and use. You can even drag it into your OS X Dock for quick access.

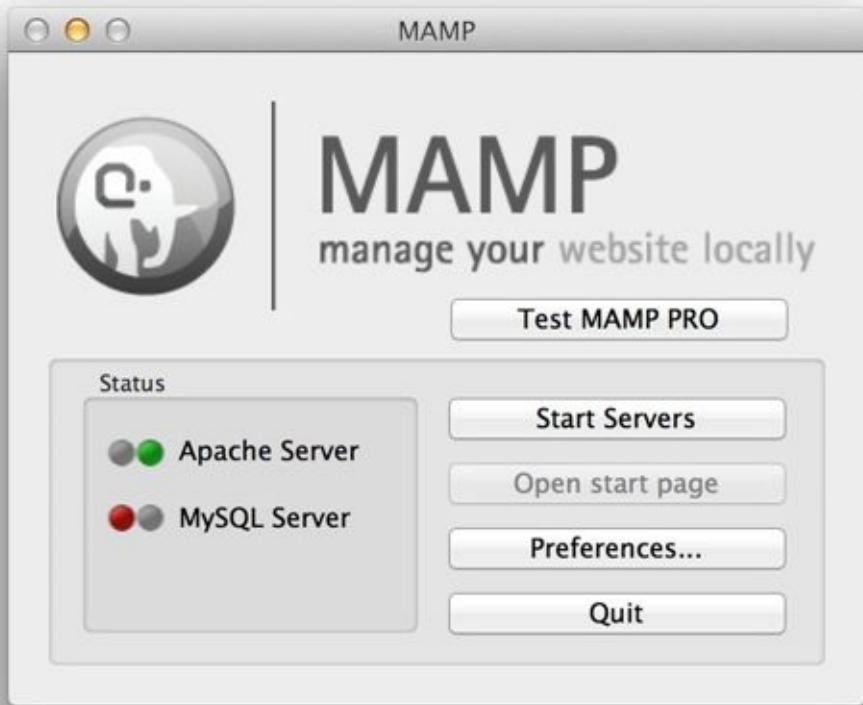


**Figure A-1. Installing MAMP**

## Install

Download the MAMP package (.pkg) installer from <http://www.mamp.info>, and double-click the MAMP package installer. Follow the on-screen instructions.

When the MAMP installer finishes, find the MAMP application in your */Applications* folder and launch it by double-clicking its application icon. After MAMP opens, click the Start Servers button to start the Apache and MySQL servers ([Figure A-2](#)). It's really that simple.



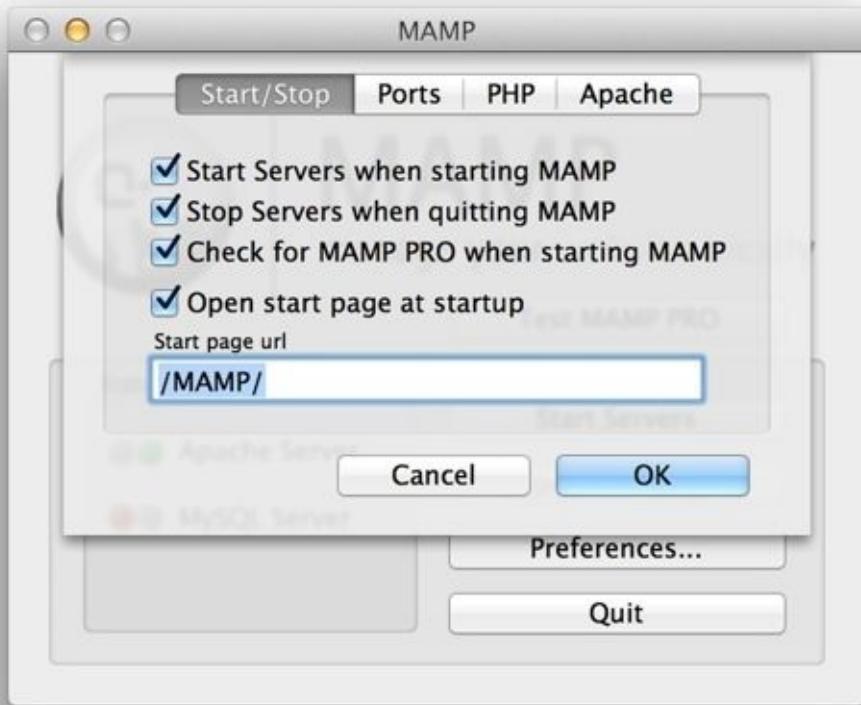
**Figure A-2. MAMP interface**

*What about PHP?*, you ask. MAMP embeds PHP inside of the Apache web server using the `mod_php` Apache module. Without getting into too much detail, you can use PHP if the Apache web server is running. We discuss PHP deployment strategies in [Chapter 7](#).

After you start the Apache and MySQL servers, open your web browser and go to <http://localhost:8888>. You should see a MAMP welcome page if MAMP is successfully installed.

The Apache web server typically listens for connections on port 80. MAMP, however, runs Apache on port 8888. Likewise, MySQL typically listens for connections on port 3306. MAMP, however, runs MySQL on port 8889. You can change MAMP's default ports in the MAMP application preferences. MAMP's Apache web server document root is `/Applications/MAMP/htdocs`. Any PHP files in this directory can be accessed in a web browser at <http://localhost:8888>.

If you will use MAMP a lot, go into the MAMP application preferences ([Figure A-3](#)) and make sure Start Servers when starting MAMP is checked. Then add the MAMP application to your OS X account's Login Items. This will start MAMP's Apache and MySQL servers automatically when you log in to OS X.



**Figure A-3. MAMP application preferences**

## Extend

It is possible to download MAMP add-ons that provide different PHP versions for your local MAMP installation. MAMP is updated frequently and most likely comes bundled with the latest PHP version. But if for whatever reason it doesn't, or if you need an older PHP version, go to the MAMP website and download the PHP version you need.

## Limitations

The MAMP free version provides only one Apache virtual host, and it does not let you easily modify PHP's configuration or extensions. MAMP is very basic and provides only the bare necessities for PHP development on OS X.

MAMP provides a paid “Pro” version that lets you create multiple Apache virtual hosts, easily edit your *php.ini* configuration file, and fine-tune PHP extensions. MAMP Pro is nice, don't get me wrong. But instead of forking out a good bit of money for MAMP Pro, you're better off learning a few command-line fundamentals so you can use the excellent [Homebrew](#) package manager instead.

# Homebrew

[Homebrew](#) is an OS X package manager comparable to Ubuntu's aptitude and RHEL's yum package managers. Homebrew lets you easily browse, find, install, update, and remove any number of custom software packages on OS X. However, *Homebrew is a command-line application*. If you are not familiar with the OS X command line, you will be more comfortable with MAMP.

Homebrew uses *formulae* to install software packages on your computer. Homebrew provides default formulae for lots of software that's not provided out of the box with OS X. For example, there are Homebrew formulae for wget, phploc, phpmd, and php-code-sniffer (to name just a few). If Homebrew's default formulae are insufficient, you can tap into third-party formulae repositories to expand your available Homebrew software selection. Homebrew is, without exception, my favorite way to install PHP on OS X.

## XCode command-line tools

Before we can install Homebrew, we must first install the XCode Command-Line Tools provided (for free) by Apple, Inc. These command-line tools include the gcc compiler (among other tools) needed by Homebrew to build and install software packages. If you are running OS X Mavericks 10.9.2 or newer, open the OS X Terminal application, type this command, and press Enter:

```
xcode-select --install
```

This command opens this modal window shown in [Figure A-4](#).



**Figure A-4. Installing XCode command-line tools**

Click Install to begin installing the XCode Command-Line Tools. Click Agree when the software license agreement appears. After the XCode Command-Line Tools software is installed, click Done and continue to the next step.

If you are using an older version of OS X, you must log into the [Apple Developer Portal](#) to download and run a standalone XCode Command-Line Tools package (.pkg) installer.

# Install

After you install the XCode Command-Line Tools, type this command in the OS X Terminal application and press Enter:

```
ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/homebrew/go/install)"
```

## Warning

This command executes Ruby code that is downloaded from a remote URL. You should *always* inspect the remote code *before* you execute it, no matter how legitimate the source may be.

## Directory permissions

Homebrew downloads and ferments software in the */usr/local/Cellar* directory. It symlinks installed software binaries to the */usr/local* directory. Your OS X user account must be able to access the */usr/local* directory to use software installed with the Homebrew package manager.

Let's make sure your OS X user account owns the */usr/local* directory. Type this command into the OS X Terminal application and press Enter. Enter your administrator password if prompted:

```
sudo chown -R `whoami` /usr/local
```

The `chown` command means “change the owner” of the specified directory, the `-R` command flag means “make this change recursively to all subdirectories” of the specified directory, and the `whoami` argument is dynamically substituted with your OS X user account name. After you run this command, your OS X user account will own (and therefore have access to) the */usr/local* directory.

## Environment PATH

Next, add the */usr/local* directory to your OS X environment PATH. The environment PATH is a list of directories to be searched when you execute software using only the software's name instead of the software's absolute filesystem path. For example, if I execute `wget`, OS X will search all directories on my environment PATH for the `wget` software. Otherwise, I'd have to type `/usr/local/wget` every time I want to use `wget`. Type this command into the OS X Terminal application and press Enter:

```
echo 'export PATH="/usr/local/bin:$PATH"' >> ~/.bash_profile
```

## Tap formulae repositories

Before we install PHP with Homebrew, we must tap additional repositories that contain PHP-related formulae that do not exist in the default Homebrew repository.

First, we'll tap the `homebrew/dupes` repository. This repository contains formulae for software that already exists on OS X. This repository, however, contains newer software versions than OS X. Type this command in the OS X Terminal application and press Enter:

```
brew tap homebrew/dupes
```

Next, we'll tap the `homebrew/versions` repository. This repository contains multiple

versions of existing OS X software. Type this command in the OS X Terminal application and press Enter:

```
brew tap homebrew/versions
```

Finally, we'll tap the homebrew/php repository. This repository contains PHP-related formulae that might not be included in the default Homebrew repositories. The default Homebrew software repository is not maintained by PHP developers. This repository is, and it includes software appropriate for PHP developers. Type this command in the OS X Terminal application and press Enter:

```
brew tap homebrew/php
```

## Install PHP

So far, we've installed the Homebrew package manager, configured filesystem permissions, updated the environment PATH, and tapped into additional formulae repositories. Now it's time to install PHP. There are Homebrew formulae for each PHP version and each PHP version's extensions. Homebrew provides a very simple way to search for available formulae. Type this command in the OS X Terminal application and press Enter:

```
brew search php
```

You should see a lengthy list of Homebrew PHP formulae. Find the latest stable PHP version in the formulae list (PHP 5.5.x will be named `php55`, PHP 5.6.x will be named `php56`, and so on). I'll pick `php56` since PHP 5.6.x is the latest stable version (as of December 2014). Type this command in the OS X Terminal application and press Enter:

```
brew install php56
```

Installation may take a while, so feel free to grab a coffee and check back in a few minutes. After the PHP software package is installed, you can confirm the installation by executing `php -v` in the OS X Terminal application; this command outputs the full name and version number of the PHP interpreter installed by Homebrew.

## Install PHP extensions

Homebrew lets you install PHP extensions separately from the PHP interpreter. You can search for PHP extensions just as you searched for PHP previously. Assuming you chose `php56`, type this command in the OS X Terminal application and press Enter:

```
brew search php56
```

You should see a lengthy list of PHP 5.6 extensions prefixed with `php56-`. After you find the extensions you want, type this command in the OS X Terminal application and press Enter. Swap the formulae in this example with the extension formulae you want to install:

```
brew install php56-intl php56-mcrypt php56-xhprof
```

The Homebrew package manager is much more powerful than what I've shown here. Type `brew` into the OS X Terminal application and press Enter to see a complete list of Homebrew commands. You can also read the complete Homebrew documentation online at <http://brew.sh>.

# Build from Source

The precompiled PHP binary provided by your operating system's package manager may not always be up-to-date or exactly what you want. If this is true, you're better off building PHP from source code. Yes, this sounds scary. It took me a long time to build up enough confidence before I compiled PHP for the first time. I can assure you, it's less scary than it sounds.

The build process is simple. We'll download and extract the PHP source code. We'll configure the source code and make sure all of its software dependencies are installed. And then we'll make the actual PHP binaries. Download. Configure. Make. Three simple steps.

Compiling PHP from source code gives you the flexibility to tweak the PHP build to your exact specifications. Although there are many ways to configure PHP, for the sake of time I'll show you how I prefer to build PHP for my own projects. In addition to PHP's default features, I typically want PHP to support:

- OpenSSL
- Bytecode caching
- FPM (FastCGI process management)
- PDO database abstraction
- Encryption
- Multibyte strings
- Image manipulation
- Network sockets
- Curl

With this list in mind, let's start building PHP. Try to follow along on your own computer. If this is your first time building PHP from source code, I strongly encourage you to do this on a virtual machine. You can set up a local virtual machine with VMware, Parallels, or VirtualBox. You can also fire up a dirt-cheap remote virtual machine with DigitalOcean, Linode, and other web hosts that bill by the hour. If you mess up, you can destroy the virtual machine, rebuild it, and try again without consequence.

Now take a deep breath, open your terminal application, and (most important) don't be afraid to make mistakes.

# Get the Source Code

First, let's download the PHP source code. Locate the latest stable version of the PHP source code at <http://www.php.net/downloads.php>. For me, the latest stable release happens to be version 5.6.3, but this may be different for you. Type the following commands into your Terminal application and press Enter after each command.

## The src/ directory

First, we create a src/ directory in our home folder. This folder will contain the source code that we download from PHP.net. We cd into the src/ directory so that it becomes our current working directory:

```
mkdir ~/src;  
cd ~/src;
```

## Download the source code

Next, we use wget to download the PHP source code as a *tar.gz* archive. The downloaded file will be located at *~/src/php.tar.gz*:

```
wget -O php.tar.gz http://www.php.net/get/php-5.6.3.tar.gz/from/this/mirror
```

Extract the PHP source code archive with the tar command, and cd into the unarchived source code directory:

```
tar -xzvf php.tar.gz;  
cd php-*;
```

## Configure PHP

We've downloaded the PHP source code. Now we need to configure it. Before we do, we must install a few software dependencies. How do I know what dependencies to install? I run the *./configure* command (see the next subsection) until it works. When the *./configure* command fails due to a missing software dependency, it indicates what software is missing. Install the missing dependency and rerun the *./configure* command. Rinse and repeat until it works.

Luckily for you, I've already figured out what software dependencies are needed for the PHP *./configure* command we'll be using. Let's install these software dependencies now. I use commands for both Ubuntu/Debian and CentOS/RHEL Linux distributions; use the commands appropriate for your Linux distribution.

### Note

If for whatever reason the *./configure* command reports additional missing dependencies, you can search for the missing dependency software packages online at <http://packages.ubuntu.com/> (for Ubuntu) or at <https://fedoraproject.org/wiki/EPEL> (for CentOS).

### Build essentials

We'll need these fundamental software binaries to build PHP on your operating system. These binaries include gcc, automake, and other fundamental development software:

```
# Ubuntu
```

```
sudo apt-get install build-essential;  
  
# CentOS  
sudo yum groupinstall "Development Tools";
```

## libxml2

We'll need the `libxml2` library. This is used by PHP's XML-related functions:

```
# Ubuntu  
sudo apt-get install libxml2-dev;  
  
# CentOS  
sudo yum install libxml2-devel;
```

## OpenSSL

We'll need the `openssl` library. This is required to enable HTTPS stream wrappers in PHP, which is *kind of* important, right?

```
# Ubuntu  
sudo apt-get install libssl-dev;  
  
# CentOS  
sudo yum install openssl-devel;
```

## Curl

We'll need the `curl` library. This is required by PHP's Curl functions:

```
# Ubuntu  
sudo apt-get install libcurl4-dev;  
  
# CentOS  
sudo yum install libcurl-devel;
```

## Image manipulation

We'll need the GD, JPEG, PNG, and other image-related system libraries. Fortunately, all of these are bundled into a single package. These are required to manipulate images with PHP:

```
# Ubuntu  
sudo apt-get install libgd-dev;  
  
# CentOS  
sudo yum install gd-devel;
```

## Mcrypt

We'll need the `mcrypt` system library to enable PHP's Mcrypt encryption and decryption functions. For whatever reason, there is no default CentOS Mcrypt package. We'll need to supplement the default CentOS packages with the third-party EPEL package repository to install Mcrypt:

```
# Ubuntu  
sudo apt-get install libmcrypt-dev;  
  
# CentOS  
wget http://dl.fedoraproject.org/pub/epel/6/x86_64/epel-release-6-8.noarch.rpm;  
sudo rpm -Uvh epel-release-6*.rpm;  
sudo yum install libmcrypt-devel;
```

# The `./configure` command

Now that our software dependencies are installed, let's configure PHP. Type the following `./configure` command in your Terminal application and press Enter:

```
./configure
```

```
--prefix=/usr/local/php5.6.3
--enable-opcache
--enable-fpm
--with-gd
--with-zlib
--with-jpeg-dir=/usr
--with-png-dir=/usr
--with-pdo-mysql=mysqlnd
--enable-mbstring
--enable-sockets
--with-curl
--with-mcrypt
--with-openssl;
```

This is a lengthy command with a lot of options. Don't be overwhelmed. Each command option has a specific purpose. You can find a list of all available options with `./configure --help`. We'll go through this `./configure` command line by line so you know exactly what it does:

`--prefix=/usr/local/php5.6.3`

The `--prefix` option defines the path to a filesystem directory that will contain the compiled PHP binaries, includes, libraries, and configuration files. I prefer to keep my custom PHP build and related files together in a single parent directory for the sake of organization. Your user account will need permission to write to this directory. If you don't have write permission to `/usr/local`, you can set the `--prefix` to a directory in your user account's home folder instead (e.g., `~/local/php-5.5.13`). Regardless, make sure the `--prefix` directory exists *before* you run the `./configure` command.

`--enable-opcache`

The `--enable-opcache` option enables PHP's built-in bytecode caching system. You will most always want to enable this. The performance benefits are tremendous.

`--enable-fpm`

The `--enable-fpm` option enables the built-in PHP FastCGI Process Manager. This lets you run PHP as a FastCGI process that is accessible via a TCP port or a local Unix socket. FPM is fast becoming the preferred way to run PHP (especially with the nginx web server). If in doubt, I recommend you enable this option.

`--with-gd`

The `--with-gd` option lets PHP interface with your operating system's GD image-manipulation library. You will want to enable this option if you plan on using PHP to manipulate images.

`--with-zlib`

The `--with-zlib` option lets PHP interface with your operating system's Zlib library. Zlib is a data-compression library that is needed by the GD image library to create and manipulate PNG image data. This option is required if you use the `--with-gd` option.

`--with-jpeg-dir`

The `--with-jpeg-dir` option specifies the path to the filesystem directory that contains the JPEG libraries. This option is required if you use the `--with-gd` option.

`--with-png-dir`

The `--with-png-dir` option specifies the path to the filesystem directory that contains the PNG libraries. This option is required if you use the `--with-gd` option.

#### `--with-pdo-mysql=mysqlnd`

The `--with-pdo-mysql` option instructs PHP to enable the PDO database abstraction API for the MySQL database using PHP's own native MySQL driver. If you use MySQL, you'll want to enable this option.

#### `--enable-mbstring`

The `--enable-mbstring` option instructs PHP to enable multibyte (read “Unicode”) string support. You’ll most always want to enable this option.

#### `--enable-sockets`

The `--enable-sockets` option instructs PHP to enable network socket support so that you can talk with remote machines via TCP sockets. You’ll most always want to enable this option.

#### `--with-curl`

The `--with-curl` option lets PHP interface with your operating system’s curl library. This lets you use PHP’s curl functions to send and receive HTTP requests. You’ll most always want to enable this option.

#### `--with-mcrypt`

The `--with-mcrypt` option lets PHP interface with your operating system’s mcrypt library for data encryption and decryption. Although this option is by no means required, it is used by a growing number of PHP components. I strongly recommend you enable this option.

#### `--with-openssl`

The `--with-openssl` option lets PHP interface with your operating system’s openssl library. This is required to use PHP’s HTTPS stream wrapper. Although this option is technically optional, it’s really not. Make Edward Snowden proud. Enable this option.

## Make and install PHP

Configuring PHP and installing its software dependencies was the hard part. It’s all downhill from here. Assuming the `./configure` command executed successfully, type this command in your terminal application and press Enter:

```
make && make install
```

This will compile PHP and may take a while. Now is a good time to grab a coffee or two. Eventually the command will finish and PHP will be installed. That wasn’t too bad, right?

The compiled PHP binaries are available in the `bin/` directory beneath your `--prefix` directory. The `php-fpm` binary is available in the `sbin/` directory beneath your `--prefix` directory. Be sure the `bin/` and `sbin/` directories are added to your system’s environment PATH so you can reference the `php` binary by name instead of absolute path.

## Create the `php.ini` file

Let's not forget about our *php.ini* file. This may not be created automatically. The PHP GitHub repository has a *php.ini* preconfigured for local development. Our *php.ini* file should exist in the *lib/* directory beneath your --prefix directory. Let's create it now. Type the following commands into your terminal application and press Enter after each command.

First, cd into our PHP installation's *lib/* directory. This path may be different if you used a different --prefix path in your ./configure command:

```
cd /usr/local/php5.6.3/lib
```

Next, download the *PHP.ini* file from PHP's GitHub repository into a file named *php.ini*:

```
curl -o php.ini \
  https://raw.githubusercontent.com/php/php-src/master/php.ini-development
```

That's it. We're all set to execute PHP files with the newly installed php interpreter. We talked more about the *php-fpm* binary when we discussed PHP deployment strategies in [Chapter 7](#).

# Windows

Yes, you can run PHP on Windows. However, I encourage you to use a Linux virtual machine instead. It is very likely that your production server will be running a Linux distribution, and you should set up your local development environment to closely match your production environment. But if you must use Windows locally, here's how.

## Binaries

The fine folks over at PHP.net provide prebuilt PHP binaries for Windows at <http://php.net/windows>. Download the appropriate PHP release (provided as a ZIP archive) and unpack it to a directory of your choice. I'll unpack it to *C:\PHP\*. Copy the *php.ini-production* file to *php.ini* in the same folder. No other changes are required to use PHP on the Windows command line. You can execute a custom PHP script with optional arguments like this:

```
C:\PHP\php.exe -f "C:\path\to\script.php"--arg1 -arg2 -arg3
```

### Tip

You should add the PHP executable to your [Windows PATH variable](#) and append the .php extension to your Windows PATHEXT variable to save your future self from a lot of extra typing.

## **WAMP**

You can also download and install [WAMP](#) to set up a quick and dirty local PHP development environment. Like its OS X counterpart, MAMP, WAMP is an all-in-one software package that provides a traditional web-development stack out-of-the-box. It includes an Apache web server, a MySQL database server, and PHP. It has a Windows software installer that will guide you through every step of the install process. WAMP also provides a configuration menu in the Windows Taskbar notification area where you can quickly and easily start, stop, or restart your Apache and MySQL servers. Like MAMP, WAMP embeds PHP in the Apache web server using the mod\_php Apache module. If your Apache server is running, you can use PHP.

WAMP is your best bet for quickly installing a local PHP development stack on your Windows machine. However, just as with MAMP, you are limited to the software and extensions provided with WAMP. You can download additional PHP versions separately on the WAMP website. Learn more at <http://www.wampserver.com/>.

## **Zend Server**

Another all-in-one solution is Zend Server. It is available in both free and paid versions. Like WAMP, it provides an Apache web server, the latest PHP interpreter and popular PHP extensions, a MySQL database server, and Zend's own debugging tools in one easy-to-install package. Just download the installer (.exe) file, run it, and follow the on-screen instructions. Learn more at <http://www zend com/en/products/server/>.

## Appendix B. Local Development Environments

We've talked a lot about production server provisioning and application deployment. However, we haven't discussed how to develop applications *on your local computer*. What tools do you use? How do you reconcile your development environment with your production environment? This chapter has answers.

Many beginner PHP developers rely on their operating system's default software stack — typically older versions of Apache and PHP. I strongly encourage you **not** to use your operating system's default software. Many OS X users (including me) have been devastated when an OS X upgrade vaporized our heavily customized Apache configuration files. Steer clear of built-in software; it's often out of date, and it may be overwritten by operating system upgrades. Instead, build a local development environment in a *virtual machine* that is safely isolated from your local operating system. A virtual machine is a software-emulated operating system. For example, you can create a virtual machine on OS X that runs Ubuntu or CentOS. The virtual machine behaves exactly like a separate computer.

### Tip

Make sure your virtual machine runs the same operating system as your production server (I prefer Ubuntu Server). It's important that your local development and production server environments use the same operating system to prevent unexpected deployment and runtime errors caused by operating system software discrepancies.

# VirtualBox

There are many software programs that create and manage virtual machines. Some are commercial products (e.g., [VMWare Fusion](#) or [Parallels](#)), and others are open source products (e.g., [VirtualBox](#)). To be honest, VirtualBox is a solid product. It works as advertised, and it's free. VirtualBox is not pretty like its commercial alternatives, but it gets the job done. You can download VirtualBox for OS X or Windows at <https://www.virtualbox.org>. It uses a traditional GUI installer appropriate for your operating system ([Figure B-1](#)).



**Figure B-1. VirtualBox installer**

# Vagrant

Although VirtualBox lets us create virtual machines, it does not provide a user-friendly interface to start, provision, stop, and destroy virtual machines. Instead, we use [Vagrant](#) — a virtualization tool that helps you create, start, stop, and destroy VirtualBox virtual machines with a single command. It complements (and abstracts) VirtualBox with a user-friendly, command-line interface. You can download Vagrant for OS X and Windows at <https://www.vagrantup.com>. It also uses a traditional GUI installer appropriate for your operating system.

# Commands

After installation, you can use the `vagrant` command in your terminal application to create, provision, start, stop, and destroy VirtualBox virtual machines. These are the Vagrant commands you'll use most often:

`vagrant init`

This creates a new `Vagrantfile` configurations script in the current working directory. We use this script to configure a virtual machine's properties and provisioning details.

`vagrant up`

This creates and/or starts a virtual machine.

`vagrant provision`

This provisions a virtual machine using the specified provisioning scripts. We'll discuss provisioning later in this chapter.

`vagrant ssh`

This logs you into a virtual machine via SSH.

`vagrant halt`

This stops a virtual machine.

`vagrant destroy`

This destroys a virtual machine.

## Tip

I recommend you create command-line *aliases* for these Vagrant commands because you'll type them a lot. Drop these into your `~/.bash_profile` file and restart your terminal application:

```
alias vi="vagrant init"
alias vu="sudo echo 'Starting VM' && vagrant up"
alias vup="sudo echo 'Starting VM' && vagrant up --provision"
alias vp="vagrant provision"
alias vh="vagrant halt"
alias vs="vagrant ssh"
```

## Boxes

We have VirtualBox and Vagrant installed. Now what? We need to choose a *Vagrant box* as a starting point for our virtual machine. A Vagrant box is a preconfigured virtual machine that provides a foundation on which we provision our server and build our PHP application. Some boxes are spartan shells used as a blank canvas. Other boxes include complete software stacks that cater to certain types of applications. You can browse available boxes at <https://vagrantcloud.com>.

I usually choose the spartan [ubuntu/trusty64](#) box, and then I use Puppet to provision the box with a specific software stack required by my application. If you find another Vagrant box that already includes the tools you need, by all means use that box to save time.

# Initialize

After you find a Vagrant box, navigate into the appropriate working directory with your terminal application. Initialize a new `Vagrantfile` with this command:

```
vagrant init
```

Open the new `Vagrantfile` file in your preferred text editor. This file is written with Ruby, but it's easy to read. Find the `config.vm.box` setting, and change its value to the name of your Vagrant box. For example, if I prefer the Ubuntu box I change this setting to `ubuntu/trusty64`. The updated `Vagrantfile` line should read:

```
config.vm.box = "ubuntu/trusty64"
```

Next, uncomment this line so we can access our virtual machine in a web browser on our local network at IP address `192.168.33.10`:

```
config.vm.network "private_network", ip: "192.168.33.10"
```

Finally, create the virtual machine with this command:

```
vagrant up
```

This command downloads the remote Vagrant box (if necessary), and it creates a new VirtualBox virtual machine based on the Vagrant box.

# Provision

Unless you use a Vagrant box that provides a preconfigured software stack, your virtual machine doesn't do anything. You need to *provision* the virtual machine with the software to run your PHP application. At the very least, you want a web server, PHP, and possibly a database. Provisioning a virtual machine is a topic far too large for this book. I can, however, point you in the right direction. You can provision a virtual machine with Vagrant and either Puppet or Chef. Both Puppet and Chef can be enabled and configured in the the `Vagrantfile` configuration file.

## Tip

[Erika Heidi](#) gave a [great NomadPHP presentation](#) on Vagrant and provisioning tools like Puppet and Chef. She also wrote the [Vagrant Cookbook](#), now available on LeanPub.

## Puppet

If you scroll down the `Vagrantfile` file, you'll see a section that looks like this. It may be commented out by default:

```
config.vm.provision "puppet" do |puppet|
  puppet.manifests_path = "manifests"
  puppet.manifest_file  = "default.pp"
end
```

If you uncomment this section, Vagrant will provision the virtual machine with Puppet using your Puppet manifests. You can learn more about Puppet at <http://puppetlabs.com>.

## Chef

If you prefer Chef's provisioning tools, you can instead uncomment this section of the `Vagrantfile` file:

```
config.vm.provision "chef_solo" do |chef|
  chef.cookbooks_path = "../my-recipes/cookbooks"
  chef.roles_path = "../my-recipes/roles"
  chef.data_bags_path = "../my-recipes/data_bags"
  chef.add_recipe "mysql"
  chef.add_role "web"

  # You may also specify custom JSON attributes:
  chef.json = { mysql_password: "foo" }
end
```

Provide your own cookbooks, roles, and recipes. Vagrant will provision your virtual machine accordingly. You can learn more about Chef at <https://www.chef.io/chef/>.

# Synced folders

In either case, it's often useful to map your local machine's project directory to a directory in the virtual machine. For example, you can map your local project directory to the virtual machine's `/var/www` directory. If the virtual machine's web server virtual host is `/var/www/public`, your local project's `public/` directory is now served by the virtual machine's web server. Any local changes are reflected *immediately* in the virtual machine. You can uncomment this line in your `Vagrantfile` file to enable synced directories between your local and virtual machines:

```
config.vm.synced_folder ".", "/vagrant_data"
```

The first argument (`.`) is your local path relative to the `Vagrantfile` configuration file. The second argument (`/vagrant_data`) is the absolute path on the virtual machine to which the local directory is mapped. The virtual machine directory largely depends on your virtual machine's web server virtual host configuration. OS X users should enable NFS synced folders. Change the `config.vm.synced_folder` line to this:

```
config.vm.synced_folder ".", "/vagrant_data", type: "nfs"
```

Then uncomment these lines and boost the VirtualBox machine's memory to 1024MB:

```
config.vm.provider "virtualbox" do |vb|
  # Don't boot with headless mode
  # vb.gui = true

  # Use VBoxManage to customize the VM. For example to change memory:
  vb.customize ["modifyvm", :id, "--memory", "1024"]
end
```

## Get started

Puppet and Chef are not easy to learn, especially for Vagrant newcomers. There are tools available to help you get started with Vagrant that don't require you to write your own Puppet and Chef manifests.

## Laravel Homestead

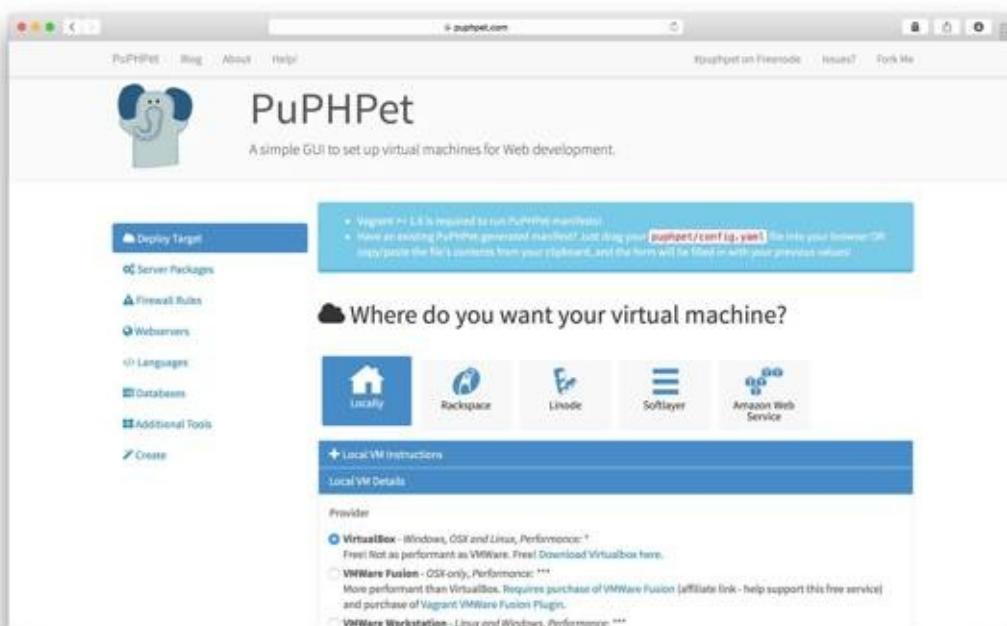
[Homestead](#) is an abstraction on top of Vagrant. It is also a Vagrant box that is preconfigured with a complete software stack including:

- Ubuntu 14.04
- PHP 5.6
- HHVM
- Nginx
- MySQL
- Postgres
- Node (With Bower, Grunt, and Gulp)
- Redis
- Memcached
- Beanstalkd
- Laravel Envoy

Homestead works great for *any* PHP application, too. I use Homestead on my local machine to develop Slim and Symfony applications. Learn more about Homestead at <http://laravel.com/docs/4.2/homestead>.

## PuPHPet

[PuPHPet](#) is ideal for those who don't know how to write Puppet manifests. This is a point-and-click website that creates a Puppet configuration automatically ([Figure B-2](#)). You download the resultant Puppet configuration and run `vagrant up`. It really is that simple.



**Figure B-2. PuPHPet**

## Vaprobash

[Vaprobash](#) is similar to PuPHPet. It doesn't provide a point-and-click website, but it's almost as easy. You download the Vaprobash `Vagrantfile`, and you uncomment the lines for the tools you need. Do you want nginx? Uncomment the `nginx` line. Do you want MySQL? Uncomment the `MySQL` line. Do you want Elasticsearch? Uncomment the `Elasticsearch` line. When ready, run `vagrant up` in your terminal application and Vagrant will provision your virtual machine.

# Index

## Symbols

- \$context argument, [Write a PSR-3 Logger](#)
- .htaccess files, [Router Scripts](#)
- @ prefix, [Errors and Exceptions](#)
- \autoload() method, [Autoloading](#)
- \invoke() magic method, [Create](#)

## A

- addDocument() method, [Code to an Interface](#)
- addRoute() method, [Attach State](#)
- aliases
  - custom, [Import and Alias](#)
  - default, [Import and Alias](#)
  - definition of term, [Import and Alias](#)
- anonymous functions, [Closures](#)
- Apache Bench, [Memory, When to Use a Profiler](#)
- auth.json files, [Composer and Private Repositories](#)
- autoloading
  - components, [Autoloading PHP components](#)
  - definition of term, [Autoloading](#)
  - importance of, [Why Autoloaders Are Important](#)
  - namespaces and classes, [PSR-1: Basic Code Style](#)
  - PSR4 autoloader standard, [Autoloading, The PSR-4 Autoloader Strategy](#)
  - purpose of, [PSR-4: Autoloaders](#)
  - writing a PSR4 autoloader, [How to Write a PSR-4 Autoloader \(and Why You Shouldn't\)](#)

## B

- bcrypt hashing algorithm, [Hash User Passwords with bcrypt](#)
- behavior-driven development (BDD), [Behavior-Driven Development \(BDD\)](#)
- benchmarking tools, [When to Use a Profiler](#)
- best practices (see good practices)
- bindTo() method, [Attach State](#)
- Bitbucket, [Version Control](#)
- Blackfire, [Blackfire Profiler](#)
- BOM (byte-order marker), [PSR-1: Basic Code Style](#)
- bound parameters, [Prepared Statements](#)
- buffer size, tuning of, [Output Buffering](#)
- bytecode caches, [Zend OPcache](#)
  - (see also Zend OPcache)

# C

- caching, tuning of, [Zend OPcache](#)
- CamelCase format, [PSR-1: Basic Code Style](#)
- Capistrano
  - application deployment, [Deploy Your Application](#)
  - application rollback, [Roll Back Your Application](#)
  - authentication, [Authenticate](#)
  - benefits of, [Capistrano](#)
  - config/deploy.rb file, [The config/deploy.rb file](#)
  - configuration of, [Configure](#)
  - hooks in, [Capistrano Hooks](#)
  - installation of, [Install](#)
  - operation of, [How It Works](#)
  - remote server preparation, [Prepare the Remote Server](#)
  - software dependencies and, [Software dependencies](#)
  - virtual hosts and, [Virtual host](#)
- case keyword, [PSR-2: Strict Code Style](#)
- catch keyword, [PSR-2: Strict Code Style](#)
- CentOS
  - nginx installation, [nginx](#)
  - non-root user creation, [Nonroot User](#)
  - PHP installation, [CentOS 7](#)
  - PHP-FPM installation, [Install](#)
  - software updates, [Software Updates](#)
- Chef, [Chef](#)
- class definition, [PSR-2: Strict Code Style](#)
- class names, [Import and Alias](#), [PSR-1: Basic Code Style](#)
  - (see also namespaces)
- classical inheritance, [Why We Use Traits](#)
- closures
  - attaching state with, [Attach State](#)
  - creating, [Create](#)
  - purpose of, [Closures](#)
  - vs. anonymous functions, [Closures](#)
- code style
  - autoloading, [PSR-1: Basic Code Style](#)
  - automating compatibility, [PSR-2: Strict Code Style](#)
  - class definition, [PSR-2: Strict Code Style](#)
  - control structures, [PSR-2: Strict Code Style](#)
  - files and lines, [PSR-2: Strict Code Style](#)
  - indentation, [PSR-2: Strict Code Style](#)
  - keywords, [PSR-2: Strict Code Style](#)

method definition, [PSR-2: Strict Code Style](#)  
names, [PSR-1: Basic Code Style](#)  
namespaces, [PSR-2: Strict Code Style](#)  
PHP tags, [PSR-1: Basic Code Style](#)  
PSR-1: basic code style, [PSR-1: Basic Code Style](#)  
PSR-2: strict code style, [PSR-2: Strict Code Style](#)  
standardization of, [Style](#)  
UTF-8 character set, [PSR-1: Basic Code Style](#)  
visibilities, [PSR-2: Strict Code Style](#)

- command line runner, [PHPUnit](#)
- command-line scripts, [Implement scan.php](#)
- components
  - autoloading, [Autoloading PHP components](#)
  - benefits of, [Components](#), [Use PHP Components](#)
  - characteristics of good, [What Are Components?](#)
  - Composer installation, [How to Install Composer](#)
  - creating, [Create PHP Components-Using the Component](#)
  - definition of term, [What Are Components?](#)
  - example project, [Example Project](#)
  - filesystem organization, [Filesystem Organization](#)
  - finding/selecting, [Find Components](#)
  - importance of, [Use PHP Components](#)
  - installing, [Component installation](#)
  - naming, [Component names](#)
  - private repositories, [Composer and Private Repositories](#)
  - using, [Use PHP Components](#)
  - vs. frameworks, [Components Versus Frameworks](#)

- Composer
  - benefits of, [Use PHP Components](#)
  - composer.lock file, [The composer.lock file](#)
  - example project, [Example Project](#)
  - importance of, [Use PHP Components](#)
  - installation of, [How to Install Composer](#)
  - installing components with, [How to Use Composer](#)
  - private repositories, [Composer and Private Repositories](#)
- composer.json files, [The composer.json File](#)
- config/deploy.rb file, [The config/deploy.rb file](#)
- config/deploy/production.rb file, [The config/deploy/production.rb file](#)
- constant names, [PSR-1: Basic Code Style](#)
- control structures, [PSR-2: Strict Code Style](#)

## D

- data
  - good practices for handling, [Sanitize, Validate, and Escape](#)

- sanitizing HTML special characters, [HTML](#)
- sanitizing input, [Sanitize Input](#)
- SQL queries, [SQL queries](#)
- streaming, [Stream Wrappers](#)
- streams, [Streams-Custom Stream Filters](#)
- user profile information, [User profile information](#)
- validation of, [Validate Data](#)
- databases
  - connections and DSNs, [Database Connections and DSNs](#)
  - ensuring credentials security, [Keep your database credentials secret](#)
  - PDO extension, [The PDO Extension](#)
  - PHP extensions for, [Databases](#)
  - prepared statements, [Prepared Statements](#)
  - query results, [Query Results](#)
  - transactions, [Transactions](#)
- dates, times, and time zones
  - DateInterval Class, [The DateInterval Class](#)
  - DatePeriod class, [The DatePeriod Class](#)
  - DateTime class, [The DateTime Class](#)
  - DateTimeZone class, [The DateTimeZone Class](#)
  - nesbot/carbon component, [The nesbot/carbon Component](#)
  - PHP classes for, [Dates, Times, and Time Zones](#)
  - setting default time zones, [Set a Default Time Zone](#)
- dedicated servers, [Dedicated Server](#)
- default aliases, [Import and Alias](#)
- deployment
  - approaches to, [Deployment](#)
  - automating, [Automate Deployment](#)
  - version control and, [Version Control](#)
  - with Capistrano, [Capistrano-Roll Back Your Application](#)
- dispatch() method, [Attach State](#)
- do while keyword, [PSR-2: Strict Code Style](#)
- DRY (Do not repeat yourself), [Why We Use Traits](#)
- DSN string argument, [Database Connections and DSNs](#)
- dynamic typing, definition of term, [Future](#)
  - (see also typing)

## E

- else keyword, [PSR-2: Strict Code Style](#)
- elseif keyword, [PSR-2: Strict Code Style](#)
- email addresses, sanitizing, [User profile information](#)
- encryption, vs. hashing, [Hash User Passwords with bcrypt](#)
- EPEL (Extra Packages for Enterprise Linux) repository, [CentOS 7](#)

- errors and exceptions
  - catching exceptions, [Catch exceptions](#)
  - differences between, [Errors and Exceptions](#), [Errors](#)
  - during development, [Errors and Exceptions During Development](#)
  - error handlers, [Error Handlers](#)
  - error logging, [Production](#)
  - error reporting, [Errors](#)
  - errors, [Errors](#)
  - exception handlers, [Exception Handlers](#)
  - exceptions, [Exceptions](#)
  - logging exceptions, [Exception Handlers](#)
  - throwing exceptions, [Throw exceptions](#)
- exec() function, [Max Execution Time](#)
- extends keyword, [PSR-2: Strict Code Style](#)
- external data sources, [Sanitize, Validate, and Escape](#)

## F

- Facebook Open Source project, [HHVM and Hack](#)
- FastCGI protocol, [HHVM, FastCGI, and Nginx](#)
- Ferrara, Anthony, [Password Hashing API](#)
- file uploads, tuning, [File Uploads](#)
- files, standards for, [PSR-2: Strict Code Style](#)
- filter\_input() function, [User profile information](#)
- filter\_var() function, [User profile information](#)
- firewalls, [Disable Passwords and Root Login](#)
- for keyword, [PSR-2: Strict Code Style](#)
- foreach keyword, [PSR-2: Strict Code Style](#)
- Forge, [Delegate Server Provisioning](#)
- framework interoperability
  - autoloading, [Autoloading](#)
  - code style, [Style](#)
  - interfaces, [Interfaces](#)
- frameworks
  - benefits of, [Not All Frameworks Are Bad](#)
  - choosing, [Use the Right Tool for the Job](#)
  - popular PHP, [Not All Frameworks Are Bad](#)
  - vs. components, [Components Versus Frameworks](#)
- front controllers, [Router Scripts](#)
- functional tests, [What Do We Test?](#)
- functions
  - anonymous, [Closures](#)
  - closures, [Closures](#)

## G

- generators
    - benefits and drawbacks of, [Use a Generator](#)
    - creating, [Create a Generator](#)
    - purpose of, [Generators](#)
    - using, [Use a Generator](#)
  - getContent() method, [Code to an Interface](#)
  - getId() method, [Code to an Interface](#)
  - Git, [Version Control](#)
  - global namespaces, [Global namespace](#)
  - good practices
    - benefits of, [Good Practices](#)
    - components, [Components-Using the Component](#)
    - data handling, [Sanitize, Validate, and Escape](#)
    - data validation, [Validate Data](#)
    - databases, [Databases-Transactions](#)
    - dates, times, and time zones, [Dates, Times, and Time Zones-The nesbot/carbon Component](#)
    - DRY (Do not repeat yourself), [Why We Use Traits](#)
    - errors and exceptions, [Errors and Exceptions-Production](#)
    - escaping output, [Escape Output](#)
    - multibyte strings, [Multibyte Strings](#)
    - passwords, [Passwords-Password Hashing API for PHP < 5.5.0](#)
    - sanitizing input, [Sanitize Input](#)
    - standards, [Standards-How to Write a PSR-4 Autoloader \(and Why You Shouldn't\)](#)
    - streams, [Streams-Custom Stream Filters](#)
    - trait definition, [How to Create a Trait](#)
    - vs. best practices, [Good Practices](#)
  - Gutmans, Andi, [Past](#)
- ## H
- Hack language
    - backwards compatibility of, [HHVM and Hack](#)
    - benefits of, [The Hack Language, Hack Goes Both Ways, HHVM/Hack vs. PHP](#)
    - converting PHP to, [Convert PHP to Hack](#)
    - data structures, [Hack Data Structures](#)
    - dynamic typing, [Dynamic Typing](#)
    - features of, [Future](#)
    - modes in, [Hack Modes](#)
    - static typing, [Static Typing](#)
    - syntax in, [Hack Syntax](#)
    - type checking, [Hack Type Checking](#)
    - vs. PHP, [HHVM/Hack vs. PHP](#)
  - hashing

algorithms for, [Hash User Passwords with bcrypt](#)  
vs. encryption, [Hash User Passwords with bcrypt](#)

- HipHop Virtual Machine (HHVM)

- applications using, [HHVM and Hack](#)  
benefits of, [Future, PHP at Facebook](#)  
choosing, [Is HHVM Right for Me?](#)  
configuration of, [Configure](#)  
development of, [HHVM](#)  
extensions for, [Extensions](#)  
implementation of, [PHP at Facebook](#)  
installation of, [Install](#)  
vs. PHP, [HHVM/Hack vs. PHP](#)  
Zend Engine parity, [HHVM and Zend Engine Parity](#)

- Homebrew, [Homebrew](#)

- Homestead, [Laravel Homestead](#)

- hooks, [Capistrano Hooks](#)

- hosting

- approaches to, [Hosting](#)  
choosing a plan, [Choose a Hosting Plan](#)  
companies available, [Hosting](#)  
on dedicated servers, [Dedicated Server](#)  
on platforms as a service (PaaS), [PaaS](#)  
on shared servers, [Shared Server](#)  
on virtual private servers (VPS), [Virtual Private Server](#)

- HPHPc compiler, [PHP at Facebook](#)

- HTML Purifier library, [HTML](#)

- HTML, sanitizing special characters, [HTML](#)

- htmlentities() function, [HTML](#), [Escape Output](#)

- HTTP server

- benefits of, [Built-in HTTP server](#)  
configuring, [Configure the Server](#)  
detecting, [Detect the Built-in Server](#)  
drawbacks of, [Drawbacks](#)  
router scripts, [Router Scripts](#)  
starting, [Start the Server](#)

- human-readable stories, [Behavior-Driven Development \(BDD\)](#)

# I

- identifiers, [Stream Wrappers](#)
- if keyword, [PSR-2: Strict Code Style](#)
- implements keyword, [PSR-2: Strict Code Style](#)
- import, definition of term, [Import and Alias](#)
- importing

multiple imports, [Multiple imports](#)  
namespaces vs. traits, [How to Use a Trait](#)

- indentation, [PSR-2: Strict Code Style](#)
- inheritance, classical, [Why We Use Traits](#)
- input, sanitizing, [Sanitize Input](#), [Prepared Statements](#)
- installation

build from source, [Build from Source](#)-[Create the php.ini file](#)  
CentOS 7, [CentOS 7](#)  
development environment, [Linux](#)  
Homebrew, [Homebrew](#)  
MAMP (Mac, Apache, MySQL and PHP), [MAMP](#)  
OS X, [OS X](#)  
package managers, [Package Managers](#)  
Ubuntu 14.04 LTS, [Ubuntu 14.04 LTS](#)  
Windows, [Windows](#)  
Xcode command-line tools, [XCode command-line tools](#)

- interfaces
  - benefits of, [Interfaces](#)
  - benefits of coding to, [Code to an Interface](#)
  - concept of, [Code to an Interface](#)
  - importance of, [Code to an Interface](#)
  - logger interface recommendations, [PSR-3: Logger Interface](#)

- interoperability methods
  - autoloading, [Autoloading](#)
  - code style, [Style](#)
  - interfaces, [Interfaces](#)
- interpreted languages, [Zend OPcache](#)
- interval specification, [The DateInterval Class](#)
- iterators, [Generators](#)

(see also generators)

## J

- just in time (JIT) compilers
  - benefits of, [Future](#)
  - HHVM, [PHP at Facebook](#)

## K

- KCacheGrind, [Types of Profilers](#)
- key-pair authentication, [SSH Key-Pair Authentication](#)
- keywords, [PSR-2: Strict Code Style](#)

## L

- Laravel Homestead, [Laravel Homestead](#)
- Lederdorf, Rasmus, [Past](#)
- LF Unix linefeed ending, [PSR-2: Strict Code Style](#)
- lines, standards for, [PSR-2: Strict Code Style](#)
- Linode, [Virtual Private Server](#), [Server Setup](#)
- local development environments
  - benefits of, [Present](#)
  - Homestead, [Laravel Homestead](#)
  - PuPHPet, [PuPHPet](#)
  - purpose of, [Local Development Environments](#)
  - syncing folders, [Synced folders](#)
  - Vagrant, [Vagrant](#)
  - Vaprobash, [Vaprobash](#)
  - VirtualBox, [VirtualBox](#)
- logger interface
  - standards for, [PSR-3: Logger Interface](#)
  - using a PSR-3 logger, [Use a PSR-3 Logger](#)
  - writing a PSR-3 logger, [Write a PSR-3 Logger](#)

## M

- magic methods
  - `_autoload()` method, [Autoloading](#)
  - `_invoke()` method, [Create](#)
- `makeRange()` method, [Use a Generator](#)
- MAMP (Mac, Apache, MySQL and PHP), [MAMP](#)
- maximum execution time, tuning, [Max Execution Time](#)
- mbstring extension, [Character Encoding](#)
- memory, tuning of, [Memory](#)
- Mercurial, [Version Control](#)
- method definition, [PSR-2: Strict Code Style](#)
- method names, [PSR-1: Basic Code Style](#)
- monolog/monolog logger, [PSR-3: Logger Interface](#), [Production](#)
- multibyte strings, [Multibyte Strings](#)

## N

- named placeholders, [Prepared Statements](#)
- names/naming
  - components, [Component names](#)
  - package name, [Vendor and Package Names](#)
  - standards for, [PSR-1: Basic Code Style](#)
  - vendor name, [Vendor and Package Names](#)
- namespaces, [Namespaces-Autoloading](#), [PSR-2: Strict Code Style](#), [Namespaces](#)
  - autoloader standard, [Autoloading](#)

benefits of, [Why We Use Namespaces](#)  
component, [Namespaces](#)  
declaring, [Declaration, PSR-2: Strict Code Style](#)  
example declaration, [Namespaces](#)  
global, [Global namespace](#)  
importing and aliasing, [Import and Alias](#)  
multiple imports, [Multiple imports](#)  
multiple in one file, [Multiple namespaces in one file](#)  
purpose of, [Namespaces](#)  
vendor namespace, [Declaration](#)  
vs. filesystems, [Namespaces](#)

- nesbot/carbon component, [The nesbot/carbon Component](#)
- New Relic, [New Relic Profiler](#)
- nginx
  - installation of, [nginx](#)
  - virtual host configuration, [Virtual Host](#)
- Nginx
  - HHVM communication with, [HHVM, FastCGI, and Nginx](#)
- non-root user, [Nonroot User](#)

## O

- object-oriented programming, [Code to an Interface](#)
- opcode cache, [Zend OPcache](#)
- OS X, [OS X](#)
- output buffering, tuning of, [Output Buffering](#)
- output, escaping, [Escape Output](#)

## P

- package managers, [Package Managers](#)
- package names, [Vendor and Package Names](#)
- Packagist, [Find Components](#), [Packagist Submission](#)
- passwords
  - correct handling of, [Never Know User Passwords](#)
  - disabling, [Disable Passwords and Root Login](#)
  - ensuring security of, [Passwords](#)
  - hashing with bcrypt, [Hash User Passwords with bcrypt](#)
  - password hashing API, [Password Hashing API-Password Hashing API for PHP < 5.5.0](#)
  - storing, [Hash User Passwords with bcrypt](#)
- PDO (PHP data objects) database extension, [The PDO Extension](#)
- PDO prepared statements, [SQL queries](#)
- performance issues, [When to Use a Profiler](#)

(see also profiling)

- period designator, [The DateInterval Class](#)
- PHP Code Sniffer (phpcs), [PSR-2: Strict Code Style](#)
- PHP community
  - benefits of, [Community](#)
  - conferences, [Conferences](#)
  - language updates, [Stay Up-to-Date](#)
  - mentoring, [Mentoring](#)
  - PUGs (PHP User Groups), [Local PUG](#)
  - resources, [Stay Up-to-Date](#)
- PHP Framework Interop Group (PHP-FIG)
  - autoloader standard, [Autoloading](#), [Autoloading](#)
  - creation of, [PHP-FIG to the Rescue](#)
  - mission of, [Framework Interoperability](#)
  - operation of, [PHP-FIG to the Rescue](#)
  - recommendations vs. rules, [PHP-FIG to the Rescue](#)
- PHP Iniscan tool, [The php.ini File](#)
- PHP keywords, [PSR-2: Strict Code Style](#)
- PHP language
  - as interpreted language, [PHP at Facebook](#)
  - closures, [Closures-Attach State](#)
  - converting to Hack, [Convert PHP to Hack](#)
  - engines for, [Present](#)
  - essential vs. nonessential features, [Features](#)
  - evolution of, [Present](#)
  - generators, [Generators-Use a Generator](#)
  - history of, [The New PHP](#)
  - HTTP server, [Built-in HTTP server-Drawbacks](#)
  - interfaces, [Code to an Interface-Code to an Interface](#)
  - namespaces, [Namespaces-Autoloading](#)
  - official draft specification, [Present](#)
  - PHP 7 release, [Future](#)
  - traits, [Traits-How to Use a Trait](#)
  - vs. Hack/HHVM, [HHVM/Hack vs. PHP](#)
  - Zend OPcache, [Zend OPcache-Use Zend OPcache](#)
- PHP tags, [PSR-1: Basic Code Style](#)
- PHP-CS-Fixer, [PSR-2: Strict Code Style](#)
- PHP-FPM (PHP FastCGI Process Manager)
  - global configuration, [Global Configuration](#)
  - installation of, [Install](#)
  - pool configuration, [Pool Configuration](#)
  - purpose of, [PHP-FPM](#)
- php.ini file, [The php.ini File](#)
- PHPUnit, [PHPUnit-Code Coverage](#)

code coverage, [Code Coverage](#)  
configuring, [Configure PHPUnit](#)  
directory structure, [Directory Structure](#)  
hypothetical test case, [The WhovianTest Test Case](#)  
hypothetical test class, [The Whovian Class](#)  
installing PHPUnit, [Install PHPUnit](#)  
installing Xdebug, [Install Xdebug](#)  
running tests, [Run Tests](#)  
vocabulary used, [PHPUnit](#)

- placeholders, [Write a PSR-3 Logger](#)
- placeholders, named, [Prepared Statements](#)
- platforms as a service (PaaS)
  - benefits of hosting on, [PaaS](#)
  - provisioning via, [Provisioning](#)
- Pool Definitions, [Pool Configuration](#)
- prepared statements, [Prepared Statements](#)
- private repositories, [Composer and Private Repositories](#)
- profiling
  - Blackfire, [Blackfire Profiler](#)
  - New Relic, [New Relic Profiler](#)
  - purpose of, [Profiling](#)
  - timing of, [When to Use a Profiler](#)
  - types of profilers, [Types of Profilers](#)
  - Xdebug, [Xdebug](#)
  - XHProf, [XHProf](#)
- provisioning
  - approaches to, [Provisioning](#)
  - automating, [Automate Server Provisioning](#)
  - delegating, [Delegate Server Provisioning](#)
  - nginx, [nginx](#)
  - overview of, [Our Goal](#)
  - PHP-FPM, [PHP-FPM-Pool Configuration](#)
  - server setup, [Server Setup-Disable Passwords and Root Login](#)
  - skills required, [Provisioning](#)
  - via Paas, [Provisioning](#)
- PSR (PHP standards recommendation)
  - benefits of, [What Is a PSR?](#)
  - importance of, [What Is a PSR?](#)
  - PSR-1: basic code style, [PSR-1: Basic Code Style](#)
  - PSR-2: strict code style, [PSR-2: Strict Code Style](#)
  - PSR-3: logger interface, [PSR-3: Logger Interface](#)
  - published recommendations, [What Is a PSR?](#)
- public code repositories, [Version Control](#)

- PUGs (PHP User Groups), [Local PUG](#)
- PuPHPet, [PuPHPet](#)
- Puppet, [Puppet](#)

## R

- README files, [The README file](#)
- realpath cache, [Realpath Cache](#)
- regular expression functions, [HTML](#)
- releases, versioning of, [Component installation](#)
- RFC 5424 syslog protocol, [Write a PSR-3 Logger](#)
- rollbacks, [Roll Back Your Application](#)
- root users, [Disable Passwords and Root Login](#)
- router scripts, [Router Scripts](#)

## S

- scan.php script, [Implement scan.php](#)
- schemes, [Stream Wrappers](#)
- Siege, [Memory](#)
- semantic versioning, [Component installation](#)
- server setup, [Server Setup-Disable Passwords and Root Login](#)
  - disabling passwords/root login, [Disable Passwords and Root Login](#)
  - firewalls, [Disable Passwords and Root Login](#)
  - first login, [First Login](#)
  - security, [Nonroot User](#)
  - software updates, [Software Updates](#)
  - SSH key-pair authentication, [SSH Key-Pair Authentication](#)
- server-side scripting, definition of term, [Past](#)
- session handling, tuning of, [Session Handling](#)
- shared servers, [Shared Server](#)
- Siege, [When to Use a Profiler](#)
- smarty/smarty template engine, [Escape Output](#)
- software dependencies, [Software dependencies](#)
- SPACE characters, [PSR-2: Strict Code Style](#), [PSR-2: Strict Code Style](#)
- SpecBDD, [Behavior-Driven Development \(BDD\)](#)
- special characters
  - multibyte strings, [Multibyte Strings](#)
  - sanitizing HTML, [HTML](#)
- specification, definition of term, [Present](#)
- spl\_autoload\_register() method, [Autoloading](#)
- SQL queries, [SQL queries](#)
- SSH key-pair authentication, [SSH Key-Pair Authentication](#)
- standards
  - framework interoperability, [Framework Interoperability](#)
  - importance of, [Standards](#)

PHP standards recommendation, [What Is a PSR?](#)  
PHP-FIG, [PHP-FIG to the Rescue](#)  
PSR-1: basic code style, [PSR-1: Basic Code Style](#)  
PSR-2: strict code style, [PSR-2: Strict Code Style](#)  
PSR-3: logger interface, [PSR-3: Logger Interface](#)  
PSR-4: autoloaders, [PSR-4: Autoloaders](#)

- state, attaching/enclosing, [Attach State](#)
- static typing, definition of term, [Future](#)  
(see also typing)
- StoryBDD, [Behavior-Driven Development \(BDD\)](#)
- streams
  - benefits of, [Streams](#)
  - custom stream filters, [Custom Stream Filters](#)
  - definition of term, [Streams](#)
  - introduction of, [Streams](#)
  - stream context, [Stream Context](#)
  - stream filters, [Stream Filters](#)
  - stream wrappers, [Stream Wrappers](#)
- stress testing, [Memory](#)
- strings, multibyte, [Multibyte Strings](#)
- Supervisord, [Monitor HHVM with Supervisord](#)
- Suraski, Zeev, [Past](#)
- switch keyword, [PSR-2: Strict Code Style](#)

## T

- TAB character, [PSR-2: Strict Code Style](#)
- targets, [Stream Wrappers](#)
- template engines, [Escape Output](#)
- test case, [PHPUnit](#)
- test runner, [PHPUnit](#)
- test suite, [PHPUnit](#)
- test-driven development (TDD), [Test-Driven Development \(TDD\)](#)
- testing
  - behavior-driven development (BDD), [Behavior-Driven Development \(BDD\)](#)
  - continuous testing, [Continuous Testing with Travis CI](#)
  - importance of, [Testing](#)
  - micro and macroscopic scales, [What Do We Test?](#)
  - stress testing, [Memory](#)
  - test-driven development (TDD), [Test-Driven Development \(TDD\)](#)
  - timing of, [When Do We Test?](#)
  - unit tests, [Unit Tests](#)
  - with PHPUnit, [PHPUnit-Code Coverage](#)
  - with Travis CI, [Continuous Testing with Travis CI](#)

- TitleCase format, [PSR-1: Basic Code Style](#)
- traits
  - benefits of, [Why We Use Traits](#)
  - compile-time class definitions, [How to Use a Trait](#)
  - creating, [How to Create a Trait](#)
  - definition of term, [Traits](#)
  - purpose of, [Why We Use Traits](#)
  - using, [How to Use a Trait](#)
- transactions, PDO support for, [Transactions](#)
- Travis CI, [Continuous Testing with Travis CI](#)
- try keyword, [PSR-2: Strict Code Style](#)
- tuning
  - benefits of, [Tuning](#)
  - file uploads, [File Uploads](#)
  - maximum execution time, [Max Execution Time](#)
  - memory, [Memory](#)
  - output buffering, [Output Buffering](#)
  - php.ini file, [The php.ini File](#)
  - realpath cache, [Realpath Cache](#)
  - session handling, [Session Handling](#)
  - Zend OPcache, [Zend OPcache](#)
- Twig template engine, [Escape Output](#)
- typing
  - benefits of static, [The Hack Language](#), [Static Typing](#)
  - definition of term, [What is a Type?](#)
  - dynamic, [Dynamic Typing](#)
  - dynamic vs. static, [Future](#)
  - static, [Static Typing](#)
  - type checking, [Hack Type Checking](#)

## U

- Ubuntu
  - nginx installation, [nginx](#)
  - non-root user creation, [Nonroot User](#)
  - PHP installation, [Ubuntu 14.04 LTS](#)
  - PHP-FPM installation, [Install](#)
  - software updates, [Software Updates](#)
  - virtual host configuration, [Virtual Host](#)
- Unicode standards, [Multibyte Strings](#)
- unit tests
  - definition of term, [What Do We Test?](#)
  - frameworks for, [Unit Tests](#)
  - purpose of, [Unit Tests](#)

- use func keyword, [Import and Alias](#)
- use keyword, [Import and Alias](#), [How to Use a Trait](#), [Attach State](#)
- user profile information, [User profile information](#)
- UTC time zone, [The DateTimeZone Class](#)
- UTF-8 character set, [PSR-1: Basic Code Style](#), [Character Encoding](#)

## V

- Vagrant, [Vagrant](#)
- Vaprobash, [Vaprobash](#)
- VARCHAR(255) database columns, [User registration](#)
- vendor names, [Vendor and Package Names](#)
- vendor namespace, [Declaration](#)
- version control
  - importance of, [Version Control](#)
  - public code repositories, [Version Control](#)
  - semantic versioning, [Component installation](#)
  - software for, [Present](#)
- virtual hosts, [Virtual Host](#), [Virtual host](#)
- virtual machines, [Local Development Environments](#)
- virtual private servers (VPS), [Virtual Private Server](#)
- VirtualBox, [VirtualBox](#)
- visibilities, [PSR-2: Strict Code Style](#)

## W

- WAMP, [WAMP](#)
- web hosting (see hosting)
- while keyword, [PSR-2: Strict Code Style](#)
- Whoops component, [Errors and Exceptions During Development](#)
- WinCacheGrind, [Types of Profilers](#)
- Windows, [Windows](#)
- work factor, [Hash User Passwords with bcrypt](#)

## X

- Xcode command-line tools, [XCode command-line tools](#)
- Xdebug profiler
  - analysis, [Analyze](#)
  - configuration of, [Configure](#)
  - drawbacks of, [Types of Profilers](#)
  - installation of, [Install Xdebug](#), [Xdebug](#)
  - triggering, [Trigger](#)
  - using with Zend OPcache, [Enable Zend OPcache](#)
- XHGUI, [XHGUI](#)
- XHProf, [Types of Profilers](#), [XHProf](#)

## Z

- Zend Engine, [Present](#), [HHVM](#), [HHVM and Zend Engine Parity](#)
- Zend Extension Source Compatibility Layer
  - monitoring with Supervisord, [Monitor HHVM with Supervisord](#)
  - web server communication, [HHVM, FastCGI, and Nginx](#)
- Zend OPcache
  - benefits of, [Zend OPcache](#)
  - configuring, [Configure Zend OPcache](#)
  - enabling, [Enable Zend OPcache](#)
  - tuning of, [Zend OPcache](#)
  - using, [Use Zend OPcache](#)
- Zend Opcodes, [PHP at Facebook](#)
- Zend Server, [Zend Server](#)
- Zend-style class names, [Import and Alias](#)

# About the Author

**Josh Lockhart** created the [Slim Framework](#), a popular PHP micro framework that enables rapid Web application and API development. Josh also started and currently curates [PHP The Right Way](#), a popular initiative in the PHP community that encourages good practices and disseminates quality information for PHP developers around the world.

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You can at [follow Josh on Twitter](#), read his blog at <https://joshlockhart.com>, and track his open source projects on [GitHub](#).

# Colophon

The animal on the cover of *Modern PHP* is a straw-necked ibis (*Threskiornis spinicollis*). It can be found throughout Australia, New Guinea, and parts of Indonesia.

Straw-necked ibises are large birds, growing up to 30 inches long. The distinctive stiff feathers on the neck from which the bird gets its name appear during adulthood. They have long, curved beaks that help them sift through water for insects, mollusks, and frogs. Farmers welcome straw-necked ibises in their fields because the birds will eat insects, grasshoppers, crickets and locusts that would have otherwise destroyed crops.

These birds are very nomadic, and travel in flocks between habitats. They favor shallow freshwater wetlands, cultivated pastures, swamps, lagoons, and grasslands. During breeding season, these ibises will build a large, cup-shaped nest of sticks and reeds high up in trees over water. They are also known to nest in colonies, often together with the Australian white ibis. For this reason, they are easily spotted standing in the high branches of bare trees, creating a striking silhouette against the sky.

Many of the animals on O'Reilly covers are endangered; all of them are important to the world. To learn more about how you can help, go to [animals.oreilly.com](http://animals.oreilly.com).

The cover image is from *Woods Illustrated Natural History*. The cover fonts are URW Typewriter and Guardian Sans. The text font is Adobe Minion Pro; the heading font is Adobe Myriad Condensed; and the code font is Dalton Maag's Ubuntu Mono.

## [1. Preface](#)

- a. [What You Need to Know About This Book](#)
- b. [How This Book Is Organized](#)
- c. [Conventions Used in This Book](#)
- d. [Using Code Examples](#)
- e. [Safari® Books Online](#)
- f. [How to Contact Us](#)
- g. [Acknowledgments](#)

## [2. I. Language Features](#)

### [3. 1. The New PHP](#)

- a. [Past](#)
- b. [Present](#)
- c. [Future](#)

### [4. 2. Features](#)

#### [a. Namespaces](#)

- i. [Why We Use Namespaces](#)
- ii. [Declaration](#)
- iii. [Import and Alias](#)
- iv. [Helpful Tips](#)

#### [b. Code to an Interface](#)

#### [c. Traits](#)

- i. [Why We Use Traits](#)
- ii. [How to Create a Trait](#)
- iii. [How to Use a Trait](#)

#### [d. Generators](#)

- i. [Create a Generator](#)
- ii. [Use a Generator](#)

#### [e. Closures](#)

- i. [Create](#)
- ii. [Attach State](#)

#### [f. Zend OPcache](#)

- i. [Enable Zend OPcache](#)
- ii. [Configure Zend OPcache](#)
- iii. [Use Zend OPcache](#)

#### [g. Built-in HTTP server](#)

- i. [Start the Server](#)
- ii. [Configure the Server](#)
- iii. [Router Scripts](#)
- iv. [Detect the Built-in Server](#)
- v. [Drawbacks](#)

- h. [What's Next](#)
- 5. [II. Good Practices](#)
- 6. [3. Standards](#)
  - a. [PHP-FIG to the Rescue](#)
  - b. [Framework Interoperability](#)
    - i. [Interfaces](#)
    - ii. [Autoloading](#)
    - iii. [Style](#)
  - c. [What Is a PSR?](#)
  - d. [PSR-1: Basic Code Style](#)
  - e. [PSR-2: Strict Code Style](#)
  - f. [PSR-3: Logger Interface](#)
    - i. [Write a PSR-3 Logger](#)
    - ii. [Use a PSR-3 Logger](#)
  - g. [PSR-4: Autoloaders](#)
    - i. [Why Autoloaders Are Important](#)
    - ii. [The PSR-4 Autoloader Strategy](#)
    - iii. [How to Write a PSR-4 Autoloader \(and Why You Shouldn't\)](#)
- 7. [4. Components](#)
  - a. [Why Use Components?](#)
  - b. [What Are Components?](#)
  - c. [Components Versus Frameworks](#)
    - i. [Not All Frameworks Are Bad](#)
    - ii. [Use the Right Tool for the Job](#)
  - d. [Find Components](#)
    - i. [Shop](#)
    - ii. [Choose](#)
    - iii. [Leave Feedback](#)
  - e. [Use PHP Components](#)
    - i. [How to Install Composer](#)
    - ii. [How to Use Composer](#)
    - iii. [Example Project](#)
    - iv. [Composer and Private Repositories](#)
  - f. [Create PHP Components](#)
    - i. [Vendor and Package Names](#)
    - ii. [Namespaces](#)
    - iii. [Filesystem Organization](#)
    - iv. [The composer.json File](#)
    - v. [The README file](#)
    - vi. [Component Implementation](#)
    - vii. [Version Control](#)

- viii. [Packagist Submission](#)
- ix. [Using the Component](#)

## 8. [5. Good Practices](#)

- a. [Sanitize, Validate, and Escape](#)
  - i. [Sanitize Input](#)
  - ii. [Validate Data](#)
  - iii. [Escape Output](#)
- b. [Passwords](#)
  - i. [Never Know User Passwords](#)
  - ii. [Never Restrict User Passwords](#)
  - iii. [Never Email User Passwords](#)
  - iv. [Hash User Passwords with bcrypt](#)
  - v. [Password Hashing API](#)
  - vi. [Password Hashing API for PHP < 5.5.0](#)
- c. [Dates, Times, and Time Zones](#)
  - i. [Set a Default Time Zone](#)
  - ii. [The DateTime Class](#)
  - iii. [The DateInterval Class](#)
  - iv. [The DateTimeZone Class](#)
  - v. [The DatePeriod Class](#)
  - vi. [The nesbot/carbon Component](#)
- d. [Databases](#)
  - i. [The PDO Extension](#)
  - ii. [Database Connections and DSNs](#)
  - iii. [Prepared Statements](#)
  - iv. [Query Results](#)
  - v. [Transactions](#)
- e. [Multibyte Strings](#)
  - i. [Character Encoding](#)
  - ii. [Output UTF-8 Data](#)
- f. [Streams](#)
  - i. [Stream Wrappers](#)
  - ii. [Stream Context](#)
  - iii. [Stream Filters](#)
  - iv. [Custom Stream Filters](#)
- g. [Errors and Exceptions](#)
  - i. [Exceptions](#)
  - ii. [Exception Handlers](#)
  - iii. [Errors](#)
  - iv. [Error Handlers](#)
  - v. [Errors and Exceptions During Development](#)

vi. [Production](#)

9. [III. Deployment, Testing, and Tuning](#)

10. [6. Hosting](#)

- a. [Shared Server](#)
- b. [Virtual Private Server](#)
- c. [Dedicated Server](#)
- d. [PaaS](#)
- e. [Choose a Hosting Plan](#)

11. [7. Provisioning](#)

- a. [Our Goal](#)
- b. [Server Setup](#)
  - i. [First Login](#)
  - ii. [Software Updates](#)
  - iii. [Nonroot User](#)
  - iv. [SSH Key-Pair Authentication](#)
  - v. [Disable Passwords and Root Login](#)
- c. [PHP-FPM](#)
  - i. [Install](#)
  - ii. [Global Configuration](#)
  - iii. [Pool Configuration](#)
- d. [nginx](#)
  - i. [Install](#)
  - ii. [Virtual Host](#)
- e. [Automate Server Provisioning](#)
- f. [Delegate Server Provisioning](#)
- g. [Further Reading](#)
- h. [What's Next](#)

12. [8. Tuning](#)

- a. [The php.ini File](#)
- b. [Memory](#)
- c. [Zend OPcache](#)
- d. [File Uploads](#)
- e. [Max Execution Time](#)
- f. [Session Handling](#)
- g. [Output Buffering](#)
- h. [Realpath Cache](#)
- i. [Up Next](#)

13. [9. Deployment](#)

- a. [Version Control](#)
- b. [Automate Deployment](#)
  - i. [Make It Simple](#)

- ii. [Make It Predictable](#)
- iii. [Make It Reversible](#)

- c. [Capistrano](#)

- i. [How It Works](#)
- ii. [Install](#)
- iii. [Configure](#)
- iv. [Authenticate](#)
- v. [Prepare the Remote Server](#)
- vi. [Capistrano Hooks](#)
- vii. [Deploy Your Application](#)
- viii. [Roll Back Your Application](#)

- d. [Further Reading](#)
- e. [What's Next](#)

## 14. [10. Testing](#)

- a. [Why Do We Test?](#)
- b. [When Do We Test?](#)
  - i. [Before](#)
  - ii. [During](#)
  - iii. [After](#)
- c. [What Do We Test?](#)
- d. [How Do We Test?](#)
  - i. [Unit Tests](#)
  - ii. [Test-Driven Development \(TDD\)](#)
  - iii. [Behavior-Driven Development \(BDD\)](#)

- e. [PHPUnit](#)

- i. [Directory Structure](#)
- ii. [Install PHPUnit](#)
- iii. [Install Xdebug](#)
- iv. [Configure PHPUnit](#)
- v. [The Whovian Class](#)
- vi. [The WhovianTest Test Case](#)
- vii. [Run Tests](#)
- viii. [Code Coverage](#)

- f. [Continuous Testing with Travis CI](#)

- i. [Setup](#)
- ii. [Run](#)

- g. [Further Reading](#)
- h. [What's Next](#)

## 15. [11. Profiling](#)

- a. [When to Use a Profiler](#)
- b. [Types of Profilers](#)

c. [Xdebug](#)

- i. [Configure](#)
- ii. [Trigger](#)
- iii. [Analyze](#)

d. [XHProf](#)

- i. [Install](#)
- ii. [XHGUI](#)
- iii. [Configure](#)
- iv. [Trigger](#)

e. [New Relic Profiler](#)

f. [Blackfire Profiler](#)

g. [Further Reading](#)

h. [What's Next](#)

16. [12. HHVM and Hack](#)

a. [HHVM](#)

- i. [PHP at Facebook](#)
- ii. [HHVM and Zend Engine Parity](#)
- iii. [Is HHVM Right for Me?](#)
- iv. [Install](#)
- v. [Configure](#)
- vi. [Extensions](#)
- vii. [Monitor HHVM with Supervisord](#)
- viii. [HHVM, FastCGI, and Nginx](#)

b. [The Hack Language](#)

- i. [Convert PHP to Hack](#)
- ii. [What is a Type?](#)
- iii. [Static Typing](#)
- iv. [Dynamic Typing](#)
- v. [Hack Goes Both Ways](#)
- vi. [Hack Type Checking](#)
- vii. [Hack Modes](#)
- viii. [Hack Syntax](#)
- ix. [Hack Data Structures](#)
- x. [HHVM/Hack vs. PHP](#)

c. [Further Reading](#)

17. [13. Community](#)

a. [Local PUG](#)

b. [Conferences](#)

c. [Mentoring](#)

d. [Stay Up-to-Date](#)

- i. [Websites](#)

- ii. [Mailing Lists](#)

- iii. [Twitter](#)
- iv. [Podcasts](#)
- v. [Humor](#)

## 18. [A. Installing PHP](#)

- a. [Linux](#)
  - i. [Package Managers](#)
  - ii. [Ubuntu 14.04 LTS](#)
  - iii. [CentOS 7](#)
- b. [OS X](#)
  - i. [MAMP](#)
  - ii. [Homebrew](#)
- c. [Build from Source](#)
  - i. [Get the Source Code](#)
- d. [Windows](#)
  - i. [Binaries](#)
  - ii. [WAMP](#)
  - iii. [Zend Server](#)

## 19. [B. Local Development Environments](#)

- a. [VirtualBox](#)
- b. [Vagrant](#)
  - i. [Commands](#)
  - ii. [Boxes](#)
  - iii. [Initialize](#)
  - iv. [Provision](#)
  - v. [Synced folders](#)
  - vi. [Get started](#)

## 20. [Index](#)